-The Living Aortic Valve-

Repair or Else?

Ismail El-Hamamsy, MD PhD

Associate Professor
Director, Aortic Surgery
Division of Cardiac Surgery
Montreal Heart Institute
Université de Montreal
1

THE AORTIC ROOT IS A LIVING STRUCTURE
AORTIC ROOT PHYSIOLOGY

Dagum et al. Circulation 1999
AORTIC VALVE

Endothelial Cells

Aortic Side

Collagen

GAGs

Elastin

Ventricular Side

Interstitial Cells

-Smooth muscle cells

-Fibroblasts

-Myofibroblasts

Smooth muscle actin

Water & Fibroblasts

Fibrosa ~45%

Spongiosa ~35%

Ventricularis ~20%

Total thickness ~200-700 μm
AORTIC VALVE

Neurofilament

Endothelium-Dependent Regulation of the Mechanical Properties of Aortic Valve Cusps

Ismail El-Hamamsy, MD,* Kartik Balachandran, MS,† Magdi H. Yacoub, FRS,* Louis M. Stevens, MD, SM,‡ Padmini Sarathchandra, PHD,* Patricia M. Taylor, PHD,* Ajit P. Yoganathan, PHD,† Adrian H. Chester, PHD*
THE AORTIC ROOT

LIVING STRUCTURE =

COMPLEX FUNCTIONS

- Laminar flow
- Excellent hemodynamics
- Resistance to infections
- Low thrombogenicity
OUTCOMES FOLLOWING AVR

Laminar Flow

Hemodynamics (gradients)

Thrombogenicity

Resistance to infections

Survival

Valve-related complications

Quality of life
A LIVING AORTIC VALVE SUBSTITUTE

IMPROVED CLINICALLY-RELEVANT OUTCOMES
NON-ELDERLY ADULTS

• High level of physical activity

• Quality of life

• Prolonged anticipated life expectancy
  = Exposure to valve-related complications
    – Degeneration + Reoperation (tissue valves)
    – Bleeding + Thromboembolisms (mechanical valves)
-2-

CONVENTIONAL AVR IN THE YOUNG

= EXCESS MORTALITY
CONVENTIONAL AVR

SEVERAL ADVANTAGES

– Standardized

– Easily reproducible

– Short operative times

– Long-term data
AVR IN THE YOUNG

Observed and Relative Survival After Aortic Valve Replacement

Per Kvidal, MD,* Prof. Reinhold Bergström, PhD,† Lars-Gunnar Hörte, PM, BA,§ Elisabeth Stähle, MD, PhD†

Uppsala and Stockholm, Sweden

Excess Mortality

= first year death risk based on all deaths

Death risk

N 2,227

1 5 10 15

Follow-up year

Kvidal et al. JACC 2000
### Table 4. Basic Data Concerning Observed and Expected Deaths Based on Data From Follow-Up Years 1 through 15*

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Patient-Years at Risk</th>
<th>Observed Number of Deaths</th>
<th>Expected Number of Deaths</th>
<th>O/E Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤50</td>
<td>2,182</td>
<td>31</td>
<td>6.8</td>
<td>4.5</td>
</tr>
<tr>
<td>51–60</td>
<td>2,954.5</td>
<td>98</td>
<td>36.9</td>
<td>2.7</td>
</tr>
<tr>
<td>61–70</td>
<td>5,578.5</td>
<td>274</td>
<td>152.1</td>
<td>1.8</td>
</tr>
<tr>
<td>≥71</td>
<td>3,579</td>
<td>212</td>
<td>208.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The younger the patients are, The higher excess mortality is
Long-term outcomes after elective isolated mechanical aortic valve replacement in young adults

Ismail Bouhout, MSc, a Louis-Mathieu Stevens, MD, PhD, b Amine Mazine, MSc, a Nancy Poirier, MD, a Raymond Cartier, MD, a Philippe Demers, MD, a and Ismail El-Hamamsy, MD, PhD a

1997-2006: 469 isolated mechanical AVR <65 years

Mean follow-up: 9.1 ± 3.5 years

Follow-up 95% complete (4099 patient-years)

Mean age: 53.2 ± 9.2
SURVIVAL – MECHANICAL AVR

Isolated mechanical AVR survival vs case-matched population

<table>
<thead>
<tr>
<th>Follow-up</th>
<th>Survival</th>
<th>Matched survival</th>
<th>N at risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td>98 ± 1%</td>
<td>99.6%</td>
<td>431</td>
</tr>
<tr>
<td>5 years</td>
<td>95 ± 1%</td>
<td>97.6%</td>
<td>387</td>
</tr>
<tr>
<td>10 years</td>
<td>87 ± 1%</td>
<td>94.2%</td>
<td>176</td>
</tr>
</tbody>
</table>
A 10 years, 1 in 5 patients is dead or reoperated
Valve-Related Complications

PROACT RESULTS
Prospective Randomized On-X Valve Anticoagulation Clinical Trial

- 65% Fewer Bleeds
- No Increase in TE
- INR: 1.5–2.0
- 63,000 INR Data Points
- 33 US Centers

Learn More
» Read the article at JTCVS
» Watch the slide presentation
» Request more information
PROACT Trial (n=375 pts)

<table>
<thead>
<tr>
<th>Primary Event</th>
<th>Test group (pt-yr = 766.2)</th>
<th>Control group (pt-yr = 878.6)</th>
<th>Rate Ratio (test/ctrl)</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patients (n)</td>
<td>Rate (%/pt-yr)</td>
<td>Patients (n)</td>
<td>Rate (%/pt-yr)</td>
<td></td>
</tr>
<tr>
<td>Bleeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major</td>
<td>12</td>
<td>1.57</td>
<td>34</td>
<td>3.87</td>
<td>0.40</td>
</tr>
<tr>
<td>Hemorrhagic stroke</td>
<td>1</td>
<td>0.13</td>
<td>4</td>
<td>0.46</td>
<td>0.29</td>
</tr>
<tr>
<td>Minor</td>
<td>9</td>
<td>1.17</td>
<td>35</td>
<td>3.98</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
<td><strong>2.74</strong></td>
<td><strong>69</strong></td>
<td><strong>7.85</strong></td>
<td><strong>0.35</strong></td>
</tr>
<tr>
<td>Ischemic stroke</td>
<td>6</td>
<td>0.78</td>
<td>7</td>
<td>0.80</td>
<td>0.98</td>
</tr>
<tr>
<td>TIA</td>
<td>11</td>
<td>1.44</td>
<td>7</td>
<td>0.80</td>
<td>1.80</td>
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<tr>
<td>Neurologic event</td>
<td>17</td>
<td>2.22</td>
<td>14</td>
<td>1.59</td>
<td>1.39</td>
</tr>
<tr>
<td>Peripheral TE</td>
<td>4</td>
<td>0.52</td>
<td>1</td>
<td>0.11</td>
<td>4.59</td>
</tr>
<tr>
<td>All TE</td>
<td>21</td>
<td>2.74</td>
<td>15</td>
<td>1.71</td>
<td>1.61</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>2</td>
<td>0.26</td>
<td>2</td>
<td>0.23</td>
<td>1.15</td>
</tr>
<tr>
<td><strong>Major event (major bleeding, all TE, thrombosis)</strong></td>
<td>35</td>
<td>4.57</td>
<td>51</td>
<td>5.80</td>
<td>0.79</td>
</tr>
<tr>
<td><strong>Primary endpoint</strong></td>
<td><strong>44</strong></td>
<td><strong>5.74</strong></td>
<td><strong>86</strong></td>
<td><strong>9.79</strong></td>
<td><strong>0.59</strong></td>
</tr>
</tbody>
</table>

Puskas et al. JTCVS 2014
Survival after valve replacement for aortic stenosis: Implications for decision making

Tomislav Mihaljevic, MD, Edward R. Nowicki, MD, Jeevanantham Rajeswaran, MSc, Eugene H. Blackstone, MD, Luigi Lagazzi, MD, James Thomas, MD, Bruce W. Lytle, MD, and Delos M. Cosgrove, MD

3,049 Perimount patients; 1991-2004

"...younger patients had worse than expected survival that was further diminished with insertion of a small prosthesis."

Mihajlevic et al. JTCVS 2008
Very Long-Term Outcomes of the Carpentier-Edwards Perimount Valve in Aortic Position

Thierry Bourguignon, MD, Anne-Lorraine Bouquiaux-Stablo, MD, Pascal Candolfi, PhD, Alain Mirza, MD, Claudia Loardi, MD, Marc-Antoine May, MD, Rym El-Khouri, MD, Michel Marchand, MD, and Michel Aupart, MD

2,659 Perimount patients; 1984-2008

Excess Mortality in Young Adults

-20 yrs

-8 yrs

Very long-term outcomes of the Carpentier-Edwards Perimount aortic valve in patients aged 50–65 years

Thierry Bourguignon, Pierre Lhomme, Rym El Khoury, Pascal Candolfi, Claudia Loardi, Alain Mirza, Julie Boulanger-Lothion, Anne-Lorraine Bouquiaux-Stablo-Duncan, Michel Marchand and Michel Aupart

AVR IN THE YOUNG

Mechanical or Biologic Prostheses for Aortic-Valve and Mitral-Valve Replacement

Andrew B. Goldstone, M.D., Ph.D., Peter Chiu, M.D., Michael Baiocchi, Ph.D., Bharathi Lingala, Ph.D., William L. Patrick, M.D., Michael P. Fischbein, M.D., Ph.D., and Y. Joseph Woo, M.D.

9,942 isolated AVR <65 years; 1996-2013

Goldstone et al. NEJM 2017
AVR IN THE YOUNG

Patients 45–54 Yr of Age

15-Year Mortality: 26-30%

No. at Risk
Biologic Mechanical
1187.1 2421.7
745.1 1548.1
406.7 853.8
98.0 300.0

Probability of
Biologic Mechanical

Patients 55–64 Yr of Age

15-Year Mortality: 32-36%

No. at Risk
Biologic Mechanical
2636.0 3684.7
1553.0 2117.5
768.9 1110.1
170.5 313.0

Goldstone et al. NEJM 2017
CONVENTIONAL AVR IN THE YOUNG

CURATIVE

PALLIATIVE
EXCESS MORTALITY IS OBSERVED UP TO 60 YEARS OF AGE AT THE TIME OF SURGERY
A LIVING AORTIC VALVE = IMPROVED OUTCOMES?
ROSS PROCEDURE = IMPROVED CLINICAL OUTCOMES
to the drugs being used in efforts to control the outbreak. The extent of the problem may be gauged from the fact that in the comparatively limited outbreak described, strains with eight different patterns of drug resistance, from full sensitivity to resistance to six different antimicrobial agents, were isolated, and that the interaction of at least three different R factors, conferring resistance to AST, SSr, and ASCTO.

REPLACEMENT OF AORTIC AND MITRAL VALVES WITH A PULMONARY AUTOGRAFT

DONALD N. ROSS
M.B., B.Sc. Cape Town, F.R.C.S.
CONSULTANT THORACIC SURGEON, GUY'S HOSPITAL, LONDON S.E.1, AND NATIONAL HEART HOSPITAL, LONDON W.1

Fig. 3—Steps in replacement of aortic valve with a pulmonary autograft.
REPLACEMENT OF THE AORTIC VALVE WITH THE AUTOLOGOUS PULMONIC VALVE

R. Cree Pillsbury, M.D. and
Norman E. Shumway, M.D., F.A.C.S.

Diseased heart valves are now readily replaced with a low operative mortality; however, continuing morbidity and mortality make

From the Stanford University School of Medicine, Division of Cardiovascular Surgery, Palo Alto, Calif.

Surgical Forum 1965
ROSS PROCEDURE

THE ONLY REPLACEMENT OPERATION THAT GUARANTEES LONG-TERM VIABILITY OF THE AORTIC VALVE/ROOT
Negative Biases

“Transforms single valve disease into double valve disease”

“High operative morbidity and mortality”

“High rate of reoperations”
SURVIVAL
Long-term outcomes after autograft versus homograft aortic root replacement in adults with aortic valve disease: a randomised controlled trial

Ismail El-Hamamsy, Zeynep Eryigit, Louis-Mathieu Stevens, Zubair Sarang, Robert George, Lucy Clark, Giovanni Melina, Johanna J M Takkenberg, Magdi H Yacoub

<table>
<thead>
<tr>
<th>Endocarditis</th>
<th>Homograft (n=108)</th>
<th>Autograft (n=108)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>86 (80%)</td>
<td>89 (82%)</td>
</tr>
<tr>
<td>Active</td>
<td>9 (8%)</td>
<td>9 (8%)</td>
</tr>
<tr>
<td>Treated</td>
<td>13 (12%)</td>
<td>10 (9%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Previous intervention†</th>
<th>Homograft (n=108)</th>
<th>Autograft (n=108)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homograft</td>
<td>33 (31%)</td>
<td>24 (22%)</td>
</tr>
<tr>
<td>Mechanical or tissue prosthesis</td>
<td>12 (11%)</td>
<td>13 (12%)</td>
</tr>
<tr>
<td>Aortic valve repair</td>
<td>9 (8%)</td>
<td>12 (11%)</td>
</tr>
<tr>
<td>Coarctation repair</td>
<td>2 (2%)</td>
<td>9 (8%)</td>
</tr>
</tbody>
</table>

El-Hamamsy et al. Lancet 2010
When is the Ross operation a good option to treat aortic valve disease?

Tirone E. David, MD, Anna Woo, MD, Susan Armstrong, MSc, and Manjula Maganti, MSc

- 1990-2004
- 212 pts
- 34 +/- 9 years
- Mean Fup: 10.1 yrs

David et al. JTCVS 2010
The Ross procedure: Outcomes at 20 years

Tirone E. David, MD, Carolyn David, BN, Anna Woo, MD, and Cedric Manlhiot, BSc

- 1990-2004
- 212 pts
- 34 +/- 9 years
- Median Fup: 13.8 years

David et al. JTCVS 2014
A multicentre evaluation of the autograft procedure for young patients undergoing aortic valve replacement: update on the German Ross Registry

- 1990-2013
- 1779 pts (8 centers)
- 45+/- 11 years
- Mean Fup: 8.3 years (662 pts >10 years)

CONCLUSION: The autograft principle results in postoperative long-term survival comparable with that of the age- and gender-matched general population and reoperation rates within the 1%/patient-year boundaries and should be considered in young, active patients who want to avoid the shortcomings of conventional prostheses.
The Ross procedure in young adults: over 20 years of experience in our Institution

Stefano Mastrobuoni*, Laurent de Kerchove, Silvia Solari, Parla Astarci, Alain Poncelet, Philippe Noirhomme, Jean Rubay and Gebrine El Khoury

- 1991-2014
- 306 pts
- 42+/- 9 years
- Median Fup: 10.6 years
Survival Free from Reoperation

Aortic Valve Replacement and the Ross Operation in Children and Young Adults

Mansour T.A. Sharabiani, PhD, Dan M. Dorobantu, MD, Alireza S. Mahani, PhD, Mark Turner, PhD, Andrew J. Peter Tometzki, MBCiB, Gianni D. Angelini, MD, Andrew J. Parry, MBCiB, Massimo Caputo, MD, Serban C. Stoica, MD

- UK National Registry
- 2000-2012
- 1501 patients

Survival free from reoperation

- ROSS: 89.6%
- MECH: 86.3%
- TISSUE: 78.8%

Sharabiani et al. JACC 2016
Ross vs. Mechanical AVR

Long-Term Outcomes of the Ross Procedure Versus Mechanical Aortic Valve Replacement
Propensity-Matched Cohort Study

Amine Mazine, MD, MSc
Tirone E. David, MD
Vivek Rao, MD, PhD
Edward J. Hickey, BM
Shakira Christie, BSc
Cedric Manlhiot, PhD
Maral Ouzounian, MD, PhD

Mazine et al. Circulation 2016
+ 1992-2016
+ 392 Ross cases
+ Propensity-matched: 275 pairs
+ 43 +/- 11 years
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>Study Period</th>
<th>N</th>
<th>Mean Follow-up (years)</th>
<th>Mean Age (years)</th>
<th>BAV (%)</th>
<th>AS (%) / AI (%) / Mixed AS-AI (%)</th>
<th>Operative Mortality (%)</th>
<th>5-Year Survival (%)</th>
<th>10-Year Survival (%)</th>
<th>15-Year Survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>El-Hamamsy et al. (2010)</td>
<td>RCT</td>
<td>1994-2001</td>
<td>216 pts (108 Ross)</td>
<td>10.2 (2173 pt-yrs)</td>
<td>38</td>
<td>49%</td>
<td>28% / 45% / 27%</td>
<td>0.9%</td>
<td>97%</td>
<td>97%</td>
<td>95%**</td>
</tr>
<tr>
<td>Sievers et al. (2015)</td>
<td>Multicenter Ross Registry (prospective)</td>
<td>1990-2013</td>
<td>1779</td>
<td>8.3 (14,288 pt-yrs)</td>
<td>44.7</td>
<td>64.8%</td>
<td>24% / 22% / 52%</td>
<td>1.1%</td>
<td>NA</td>
<td>NA</td>
<td>90%**</td>
</tr>
<tr>
<td>David et al. (2014)</td>
<td>Single center</td>
<td>1990-2004</td>
<td>212</td>
<td>13.8*</td>
<td>34</td>
<td>71.7%</td>
<td>50% / 36% / 13%</td>
<td>0.4%</td>
<td>98.6%</td>
<td>97.5%</td>
<td>93.6%**</td>
</tr>
<tr>
<td>Mastrobuoni et al. (2015)</td>
<td>Single center</td>
<td>1991-2014</td>
<td>306</td>
<td>10.6*</td>
<td>42</td>
<td>58.5%</td>
<td>68% / 31% / 0%</td>
<td>2.3%</td>
<td>NA</td>
<td>NA</td>
<td>88%**</td>
</tr>
<tr>
<td>Skillington et al. (2013)</td>
<td>Single center</td>
<td>1992-2012</td>
<td>310</td>
<td>9.4</td>
<td>39.3</td>
<td>92%</td>
<td>46% / 32% / 22%</td>
<td>0.3%</td>
<td>98%</td>
<td>98%</td>
<td>97%**</td>
</tr>
<tr>
<td>Da Costa et al. (2014)</td>
<td>Single center</td>
<td>1995-2013</td>
<td>414</td>
<td>8.2</td>
<td>30.8</td>
<td>50%</td>
<td>29% / 39% / 31%</td>
<td>2.7%</td>
<td>NA</td>
<td>NA</td>
<td>89.3%**</td>
</tr>
<tr>
<td>Kalfa et al. (2015)</td>
<td>Single center</td>
<td>1990-2013</td>
<td>221</td>
<td>11.4*</td>
<td>41.5</td>
<td>76.5%</td>
<td>81% / 0% / 19%</td>
<td>0.9%</td>
<td>NA</td>
<td>NA</td>
<td>92%</td>
</tr>
<tr>
<td>Andreas et al. (2014)</td>
<td>Single center</td>
<td>1991-2011</td>
<td>246</td>
<td>10*</td>
<td>29</td>
<td>75%</td>
<td>29% / 40% / 31%</td>
<td>1.6%</td>
<td>96%</td>
<td>94%</td>
<td>91%**</td>
</tr>
</tbody>
</table>

>3600 pts
“Late mortality rates are low and resemble the adult series age-matched population mortality.”
CONCLUSIONS AND RELEVANCE  Data from primarily observational studies suggest that the Ross procedure is associated with lower all-cause mortality compared with mechanical aortic valve replacement. These findings highlight the need for a large, prospective randomized clinical trial comparing long-term outcomes between these 2 interventions.
THE ONLY REPLACEMENT OPERATION THAT RESTORES LONG-TERM SURVIVAL FOLLOWING AORTIC VALVE REPLACEMENT
WHAT ABOUT THE ROSS IN PATIENTS WITH Ao REGURGITATION AND A DILATED ANNULUS?
ACHILLE’S HEEL?

Reoperation

Operative Risk
The Ross operation: a Trojan horse?†

Loes M.A. Klieverik¹*, Johanna J.M. Takkenberg¹, Jos A. Bekkers¹, Jolien W. Roos-Hesselink², Maarten Witsenburg³, and Ad J.J.C. Bogers¹

Children vs. adults
Log–rank test $P = 0.02$

Freedom from reoperation (%)

Patients younger than 16 years

Patients older than 16 years

Number at risk

Time (years)

$n = 134$

$n = 123$

$n = 106$

$n = 81$

$n = 46$

$n = 25$

$n = 13$
The Ross procedure in children and young adults: A word of caution

Antonio Laudito, MD
Michael M. Brook, MD
Sam Suleman, BS
Mark S. Bleiweis, MD
Lenardo D. Thompson, MD
Frank L. Hanley, MD
V. Mohan Reddy, MD

TABLE 1. Predictors of autograft failure in univariate Cox proportional hazards models

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Hazard ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1.39</td>
<td>0.30-6.4</td>
<td>.67</td>
</tr>
<tr>
<td>Age (per year)</td>
<td>0.95</td>
<td>0.87-1.04</td>
<td>.30</td>
</tr>
<tr>
<td>Prior LVOT surgery</td>
<td>0.83</td>
<td>0.27-2.6</td>
<td>.75</td>
</tr>
<tr>
<td>Ross (vs Ross-Konno)</td>
<td>0.74</td>
<td>0.22-2.5</td>
<td>.62</td>
</tr>
<tr>
<td>Attempted repair</td>
<td>0.47</td>
<td>0.06-3.7</td>
<td>.47</td>
</tr>
<tr>
<td>Sinus obliteration technique</td>
<td>2.6</td>
<td>0.72-9.1</td>
<td>.15</td>
</tr>
</tbody>
</table>

Hemodynamic diagnosis of AI (vs AS)*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Hazard ratio</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV anulus (per mm)</td>
<td>4.2</td>
<td>1.14-15.7</td>
<td>.031</td>
</tr>
<tr>
<td>Stenotic (vs normal)†</td>
<td>0.91</td>
<td>0.11-7.8</td>
<td>.93</td>
</tr>
<tr>
<td>Dilated (vs normal)†</td>
<td>0.42</td>
<td>0.10-1.8</td>
<td>.24</td>
</tr>
<tr>
<td>PV-AV (per mm)</td>
<td>1.07</td>
<td>0.92-1.23</td>
<td>.37</td>
</tr>
<tr>
<td>Crossclamp time (per hour)</td>
<td>0.90</td>
<td>0.39-2.1</td>
<td>.81</td>
</tr>
<tr>
<td>Total CPB time (per hour)</td>
<td>0.68</td>
<td>0.36-1.27</td>
<td>.23</td>
</tr>
<tr>
<td>Additional procedure</td>
<td>0.79</td>
<td>0.24-2.6</td>
<td>.70</td>
</tr>
<tr>
<td>Absolute PV anulus</td>
<td>1.01</td>
<td>0.80-1.27</td>
<td>.96</td>
</tr>
<tr>
<td>Absolute PV-AV anulus</td>
<td>1.7</td>
<td>0.33-9.3</td>
<td>.52</td>
</tr>
</tbody>
</table>
When is the Ross operation a good option to treat aortic valve disease?

Tirone E. David, MD, Anna Woo, MD, Susan Armstrong, MSc, and Manjula Maganti, MSc

**TABLE 2. Freedom from reoperation on the pulmonary autograft**

<table>
<thead>
<tr>
<th></th>
<th>5 y</th>
<th>10 y</th>
<th>15 y</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operative technique</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcoronary/inclusion</td>
<td>96.3 ± 1.8 (98)</td>
<td>92.1 ± 3.3 (34)</td>
<td>92.1 ± 3.3 (10)</td>
<td></td>
</tr>
<tr>
<td>Root replacement</td>
<td>96.9 ± 1.7 (86)</td>
<td>94.1 ± 2.5 (62)</td>
<td>92.4 ± 3.0 (4)</td>
<td>.82</td>
</tr>
<tr>
<td><strong>Aortic/pulmonary annulus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No mismatch</td>
<td>98.2 ± 1.2 (98)</td>
<td>98.2 ± 1.2 (44)</td>
<td>98.2 ± 1.2 (6)</td>
<td></td>
</tr>
<tr>
<td>Mismatch</td>
<td>94.6 ± 2.3 (85)</td>
<td>88.5 ± 3.6 (52)</td>
<td>86.5 ± 4.0 (8)</td>
<td>.01</td>
</tr>
<tr>
<td><strong>Aortic annulus diameter</strong></td>
<td></td>
<td></td>
<td></td>
<td>.003</td>
</tr>
<tr>
<td>&lt;27 mm</td>
<td>100 (80)</td>
<td>100 (43)</td>
<td>100 (3)</td>
<td></td>
</tr>
<tr>
<td>≥27 mm</td>
<td>94.0 ± 2.1 (104)</td>
<td>88.7 ± 3.29 (53)</td>
<td>86.8 ± 3.7 (11)</td>
<td></td>
</tr>
<tr>
<td><strong>Aortic valve lesion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stenosis</td>
<td>99.0 ± 0.9 (93)</td>
<td>97.4 ± 1.9 (47)</td>
<td>97.4 ± 1.9 (3)</td>
<td></td>
</tr>
<tr>
<td>Insufficiency</td>
<td>92.1 ± 3.1 (65)</td>
<td>87.5 ± 4.2 (34)</td>
<td>84.3 ± 5.2 (10)</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>100 (26)</td>
<td>3.7 ± 6.0 (15)</td>
<td>93.7 ± 6.0 (1)</td>
<td>.01</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>100 (61)</td>
<td>100 (35)</td>
<td>100 (7)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>94.8 ± 1.8 (140)</td>
<td>90.0 ± 2.9 (61)</td>
<td>88.1 ± 3.4 (7)</td>
<td>.03</td>
</tr>
</tbody>
</table>
The Ross Procedure Performed for Aortic Insufficiency Is Associated With Increased Autograft Reoperation

William H. Ryan, MD, Syma L. Prince, RN, BSN, Dan Culica, MD, PhD, and Morley A. Herbert, PhD

---

**Surviving Percentage (%)**

- **AS Pats**
- **AI Pats**

---

**Event (Re-op) Free Percentage**

- **AS Patients**
- **AI Patients**

---

**Follow-up Time (yrs)**

- 0
- 2
- 4
- 6
- 8
- 10
- 12

---

**# at risk**

- **AI Pats**
- **AS Pats**

---

**Right censored values**

---

**p=0.266 (log-rank)**

---

**p=0.045 (log-rank)**
ROSS PROCEDURE
Ross Procedure at the Crossroads

Tirone E. David, MD

valve failure in these patients. At present, I no longer recommend the Ross procedure in patients with AI and dilated aortic annulus. In our practice, most of these patients have a congenital bicuspid aortic valve.
PARADIGM CHANGE

ANTICOAGULATION VS. REOPERATION

SURVIVAL + QUALITY OF LIFE
<table>
<thead>
<tr>
<th>Study</th>
<th>Study Type</th>
<th>Study Period</th>
<th>N</th>
<th>Mean Follow-up (years)</th>
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<th>BAV (%)</th>
<th>AS (%) / AI (%) / Mixed AS-AI (%)</th>
<th>Operative mortality (%)</th>
<th>5-Year Survival (%)</th>
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<td>216 pts (108 Ross)</td>
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<td>49%</td>
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<td>44.7</td>
<td>64.8%</td>
<td>24% / 22% / 52%</td>
<td>1.1%</td>
<td>NA</td>
<td>NA</td>
<td>90%**</td>
</tr>
<tr>
<td>David et al. (2014)</td>
<td>Single center</td>
<td>1990-2004</td>
<td>212</td>
<td>13.8*</td>
<td>34</td>
<td>71.7%</td>
<td>50% / 36% / 13%</td>
<td>0.4%</td>
<td>98.6%</td>
<td>97.5%</td>
<td>93.6%**</td>
</tr>
<tr>
<td>Mastrobuoni et al. (2015)</td>
<td>Single center</td>
<td>1991-2014</td>
<td>306</td>
<td>10.6*</td>
<td>42</td>
<td>58.5%</td>
<td>68% / 31% / 0%</td>
<td>2.3%</td>
<td>NA</td>
<td>NA</td>
<td>88%**</td>
</tr>
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<td>50%</td>
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<td>2.7%</td>
<td>NA</td>
<td>NA</td>
<td>89.3%**</td>
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<td>221</td>
<td>11.4*</td>
<td>41.5</td>
<td>76.5%</td>
<td>81% / 0% / 19%</td>
<td>0.9%</td>
<td>NA</td>
<td>92%</td>
<td>90.5%</td>
</tr>
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<td>10*</td>
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<td>75%</td>
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<td>1.6%</td>
<td>96%</td>
<td>94%</td>
<td>91%**</td>
</tr>
</tbody>
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Excessive pulmonary autograft dilatation causes important aortic regurgitation

R B Hokken, J J M Takkenberg, L A van Herwerden, J R T C Roelandt, A J J C Bogers

Heart 2003;89:933–934

There was a significant increase of the PAG annulus and sinus diameters during follow up, 22% and 27%, respectively (table 1). Most of the diameter increase was already reached at hospital discharge, with diminished increase thereafter. The
TECHNIQUE MATTERS
The Ross Procedure: How I Teach It

Amine Mazine, MD, MSc,* Aly Ghoneim, MD,* and Ismail El-Hamamsy, MD, PhD
Division of Cardiac Surgery, Montreal Heart Institute, Université de Montréal, Montreal, Quebec, Canada

Ann Thorac Surg 2018


The Ross procedure: total root technique

Jessica Forcilloa, Mustafa Cikirikciogluab, Nancy Poiriera and Ismail El-Hamamsya,*

aDepartment of Cardiac Surgery, Montreal Heart Institute, Université de Montréal, Quebec, Canada
bDivision of Cardiovascular Surgery, Department of Surgery, University Hospitals and Medical Faculty of Geneva, Geneva, Switzerland

MMCTS 2014
Tailored Approaches to AI

Mazine, El-Hamamsy et al. JACC 2018 (in press)
Tailored Ross Technique

• Trimming of infudibular muscle below the valve

• Scalloping
Pulmonary Autograft Trimming
Tailored Ross Technique

Proximal suture line

• Place the autograft in an infra-annular position (inside the LVOT)

• Interrupted sutures

• Commissural Symmetry
Aortic vs Pulmonary Anatomy
Tailored Ross Technique
Extra-Aortic Annuloplasty

• Extra-aortic ring annuloplasty is used if:
  
  – AI or mixed AS/AI (with predominant AI) is the indication
  
  – Annulus mismatch >2mm (Aortic > Pulmonary)
Extra-Aortic Annuloplasty
Early results of extra-aortic annuloplasty ring implantation on aortic annular dimensions

Lauren Basmadjian, MD, a Arsène J. Basmadjian, MD, MSc, b Louis-Mathieu Stevens, MD, PhD, c François-Pierre Mongeon, MD, b Raymond Cartier, MD, a Nancy Poirier, MD, a and Ismail El Hamamsy, MD, PhD a

Reimplantation versus remodelling with ring annuloplasty: comparison of mid-term outcomes after valve-sparing aortic root replacement†

Marien Lenoir a, Bart Maesen b, Louis-Mathieu Stevens c, Raymond Cartier a, Philippe Demers a, Nancy Poirier a, Michaël Tousch a and Ismail El-Hamamsy a,*
Annular reduction and Stabilization

Basmadjian et al. JTCVS 2017

Lenoir et al. EJCTS 2018 (in press)
Aortic Annuloplasty
Aortic Annuloplasty
Aortic Annuloplasty
Aortic Annuloplasty
Aortic Annuloplasty
Aortic Annuloplasty
Tailored Ross Technique

Distal Suture Line

- Short autograft above STJ (or coronary anastomosis) (max 2-3mm)
- Short interposition graft if ascending aorta ≥40mm
- Careful attention to commissural symmetry
Tailored Ross Technique

Postoperative Management

• Strict BP control in the perioperative period (max sBP 100-110mmHg)

• Home BP monitoring 6 months (max sBP 100-110mmHg)
BP Remote Monitoring

- Amazon.com: Blood Pressure Log - MyDiary
- Aujourd'hui: Pression Artérielle Moniteur - Famil... Taconic System LLC
- Chat de votre médecin et configuration de votre santé
Pression artérielle (mmHg)

- 2017-juill.
- août
- 2017-sept.
- oct.

Ross Procedure June 2017
Montreal Ross Program (N=356 patients)

- 2011: 17
- 2012: 36
- 2013: 40
- 2014: 36
- 2015: 48
- 2016: 73
- 2017: 60
- 2018: 46

Jan-July
Montreal Aortic Program (N=611 patients)

- **Ross Procedure** – N= 356 patients
- **Valve-Sparing/Repair** – N= 255 patients

Yearly counts from 2005 to 2018:
- 2005: 4, 4, 4
- 2006: 4, 5, 6
- 2007: 9
- 2008: 17
- 2009: 15
- 2010: 19
- 2011: 36
- 2012: 40
- 2013: 48
- 2014: 36
- 2015: 20
- 2016: 22
- 2017: 36
- 2018: 37

Years with higher counts:**2016, 2017, 2018**
MONTREAL HEART INSTITUTE (N=356)

2011-2018

356 patients: Mean age 42 yrs (16-67 yrs)

• 15% redos (N=53)
• 60% concomittant procedures (N=208)
• 5% active endocarditis (N=17)

Operative mortality: 0.6% (n=2)
• The first 100 patients
  – Temporary dialysis (n=5)
  – Reexploration for bleeding (n=4)
  – Mortality (n=2)

• The last 256 patients
  – Temporary dialysis (n=3): 1.2%
  – Reexploration for bleeding (n=2): <1%
  – Mortality (n=0): 0%
Montreal Ross Program

2011 – 2018 : 281 consecutive Ross procedures with ≥ 1 year of follow-up
(Mean age : 46 ± 7 years)

Exclusions:
- Endocarditis (n=18)
- Previous AVR (n=22)

241 Ross procedures

AR group (n=73)

AS group (n=168)

Mean Follow-up: 29 ± 11 months
100% complete for yearly clinical and echo follow-up

Bouhout,...,El-Hamamsy. EACTS 2018
Ross Procedure with Ring Annuloplasty

Annulus

Sinus of Valsalva

Freedom from autograft reintervention

Freedom from AR ≥ 2

Bouhout,..,El-Hamamsy. EACTS 2018
ANY Reoperation

![Graph showing the freedom from need of any reoperation.](image)

**El-Hamamsy et al. Lancet 2010**
Ross Reoperation

A multicentre evaluation of the autograft procedure for young patients undergoing aortic valve replacement: update on the German Ross Registry†


• N= 1779 adult patients (1990-2013)
• 8 centers
• Mean follow-up 8.3 years

CONCLUSION: The autograft principle results in postoperative long-term survival comparable with that of the age- and gender-matched general population and reoperation rates within the 1%/patient-year boundaries and should be considered in young, active patients who want to avoid the shortcomings of conventional prostheses.

Sievers et al. EJCTS 2015
# Freedom from Reoperation

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<td>31% / 0%</td>
<td>2.3%</td>
<td>NA</td>
<td>NA</td>
<td>(AS 83%) (Al 65%)</td>
</tr>
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1%/patient-year reoperation range
The Ross procedure: time for a hard look at current practices and a reexamination of the guidelines

Ismail El-Hamamsy, Ismail Bouhout

The Ross procedure is the best operation to treat aortic stenosis in young and middle-aged adults

Maral Ouzounian, MD, PhD, Amine Mazine, MD, MSc, and Tirone E. David, MD

Is it Time to Reconsider Use of the Ross Procedure for Adults?*

Gösta B. Pettersson, MD, PhD, Eugene H. Blackstone, MD

The Ross procedure: Time to reevaluate the guidelines

Martin Misfeld, MD, PhD, and Michael A. Borger, MD, PhD
PARADIGM CHANGE

ANTICOAGULATION VS. REOPERATION

SURVIVAL + QUALITY OF LIFE
SIMILAR OPERATIVE RISK

RESTORED LATE SURVIVAL

EXCELLENT QUALITY OF LIFE

BETTER HEMODYNAMICS

BETTER FREEDOM FROM VALVE-RELATED COMPLICATIONS
CONCLUSION

• **YOUNG ADULTS** = The choice of prosthesis has a direct impact on long-term prognosis

• **CONVENTIONAL AVR IN THE YOUNG** = Excess long-term mortality versus general population

• **ROSS PROCEDURE** = Improved long-term survival and quality of life in selected patients

• **IN PATIENTS WITH NON-REPAIRABLE AI**, a tailored Ross procedure = Improved durability
i.elhamamsy@icm-mhi.org