Aortic Valve Repair: State of the art

Laurent de Kerchove, MD, PhD
Cliniques Universitaires St-Luc, IREC, UCL, Brussels
AV repair: the origine of annuloplasty

Circumclusion
Taylor 1958
Carpentier 1990

Commissural annoplasty
Cabrol 1966
Carpentier 1990
Cosgrove 1991
Duran 1996

Reimplantation
T. David 1992

Partial external band
T. David 1996
AV repair: the origine of cusp repair

80ties-90ties:
Trusler, Duran, Cosgrove, Fraser, Tolan, Kadri

Commissurotomy

Commissural Cusp plication

Perforation closure with patch

Fig. 1 - Debridement of cusp and aortic valve commissurotomy.

Fig. 3 - Resuspension of the redundant free edge of aortic cusp.

Central Cusp plication

Comissure restoration with patch

Fig. A, B, C, D, E
Patients selection for AV repair

1. Paediatric
2. Young adults

Main TARGET of AV repair
Pathologies treated by AV repair

1. Aortic insufficiency
2. Aortic root and ascending aorta dilatation
3. (Congenital stenosis)
AV repair

Congenital etiologies

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

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

Redo
- Ross repair
- Re-repair
Classification of AV repair
Lesson from the mitral valve

Type I
Annulus dilatation

Type II
Leaflet prolapse

Type III a,b
Leaflet restrictive motion

A. Carpentier, 1983
## Repair-oriented 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></td>
<td>Ia</td>
<td>Ib</td>
<td>Ic</td>
</tr>
</tbody>
</table>

### Mechanism

<table>
<thead>
<tr>
<th>Repair Techniques (Primary)</th>
<th>STJ remodeling</th>
<th>Aortic Valve sparing: Reimplantation or Remodeling with SCA</th>
<th>SCA</th>
<th>Patch Repair</th>
<th>Prolapse Repair</th>
<th>Leaflet Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STJ remodeling</td>
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<td>SCA</td>
<td>Patch Repair</td>
<td>Prolapse Repair</td>
<td>Leaflet Repair</td>
</tr>
<tr>
<td>(Secondary)</td>
<td>SCA</td>
<td>SCA</td>
<td>SCA</td>
<td>SCA</td>
<td>SCA</td>
<td>SCA</td>
</tr>
</tbody>
</table>

Functional classification of aortic regurgitation
Mechanism of AV dysfunction

Type 1 AR

Type 1a
Asc Ao. (STJ)

Type 1b
Root (STJ + VAJ)

Type 1c
Annulus (VAJ)
AV Repair: Leaflets lesions

Type 2 AR: Cusp prolapse
Functional classification of aortic regurgitation

Mechanism of AV dysfunction

*Type 3 AR: Restrictive cusp motion*
Type 1d AR: Cusp perforation/defect
(no prolapse, no restriction)
AV Repair: Techniques

- Type 1a → Asc ao replacement
- Type 1b → Valve Sparing Root Replacement
- Type 1c → Annuloplasty
- Type 2 & 3 → Cusp repair techniques

Aim of repair

- To restore matching between cusp & AV orifice
- To create an optimal coaptation, stable over time
AI Type 1b repair: Valve sparing root replacement
Evolution of the Remodeling technique

M. Yacoub

Hanke T. JTCS 2009
Kunihara T. JTCS 2012
Evolution of the Remodeling technique

M. Yacoub

Partial external band

T. David 1996

Suture Anpl.

E. Lansac 2006

HJ. Schäfers 2013
Evolution of the Reimplantation technique

Reimplantation

T. David 1992

L. da Vinci 1512

Bissell M. Eur Heart J. 2014

Katayama JTCVS 2008
Evolution of the Reimplantation technique

Reimplantation

T. David 1992

T. David “V”

Stanford Modification

C. Miller

Cardioroot

Sinus prosthesis
Predictors of recurrent AI

Coaptation height

Predictors of recurrent AI

Coaptation height

Predictors of recurrent AI

Coaptation height

Bierbach B.O.  EJTCS 2010

Aicher D. Circulation ;123:178-85, 2011
Reimplantation Technique
Reimplantation Technique
Post-repair TEE
Reimplantation Technique
Reimplantation Technique

Post-repair TEE
Cusp repair techniques

Cusp lesions

- Prolapse (Type 2)
  - Free margin elongation
  - Fenestration (large/ruptured)
  - Commissure disruption
- Restriction (Type 3)
  - Raphe in BAV
  - Unicuspid valve
  - Calcification
- Perforation (Type 1d)

Repair techniques

- Central plication / GTx resusp.
- GTx resusp. / Patch
- Trusler stitch
- Resection/direct closure/patch
- Patch
- Leaflet replac. with patch
- Patch
AV Repair
Central Plication
AV Repair
Patch: Perforation Closure
AV Leaflet Repair: Fenestration Patch
BAV Repair

Cusp Anatomy
- Type 0
  - Prolapsing
    - Raphe Thinned
    - Central Plication, Triangular Resection
- Type 1
  - Restrictive
    - Raphe Resected
      - Quantity of Cusp Tissue?
      - Adequate: \(\approx 180^\circ\) and \(\approx 120^\circ\)
      - Inadequate: \(\approx 180^\circ\) Triangular Patch, \(\approx 120^\circ\) Commissural Patch

Raphe Morphology
- Raphe Resected
  - Central Plication, Triangular Resection
  - Tricuspidisation
BAV Repair

• Type 0

• Type I:
  – Prolapsing raphe: plication
  – Restrictive raphe
    • Direct closure
    • Tricuspidisation
    • Bicuspid patch
    • Tricuspidisation w/ patch
BAV Repair

- Type 0
- Type I:
  - Prolapsing raphe
  - Restrictive raphe
    - Direct closure
    - Tricuspidisation
    - Bicuspid patch repair
    - Tricuspidisation w/
BAV Repair

• Type 0

• Type I:
  – Prolapsing raphe
  – Restrictive raphe
    • Direct closure
    • Tricuspidisation w/o patch
    • Bicuspid patch repair
    • Tricuspidisation w/ patch
AV repair

VAJ dilatation (AI Type 1c)

No annuloplasty

SC annuloplasty

Aicher D. Circ. 2011

Navarra E. EJCTS 2013
Techniques of Circumferential Prosthetic Annuloplasty

- Partial external band
- External Ring
- Suture Anpl.
- Internal Ring

T. David 1996
E. Lansac 2006
HJ. Schäfers 2013
J.S. Rankin 2012
AV Repair:
Ring annuloplasty
AV Repair: Hospital Mortality

- 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: Valve related event**

### VSRR

<table>
<thead>
<tr>
<th>Pooled Late Outcome Events</th>
<th>LOR + 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late mortality</td>
<td>1.53 (1.19–1.96)</td>
</tr>
<tr>
<td>Reoperation on aortic valve</td>
<td>1.32 (1.0–1.74)</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>0.23 (0.13–0.42)</td>
</tr>
<tr>
<td>Thromboembolism</td>
<td>0.41 (0.22–0.77)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>0.23 (0.11–0.51)</td>
</tr>
<tr>
<td>MAVRE</td>
<td>1.66 (1.24–2.23)</td>
</tr>
</tbody>
</table>

### Bentall

<table>
<thead>
<tr>
<th>Pooled Late Outcome Events</th>
<th>LOR + 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late mortality&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.02 (1.77–2.31)</td>
</tr>
<tr>
<td>Valve-related mortality</td>
<td>0.46 (0.36–0.59)</td>
</tr>
<tr>
<td>Root reoperation&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.46 (0.36–0.59)</td>
</tr>
<tr>
<td>Valve reoperation</td>
<td>0.30 (0.22–0.41)</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>0.64 (0.47–0.87)</td>
</tr>
<tr>
<td>Thromboembolism</td>
<td>0.77 (0.60–1.00)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>0.39 (0.33–0.46)</td>
</tr>
<tr>
<td>MAVRE</td>
<td>2.66 (2.17–3.24)</td>
</tr>
</tbody>
</table>

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*B. Arabkhani, JJ. Takkenberg ATS 2015
A. Mookhoek, JJ. Takkenberg ATS 2016*
AV Repair: Long term Survival

V. Sharma, H. Schaff JTCVS 2014

J. Price ATS 2013

T. David JTCVS 2014
AV repair for AI: Root dilatation (Type 1b)

- Toronto: 1988 – 2010, 371 pts, 9% BAV, 50% cusp repair

No predictors of recurrent AR

T. David JTCVS 2014
AV repair for AI: Root dilatation (Type 1b)

- Brussels: 1996 – 2014, 275 pts, 43% BAV, 70% cusp repair

![Graph showing freedom from AV reoperation: BAV vs TAV](image)

- Log-rank p-value=0.03

<table>
<thead>
<tr>
<th>Number at risk</th>
<th>analysis time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
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<tr>
<td>bicuspidav = 0</td>
<td>153</td>
</tr>
<tr>
<td>bicuspidav = 1</td>
<td>114</td>
</tr>
</tbody>
</table>
AV Repair:
Type of Aortic Regurgitation

M. Boodhwani, JTCVS 2009
AV repair
Risk factor of repair failure: **Patch repair**

Boodhwani M. JTCVS 2010

Aicher D. Circ. 2011
AV Leaflet Repair: Conclusions

• The mechanism of AR are actually well understood and the use of a classification of AR help to plan AV repair.

• Surgeon dispose of a wide armamentarium of repair techniques adapted to the variety of valve lesions.

• Durability of cusp repair depend on the quality and quantity of tissues. Long term results of AV repair are excellent for AI Type 1 & 2 repair and acceptable for AI Type 3 (restrictive cusp). New patch material will probably improve results of in this group.

• Next to cusp tissues quality, optimal valve coaptation (eH) and circumf. annuloplasty are other determinants of repair durability.

• Longer follow-up is necessary to investigate 2° and 3° decade after repair.
Thank you
AV Repair for AI: VSRR +/- Cusp repair

Fig 1. Actuarial freedom from aortic regurgitation greater than II after valve-preserving aortic replacement in patients with intact leaflets (triangles) or leaflet prolapse requiring correction (squares).


L. de Kerchove Circulation 2009
AV Repair:
Leaflet repair with patch

Mozala Nezhad Z. EJCTS 2014
Surgical anatomy of the AV
Adjacent structures to the aortic root

Surgical anatomy of the AV
Functional unit

STJ (25mm)
Sinuses (30mm)
VAJ (24mm)
Surgical anatomy of the AV
Cusp size

- Cusp height (geometric height): 19 – 20 mm (24 in BAV)
- Free margin length: 32 – 35 mm
- Cusp insertion length:
- Cusp area: 3 cm²
Surgical anatomy of the AV

Cusp coaptation

- Coapt area: 1 – 1.5 cm²
- Coapt area 40% of cusp area
Type 1 characteristics

- Central jet ⊥ to subvalvular plane
- All cusps have same coaptation height
- Lack of central coaptation
Functional classification of aortic regurgitation
Mechanism of AV dysfunction

Type 2 AI characteristics:

- Eccentric jet
  Sens. 92%, spec. 96%

- Cusp ≠ coaptation height

- Transverse fold in cusp curvature
  Sens. 57%, spec. 92%

M. Boodhwani, JTCVS 2013
AV Repair: Cusp prolapse
Transverse fold in cusp curvature
Valve Sparing root replacement

Probability of Cusp Repair

![Bar chart showing the probability of cusp repair for different cusp configurations and root types.](chart.png)
Valve Sparing root replacement
Probability of Cusp Repair

- No AR  → low 10%
- AR, central jet  → Moderate 50%
- AR, eccentric jet  → High ≈ 100%
Role of the Sinus of Valsalva

- Maximal opening
- Smooth & “Stress less” closure
**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_
VAJ size after SCA

30 y♂: BAV, rapher res+direct closure, cusps resusp (Gtx), SCA

41 y♂: TAV, RC plication and resuspension (Gtx), SCA

VAJ dilatation

→ 6.5 y later: AI 3+

→ 2 y later: AI 3+
AV repair

VAJ dilatation (AI Type 1c)

Matched comparison VSR vs SCA in BAV repair

Freedom from AR>1+

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
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:
Prolapse repair (Type 2)

Freedom from AV Reoperation

Freedom from Recurrent AI

M. Boodhwani, JTCVS 2011
Conclusions

Objective: Optimal coaptation + Stabilisation

- Effective height ($eH$) ≥ 9 mm
- Coaptation length ≥ 4 mm
- Circumferential annuloplasty
  VAJ >26
- No residual AR

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
AV repair for AI: Root dilatation (Type 1b) in Marfan syndrome

- Toronto: 1988 – 2006, 103 pts, mean age 37 y
AV repair for AI: Root dilatation (Type 1b)

- Homburg: 1995 – 2009, 430 pts, 30% BAV, 73% cusp repair

Freedom from AV reop.

Freedom from AR ≥2+

T. Kunihara JTCVS 2012
## 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</th>
<th>FF recurrent AR &gt;2+</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>10 y 80%</td>
<td>10 y 75%</td>
</tr>
<tr>
<td>T. Kunihara JTCVS 2012</td>
<td>1995-2007</td>
<td>640</td>
<td>Cusp 80% Sparing 50%</td>
<td>10 y 88%</td>
<td>10 y 80%</td>
</tr>
<tr>
<td>J. Price ATS 2013</td>
<td>1995-2010</td>
<td>475</td>
<td>Cusp 68% Sparing 50%</td>
<td>10 y 86%</td>
<td>10 y 85%</td>
</tr>
<tr>
<td>T. David JTCVS 2014</td>
<td>1988-2010</td>
<td>371</td>
<td>Cusp 50% Sparing 100%</td>
<td>10 y 97%</td>
<td>10 y 93%</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 decreases with experience)
  • P.P. Urbanski EJCTS 2012
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>&lt;</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 Leaflet Repair: Results
Unicuspid valve repair

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

D. Aicher JTCVS 2013
Functional classification of aortic regurgitation
The functional aortic valve unit

1. Cusp
2. STJ
3. VAJ
Functional classification of aortic regurgitation

Mechanism of AV dysfunction

*STJ* dilatation
Functional classification of aortic regurgitation
Mechanism of AV dysfunction

VAJ dilatation, “Annuloectasia”
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

**Table II. Degree of AR and aortic root size indexed by body surface area at follow-up study**

<table>
<thead>
<tr>
<th>Type of Size</th>
<th>Mild AR (cm/m²) (n = 67)</th>
<th>Moderate AR (cm/m²) (n = 45)</th>
<th>Severe AR (cm/m²) (n = 15)</th>
<th>p Value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic anulus</td>
<td>1.29 ± 0.23</td>
<td>1.38 ± 0.23</td>
<td>1.39 ± 0.11</td>
<td>0.055</td>
</tr>
<tr>
<td>Valsalva sinuses</td>
<td>1.89 ± 0.34</td>
<td>2.04 ± 0.31</td>
<td>2.09 ± 0.32</td>
<td>0.025</td>
</tr>
<tr>
<td>Supraaortic ridge</td>
<td>1.49 ± 0.30</td>
<td>1.71 ± 0.35</td>
<td>1.76 ± 0.43</td>
<td>0.001</td>
</tr>
<tr>
<td>Ascending aorta</td>
<td>1.97 ± 0.42</td>
<td>2.16 ± 0.49</td>
<td>2.19 ± 0.47</td>
<td>0.049</td>
</tr>
</tbody>
</table>

Padial LR, Am Heart J. 1997

Keane MG, Circulation. 2000

---

*None, Mild, Moderate, Severe*
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
AV Repair

Aorta lesions

• Type 1a: STJ (Asc Ao)

• Type 1b: STJ + VAJ (Root)

• Type 1c: VAJ

Repair techniques

→ Supra cor. Asc Ao replac.

→ AV sparing Reimpl./ Remodel.

→ SCA / Ring annuloplasty
AV Repair

Aorta lesions

- Type 1a: STJ (Asc Ao)

Repair techniques

→ Supra cor. Asc Ao replac.
AV Repair

Aorta lesions

- Type 1c: VAJ

Repair techniques

→ SCA / Ring annuloplasty
Principles of AV repair/sparing surgery

1. Repair and preserve cusp geometry and motion + 2. Remodel and stabilize the FAA

To create an optimal area of coaptation, stable over time
Principles of AV repair/sparing surgery

Optimal coaptation?
BAV repair
Valve sparing Reimplantion

1. Circumferential prosthetic based annuloplasty
2. Modify commissure orientation (≈180°)
   - Improve durability
   - Reduce the need of patch repair
AV Repair

• Classification
• Techniques of repair
  • Cusp repair
  • Aortic repair/ annuloplasty
• Results of repair
### BAV Repair

Classification of cusp phenotypes

<table>
<thead>
<tr>
<th>main category: number of raphes</th>
<th>0 raphe - Type 0</th>
<th>1 raphe - Type 1</th>
<th>2 raphes - Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 (7)</td>
<td></td>
<td></td>
<td>14 (5)</td>
</tr>
</tbody>
</table>

#### 1. subcategory: spatial position of cusps in Type 0 and raphes in Types 1 and 2

<table>
<thead>
<tr>
<th>lat ap</th>
<th>L – R</th>
<th>N – L</th>
<th>L – R / R – N</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 (4)</td>
<td>216 (71)</td>
<td>8 (3)</td>
<td>14 (5)</td>
</tr>
</tbody>
</table>

#### 2. subcategory: Valvular

<table>
<thead>
<tr>
<th>Valvular</th>
<th>VF</th>
<th>IS</th>
<th>PS</th>
<th>BS (I + S)</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 (2)</td>
<td>1 (0.3)</td>
<td>79 (26)</td>
<td>7 (2)</td>
<td>3 (1)</td>
</tr>
<tr>
<td></td>
<td>7 (2)</td>
<td>5 (2)</td>
<td>119 (39)</td>
<td>15 (5)</td>
<td>3 (1)</td>
</tr>
<tr>
<td></td>
<td>1 (0.3)</td>
<td>15 (5)</td>
<td>7 (2)</td>
<td>2 (1)</td>
<td>2 (1)</td>
</tr>
<tr>
<td></td>
<td>3 (1)</td>
<td>1 (0.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BAV repair
Classification of cusp phenotypes

Type 0 (Sievers Classif.)
- ≈ 180°
- No raphe
- Prolapse

Type 1 (Sievers classif.)
- Raphe
- Complete fusion
- 160° – 180°
- Prolapse
- Thick, calc. raphe
- Incomplete fusion
- 120° – 160°
- Restrictive
BAV Repair
Aortopathy

- Dilated ventriculo-aortic junction 28 – 30 mm

* de Kerchove JTCVS 2010
* Schäfers JTCVS 2013
AV repair

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

*Pethig K. ATS 2002*

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

*Aicher D. Circ. 2011*
Effect of VAJ annuloplasty on repair durability

✓ Lansac E., EJCTS 2006:

- 87 pts, 95% TAV
- 100% Remodeling, 60% with ring annuloplasty
- Less early residual or recurrent AI in Remodeling + ring group

✓ Aicher D., JTCS 20013:

- 559 BAV repair
- 193 (34%) VAJ suture annuloplasty in patient VAJ >27 mm
- Less early residual or recurrent AI in annuloplasty group
VAJ and valve sparing root replacement

Remodeling

Reimplantation

• Birks EJ., Yacoub MH. Circulation. 1999
• De Olierera NC., David TE. JTCVS 2003
• Miller DG. JTCVS 2003
• Bethea BT., Cameron D. ATS 2004
• David T. JTCVS 2006
• Erasmi A., Sievers HH. ATS 2007

Suggest better repair durability with the Reimplantation technique
Functional classification of aortic regurgitation

Mechanism of dysfunction may coexist

Type 1a+2

Type 1b+2

Type 1c+2
Valve Sparing root replacement

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%