Aortic Valve Repair: The Brussels Approach

Laurent de Kerchove, MD, PhD
Cliniques Universitaires St-Luc, IREC, UCL, Brussels, Belgium
AV repair program in Brussels

• 1994

• 1996 – 2016: **850 Aortic valve repair/sparing**
Pathologies amenable to AV repair

**Congenital**
- Bicuspid
- Connective tissue disorders (Marfan, Loeys-Dietz, Ehler-Danlos, Familial Aneurysmal disease, ...)
- Unicuspid
- Quadricuspid
- Supra-aortic stenosis
Acquired

- Degenerative cusp
- Degenerative aortic aneurysm (Atherosclerosis)
- Traumatic
- Infectious
- Acute aortic dissection
Pathologies amenable to AV repair

Redo
- Ross repair
- Re-repair
Functional classification of AI
Lesson from the mitral valve

Etiology
  ↓
Lesion
  ↓
Dysfunction

MV
  ↓
FED
  ↓
Cordale rupture
  ↓
Prolapse eccentric MI

AV
  ↓
Marfan
  ↓
Root dilatation
  ↓
Cusp tethering central AI
Functional classification of AI

Lesson from the mitral valve

A. Carpentier

Type I
Annulus dilatation

Type II
Leaflet prolapse

Type III a,b
Leaflet restrictive motion

✓ Common language
✓ Plan surgical strategy
✓ Predict the outcomes
Functional classification of AI

1. Cusp
2. STJ
3. VAJ

The Functional Aortic Valve Unit
## Functional classification of AI

<table>
<thead>
<tr>
<th>AI Class</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal cusp motion with FAA dilatation or cusp perforation</td>
<td>Cusp Prolapse</td>
<td>Cusp Restriction</td>
</tr>
<tr>
<td>Mechanism</td>
<td>la</td>
<td>lb</td>
<td>lc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Repair Techniques (Primary)</th>
<th>STJ remodeling</th>
<th>Aortic Valve sparing: Reimplantation or Remodeling with SCA</th>
<th>Patch Repair</th>
<th>Prolapse Repair</th>
<th>Leaflet Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending aortic graft</td>
<td>SCA</td>
<td>Autologous or bovine pericardium</td>
<td>Plication</td>
<td>Triangular resection</td>
<td>Shaving Decalcification Patch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Secondary)</th>
<th>STJ Remodeling</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCA</td>
<td>SCA</td>
</tr>
</tbody>
</table>

Functional classification of AI

Type 1: “FAA Dilatation”

- Type 1a: Asc. Ao. (STJ)
- Type 1b: Root (STJ + VAJ)
- Type 1c: VAJ

31 mm
Type 1a and 1b: STJ dilatation

- Functional restriction of the cusp (tethering) → central AI

- Effective height = supra normal (>9-10mm)

- Free margin elongation

- Commissural fenestration
Functional classification of AI

Type 1b and 1C: VAJ dilatation

- Effective height = infra normal (<9-10mm)
- Frequently associated with cusp prolapse
Functional classification of AI

Type 2: “Prolapse”

- Eccentric jet
- Cusp billowing
- Transverse fold in cusp curvature

M. Boodhwani, JTCVS 2013
Functional classification of AI

Type 2: “Prolapse”

✓ Transverse fold in cusp curvature

✓ = Free margin elongation

✓ below other normal FM

✓ Commissural fenestration
Functional classification of AI

**Type 3: Restrictive cusp motion**
Functional classification of AI

Type 3: Restrictive cusp motion
Functional classification of AI

_Type 1d:_ Cusp perforation/destruction
_(no prolapse, no restriction)_
Functional classification of AI

Type 1b+2

Type 1c+2
Principles of AV repair

1. Restore and preserve cusp geometry and motion

2. Remodel and stabilize the FAA

Optimal area of coaptation, stable over time
Principles of AV repair: Optimal coaptation

Tips > annulus, No AR
Residual AR, Coapt L > 4 mm
Tips > annulus, Residual AR, Coapt L < 4 mm
Tips < annulus

Pethig K. ATS 2002
Ie Polain JB. JACC Card. Im. 2009
Principles of AV repair: Optimal coaptation

Schafers H.J. JCTVS 2006
Bierbach B.O., EJCTS 2010
Aicher D. Circ. 2011
Techniques of cusp repair

**Cusp lesions**

- Prolapse (type 2)
  - Free margin elongation
  - Fenestration
  - Commissure disruption
- Restriction/retraction (type 3)
  - Raphe in BAV
  - Unicuspid valve
  - Fibrosis/Calcification
- Perforation/destruction (type 1d)

**Repair techniques**

- Central plication or Goretex resuspension
- Goretex resuspension or Patch
- Commissure reattaching or Patch
- Resection + direct closure or patch
- Resection + Patch
- Resection + Patch
- Patch
Techniques of cusp repair

Cusp lesions
• Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption
• Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibrosis/Calcification
• Perforation/destruction

Repair techniques
→ Central plication
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 1 cusp prolapse
Central Plication Technique: 3 cusps prolapse

\[ \approx 9-10 \text{ mm eH} \]
Central Plication Technique: 3 cusps prolapse

LCC  NCC

$\approx 9-10 \text{ mm eH}$
Central Plication Technique: 3 cusps prolapse

\[ \approx 9-10 \text{ mm eH} \]

LCC  NCC
Techniques of cusp repair

Cusp lesions

- Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption
- Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibosis/Calcification
- Perforation/destruction

Repair techniques

→ Central plication
Techniques of cusp repair

Cusp lesions

• Prolapse
  - Free margin elongation
  - Fenestration « small »
  - Commissure disruption
• Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
• Fibosis/Calcification
• Perforation/destruction

Repair techniques

→ Central plication + Gtx Resuspension
Techniques of cusp repair

Cusp lesions

- Prolapse
  - Free margin elongation
  - Fenestration « large »
  - Commissure disruption
- Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibosis/Calcification
- Perforation/ destruction

Repair techniques

→ Patch repair (2 patches) + Gtx resuspension
Techniques of cusp repair

Cusp lesions

- Prolapse
  - Free margin elongation
  - Fenestration «ruptured»
  - Commisure disruption
- Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
- Fibrosis/Calcification
- Perforation/destruction

Repair techniques

→ Patch repair (butterfly techn.) + Central Plication
Techniques of cusp repair

Cusp lesions

• Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption

• Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibosis/Calcification

• Perforation/destruction

Repair techniques

→ Comm. reattachment + Goretex resuspension
Techniques of cusp repair

Cusp lesions

- Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption
- Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibosis/Calcification
- Perforation/destruction

Repair techniques

→ Resection direct closure + VS Reimplantation
Techniques of cusp repair

Cusp lesions

• Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption

• Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibrosis/Calcification

• Perforation/destruction

Repair techniques

→ Resection + Patch repair
Techniques of cusp repair

Cusp lesions

• Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption

• Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibosis/Calcification

• Perforation/destruction

Repair techniques

→ Resection + Patch repair
Techniques of cusp repair

Cusp lesions

• Prolapse
  - Free margin elongation
  - Fenestration
  - Commissure disruption
• Restriction/retraction
  - Raphe in BAV
  - Unicuspid valve
  - Fibrosis/Calcification
• Perforation/destruction

Repair techniques

→ Cusp extension with patch
Techniques of cusp repair

Cusp lesions

- Prolapse
  - Free margin elongation
  - Fenestration (large/ruptured)
  - Commissure disruption
- Restriction
  - Raphe in BAV
  - Unicuspid valve
  - Fibrosis/Calcification
- Perforation/Destruction

Repair techniques

→ Patch repair
Techniques of cusp repair: Outcome following type of AI

All repair cohort

Freedom from AR >2+

M. Boodhwani, JTCVS 2009

BAV repair

Freedom from AR >2+

Boodhwani M. JTCVS 2010

P=0.03

P=0.02
## Techniques of FAA repair

<table>
<thead>
<tr>
<th>Aorta lesions</th>
<th>Repair techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 1a: Asc Ao (STJ)</strong></td>
<td>→ Supra coronary ascending aorta replacement</td>
</tr>
<tr>
<td><strong>Type 1b: Root (STJ + VAJ)</strong></td>
<td>→ Valve Sparing Reimplantation</td>
</tr>
<tr>
<td><strong>Type 1c: VAJ</strong></td>
<td>→ Subcommissural annuloplasty or Ring annuloplasty</td>
</tr>
</tbody>
</table>
Techniques of FAA repair

Aorta lesions

- Type 1a: Asc Ao (STJ)
- Type 1b: Root (STJ + VAJ)
- Type 1c: VAJ

Repair techniques

→ Supra coronary ascending aorta replacement
Techniques of FAA repair

Aorta lesions

• Type 1a: Asc Ao (STJ)
• Type 1b: Root (STJ + VAJ)
• Type 1c: VAJ

Repair techniques

→ Valve Sparing Reimplantation
VS Reimplantation: Brussels Technique

1. Valve inspection
2. Root dissection
3. Complex cusp repair
4. Graft sizing & proximal suture line
5. Com. reimplantation & distal suture line
6. Residual prolapse repair
7. Coronary reimplantation
Techniques of FAA repair

Aorta lesions

- Type 1a: Asc Ao dilat (STJ)
- Type 1b: Root (STJ + VAJ)
- Type 1c: VAJ

Repair techniques

→ Subcommissural annuloplasty or Ring annuloplasty
Techniques of FAA repair

Ring annuloplasty
Techniques of FAA repair

SCA: Root < 45 mm

VSR: Root > 45 mm
Techniques of FAA repair
Subcommissural annuloplasty and VAJ size

![BAV](image1.png)

FF AR >1+

![TAV](image2.png)

FF AR >1+

VAJ <30mm

VAJ ≥30mm

p < 0.01

Navarra E. EJCTS 2013

De Kerchove L. EJCTS 2015
Techniques of FAA repair

SCA and VAJ size

30 y♂: BAV, rapher res+direct closure, cusps resusp (Gtx), SCA → 6.5 y later: AI 3+

41 y♂: TAV, RC plication and resuspension (Gtx), SCA → 2 y later: AI 3+
Techniques of FAA repair
VS Reimplantation and VAJ size

FF AR >1+

VAJ <30mm
VAJ ≥30mm

p = 0.93

VAJ <28mm
VAJ ≥28mm

p = 0.4

Navarra E. EJCTS 2013
De Kerchove L. EJCTS 2015
Techniques of FAA repair

SCA and VAJ size

De Kerchove L. EJCTS 2015
Brussels annuloplasty strategy (AV repair for severe AI)

- **Normal Root (<40 mm)**
  - Normal VAJ (<28 mm)
  - «Old patient» (>50 y)

- **Large VAJ (≥28 mm)**
  - Large VAI (≥28 mm)

- **Dilated Root (≥40 mm)**
  - Large VAJ (≥28 mm)
  - Root wall fragility
  - Remodel BAV geometry 180°

- **Subcom. annuloplasty**
- **External Ring Annuloplasty**
- **VS Reimplantion**

Images show surgical procedures and anatomical views corresponding to the annuloplasty strategies.
Thank you
Main goal of AV repair: Optimal coaptation + Stabilisation

- Effective height (eH) ≥ 9 mm
- Coaptation length ≥ 4 mm
- Circumferential annuloplasty VAJ ≥28
- No residual AI
- Good cusp mobility

Pethig K. ATS 2002
le Polain de Waroux JB. JACC Card. Im. 2009
Bierbach BO. EJCTS 2010
Aicher D. Circ. 2011
De Kerchove L. JTCVS 2011
Brussels AV repair: Conclusions

- The mechanisms of AI are actually well understood and the use of a classification help to discuss indication, plan surgical strategy and analyze the outcomes.

- Surgeon dispose of a wide armamentarium of repair techniques adapted to the variety of valvular lesions.

- Durability of leaflet repair depend on the quality and quantity of tissues; long term results are excellent for in Type 1 (FAA dilatation) and 2 (Prolapse) and acceptable in type 3 (Restrictive).

- Next to leaflet tissues quality, optimal valve coaptation and annuloplasty are the principal determinants of repair durability.
AV Repair: Hospital Mortality (elective surgery)

- 0.6%  V. Sharma, H. Schaff JTCVS 2014
- 0.8%  J. Price, G. Elkhoury ATS 2013
- 0.8%  D. Aicher, H-J Schafers EJCTS 2010
- 1%    T. David JTCVS 2014
AV Repair: Long term Survival

V. Sharma, H. Schaff JTCVS 2014

J. Price ATS 2013

T. David JTCVS 2014
## AV Repair: Freedom from Reoperation & AI

<table>
<thead>
<tr>
<th>Authors</th>
<th>Period</th>
<th>Cohort</th>
<th>Technique</th>
<th>FF AV Reop 10 y</th>
<th>FF recurrent AR ≥2+ 10 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. Schaff JTCVS 2014</td>
<td>1986-2011</td>
<td>331</td>
<td>Cusp 100% Sparing 0%</td>
<td>80%</td>
<td>75%</td>
</tr>
<tr>
<td>T. Kunihara JTCVS 2012</td>
<td>1995-2007</td>
<td>640</td>
<td>Cusp 80% Sparing 50%</td>
<td>88%</td>
<td>80%</td>
</tr>
<tr>
<td>J. Price ATS 2013</td>
<td>1995-2010</td>
<td>475</td>
<td>Cusp 68% Sparing 50%</td>
<td>86%</td>
<td>85%</td>
</tr>
<tr>
<td>T. David JTCVS 2014</td>
<td>1988-2010</td>
<td>371</td>
<td>Cusp 50% Sparing 100%</td>
<td>97%</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18 y 97%</td>
<td>18 y 78%</td>
</tr>
</tbody>
</table>

*Root pathology > Cusp pathology*
AV Repair: Valve sparing in Marfan Syndrome

Freedom from AV reoperation

Freedom from AR >2+

T. David, JTCVS 2009
AV Repair:
Leaflet repair in valve sparing surgery

Cusp repair = risk factor of reoperation or recurrent AR

- E. Lansac EJCTS 2010 (negative impact of cusp repair decrease with experience)
- P.P. Urbanski EJCTS 2012
AV repair

Risk factor of repair failure: **Cusp coaptation**

*Pethig K. ATS 2002*

*Le Polain JB. JACC Card. Im. 2009*

*Aicher D. Circ. 2011*
AV repair
Risk factor of repair failure: VAJ dilatation

No annuloplasty  SC annuloplasty

Aicher D. Circ. 2011  Navarra E. EJCTS 2013
AV repair
TAV versus BAV

Freedom from reoperation

<table>
<thead>
<tr>
<th>BAV</th>
<th>&lt;</th>
<th>TAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>84% (7 y) Casselman JTCVS 1999</td>
<td>•</td>
<td>94% (12 y) David JTCVS 2010</td>
</tr>
<tr>
<td>81% (10 y) Aicher EJCTS 2010</td>
<td>•</td>
<td>93% (10 y) Aicher EJCTS 2010</td>
</tr>
<tr>
<td>81% (10 y) Price ATS 2013</td>
<td>•</td>
<td>89% (10 y) Price ATS 2013</td>
</tr>
</tbody>
</table>
AV repair
Valve sparing reimplanation in BAV repair

Matched comparison VSR vs SCA

Freedom from AR>1+

p=0.0006

No. at risk
Group 1  53  42  33  27  21  18  15  10  8
Group 2  53  39  29  23  20  14  9  6  2

De Kerchove L. JTCVS 2011
AV repair
Aorta/Annuloplasty repair strategy

AV repair for AR

- Normal Root (<45 mm)
  - Normal VAJ (<26 mm) → Subcom. Anpl.
  - Large VAJ (>26 mm) → Ring Annuloplasty
- Dilated Root (≥45 mm)
  - Large VAJ (>26 mm) + Modify valve geometry → VS Reimplantation
AV repair

Risk factor of repair failure: **Patch repair**

**Boodhwani M. JTCVS 2010**

**Aicher D. Circ. 2011**
AV repair:
Probability of Cusp Repair in valve sparing surgery

• No AR → low 10 %

• AR, central jet → Moderate 30-50 %

• AR, eccentric jet → High ≈ 100 %
AV Repair: Valve related event

- Thromboembolic event
  - 0.2% - 0.7%/y
  - 92-95% @ 10 y; 87-90% @ 15 y
- Endocarditis
  - 0.2%/y
- All VRE (reop, thromb, bleed, endoc)
  - 74-90% @ 10 y; 80% @ 18 y

V. Sharma, H. Schaff JTCVS 2014
J. Price, G. Elkhoury ATS 2013
D. Aicher, H-J Schafers EJCTS 2010
T. David JTCVS 2014
AV Repair:
Prolapse repair (Type 2)

M. Boodhwani, JTCVS 2011
AV Repair:
Leaflet repair with patch

Mozala Nezhad Z. EJCTS 2014
BAV Repair

Cusp Anatomy
- Type 0
- Type 1
  - Prolapsing

Raphe Morphology
- Restrictive
- Raphe Thinned

Raphe Resected
- Quantity of Cusp Tissue?
  - Adequate: ≈ 180°, ≈ 120°
  - Inadequate: ≈ 180° Triangular Patch
  - ≈ 120° Commissural Patch

Central Plication, Triangular Resection
- Tricuspidisation
AV Leaflet Repair: Results
Unicuspid valve repair

• 2001 – 2011: 118 pts
• mean age: 27 years
• FF reoperation @ 3 years: 80%

Design I

Design II

D. Aicher JTCVS 2013
In patients with chronic AR, the severity of AR is correlated with the degree of STJ and VAJ dilatation.
Functional classification of aortic regurgitation
Mechanism of AV dysfunction

**Type I characteristics**

- Central jet \( \perp \) to subvalvular plane
- All cusps have same coaptation height
- Lack of central coaptation
Principles of AV repair/sparing surgery
Optimal coaptation?
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse repair
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Central Plication Technique: 2 cusp prolapse
Reimplantation Technique
Probability of Cusp Repair

AV morphology

- In tricuspid 52%  
  T. David JTCS. 2006: ±58%
  D. Aicher. JTCS 2007: ±53%

- In bicuspid 93%  
  D. Aicher. JTCS 2007: ±86%
Reimplantation Technique
Probability of Cusp Repair

➢ Preoperative AR

• In tricuspid 52%

D. Aicher. JTCS 2007
E. Lansac EJCTS. 2010
Reimplantation Technique

Probability of Cusp Repair
Reimplantation Technique
Probability of cusp repair

- AV morphology
  - In tricuspid: 52%
  - In bicuspid: 93%

D. Aicher, JTCS 2007
E. Lansac, EJCTS, 2010
Reimplantation Technique

Probability of cusp repair

➢ Preoperative AR 0-1+

• In tricuspid
Reimplantation Technique
Water Test, residual prolapse repair
**AV Repair**

_Surgery for AI_

- Symptomatic severe AI
- Asympt severe AI + EF <50%
  
or + LVED >65 (70) mm, LVES >50 mm

_Surgery for Ao. Aneurism_

- > 55 mm in TAV
- > 50 mm in Marfan, BAV at risk
- > 45 mm in Marfan at risk, if surgery for severe AI
2. Patients selection for AV repair

1. Pediatric
2. Young adults
3. > 65 years

Main TARGET of AV repair

= 23% of AV repair population (1996 – 2012, 620 pts)
BAV Repair

Classification of cusp phenotypes

Techniques of cusp repair

Cusp lesions

• Prolapse
  - Free margin elongation
  - Fenestration « large »
  - Commissure disruption

• Restriction
  - Raphe in BAV
  - Unicuspid valve
  - Fibosis/Calcification

• Perforation/destruction

Repair techniques

→ Patch repair (2 patches)
**BAV repair**

**Classification of cusp phenotypes**

<table>
<thead>
<tr>
<th>Type 0 <em>(Sievers Classif.)</em></th>
<th>Type 1 <em>(Sievers classif.)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>• ≈ 180°</td>
<td>• Thick, calc. raphe</td>
</tr>
<tr>
<td>• No raphe</td>
<td>• Incomplete fusion</td>
</tr>
<tr>
<td>• Prolapse</td>
<td>• 120° – 160°</td>
</tr>
<tr>
<td></td>
<td>• Restrictive</td>
</tr>
<tr>
<td></td>
<td>• Raphe</td>
</tr>
<tr>
<td></td>
<td>• Complete fusion</td>
</tr>
<tr>
<td></td>
<td>• 160° – 180°</td>
</tr>
<tr>
<td></td>
<td>• Prolapse</td>
</tr>
</tbody>
</table>
BAV Repair
Aortopathy

- Dilated ventriculo-aortic junction 28 – 30 mm

*de Kerchove JTCVS 2010
Schäfers JTCVS 2013*
BAV repair
Valve sparing Reimplantion

1. Circumferential prosthetic based annuloplasty
2. Modify commissure orientation (≈180°)
   • Improve durability
   • Reduce the need of patch repair
Techniques of FAA repair
SCA vs VSR (matched comparison)

De Kerchove L. JTCS 2010

De Kerchove L. EJCTS 2015