Modified Ross Procedure

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No disclosures
History of the Ross Procedure

Early Popularity

- 1967 – first pulmonary autograft AVR by Ross
  - Subcoronary implant technique
  - Not widely adopted.
    - Technically challenging
    - Potential for distorted 3-D geometry led to significant early failures
- Full Root implant technique popularized beginning late 80’s
  - More reproducible
    - Less potential for distortion of the 3-D geometry of the valve
    - Improved early results
  - Markedly increased popularity in 1990’s
  - Most Ross procedures done as full root replacements

Donald Ross, 1922-2014
Ross Procedure
Fall from Grace

• Beginning ~ 2000 reports increased showing late autograft root dilatation and development of aortic regurgitation.
  – Klieverik et al – freedom from autograft failure 98% at 5 yrs but only 69% at 13 yrs (only 56% in patients > 16 yrs old)
  – Elkings et al – freedom from autograft failure 86% at 10 yrs and 74% at 16 yrs

• This disappointing autograft durability led many surgeons to abandon the Ross Procedure, at least in adults

• There are still several significant advantages of the Ross Procedure
  – Excellent patient survival – in most series equal to age-matched general population
  – Excellent hemodynamics
  – Almost complete freedom from thromboembolism
  – Very low incidence of endocarditis 0.1-0.3%/y
Ross Procedure
Efforts to improve durability

- Subcoronary implant
  - Good freedom from root dilation
  - Technically more subject to error and early failure due to distortion of 3-D geometry

- Inclusion root replacement
  - Good freedom from root dilation
  - Limited by the native root anatomy
  - Also subject to distortion

- External support at the annulus and sinotubular junction
  - Corrects annular size mismatch and prevents dilatation of annulus
  - Does not prevent aortic sinus dilation

- Full Root replacement with partial support by the preserved native non-coronary sinus and the pillar of aortic wall at the L/R commissure
Ross Procedure
Efforts to improve durability

• Common operation for the “failed autograft” is the Valve Sparing Root Replacement
  – Results appear to be excellent

• This has led several surgeons to consider complete autograft support within a dacron root prosthesis at the time of initial Ross procedure
  – Has been described with straight tube grafts
  – Also described with Valsalva grafts which may better preserve neo-aortic leaflet geometry and motion, possibly improving durability
• Meta-analysis—9 reports of 5837 patients with **porcine** bioprostheses
Prognosis After Aortic Valve Replacement With a Bioprosthesis
Predictions Based on Meta-Analysis and Microsimulation

J.P.A. Puvimanasige, MBBS, MSc, MD; E.W. Steyerberg, PhD; J.J.M. Takkenberg, MD;
M.J.C. Eijkemans, MSc; L.A. van Herwerden, MD, PhD;
A.J.J.C. Bogers, MD, PhD; J.D.F. Habbema, PhD

(Circulation. 2001;103:1535-1541.)
Bioprosthetic Aortic Valve Replacement in Nonelderly Adults
A Systematic Review, Meta-Analysis, and Microsimulation

**Figure 2.** Pooled Kaplan-Meier freedom from all-cause mortality of the study population compared with the age- and sex-matched general population.

**Figure 7.** Microsimulation-based age-specific mean life expectancy after bioprosthetic AVR compared with the age- and sex-matched general population.

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.

RESULTS
From 1996 through 2013, the use of biologic prostheses increased substantially for aortic-valve and mitral-valve replacement, from 11.5% to 51.6% for aortic-valve replacement and from 16.8% to 53.7% for mitral-valve replacement. Among patients who underwent aortic-valve replacement, receipt of a biologic prosthesis was associated with significantly higher 15-year mortality than receipt of a mechanical prosthesis among patients 45 to 54 years of age (30.6% vs. 26.4% at 15 years; hazard ratio, 1.23; 95% confidence interval [CI], 1.02 to 1.48; P=0.03) but not among patients 55 to 64 years of age. Among patients who underwent mitral-valve replacement, receipt of a biologic prosthesis was associated with significantly higher mortality than receipt of a mechanical prosthesis among patients 40 to 49 years of age (44.1% vs. 27.1%; hazard ratio, 1.88; 95% CI, 1.35 to 2.63; P<0.001) and among those 50 to 69 years of age (50.0% vs. 45.3%; hazard ratio, 1.16; 95% CI, 1.04 to 1.30; P=0.01). The incidence of reoperation was significantly higher among recipients of a biologic prosthesis than among recipients of a mechanical prosthesis. Patients who received mechanical valves had a higher cumulative incidence of bleeding and, in some age groups, stroke than did recipients of a biologic prosthesis.
Improved Survival After the Ross Procedure Compared With Mechanical Aortic Valve Replacement

Edward Buratto, MBBS, William Y. Shi, MBBS, PhD, Rochelle Wynne, PhD, Chin L. Poh, MBBS, Marco Larobina, MBBS, Michael O’Keefe, MBBS, John Goldblatt, MBBS, James Tatoulis, MD, Peter D. Skillington, MBBS

ABSTRACT

BACKGROUND It is unclear whether the Ross procedure offers superior survival compared with mechanical aortic valve replacement (AVR).

OBJECTIVES This study evaluated experience and compared long-term survival between the Ross procedure and mechanical AVR.

METHODS Between 1992 and 2016, a total of 392 Ross procedures were performed. These were compared with 1,928 isolated mechanical AVRs performed during the same time period as identified using the University of Melbourne and Australia and New Zealand Society of Cardiac and Thoracic Surgeons’ Cardiac Surgery Databases. Only patients between 18 and 65 years of age were included. Propensity-score matching was performed for risk adjustment.

RESULTS Ross procedure patients were younger, and had fewer cardiovascular risk factors. The Ross procedure was associated with longer cardiopulmonary bypass and aortic cross-clamp times. Thirty-day mortality was similar (Ross, 0.3%; mechanical, 0.8%; p = 0.5). Ross procedure patients experienced superior unadjusted long-term survival at 20 years (Ross, 95%; mechanical, 68%; p < 0.001). Multivariable analysis showed the Ross procedure to be associated with a reduced risk of late mortality (hazard ratio: 0.34; 95% confidence interval: 0.17 to 0.67; p < 0.001). Among 275 propensity-score matched pairs, Ross procedure patients had superior survival at 20 years (Ross, 94%; mechanical, 84%; p = 0.018).

CONCLUSIONS In this Australian, propensity-score matched study, the Ross procedure was associated with better long-term survival compared with mechanical AVR. In younger patients, with a long life expectancy, the Ross procedure should be considered in centers with sufficient expertise. (J Am Coll Cardiol 2018;71:1337-44) Crown Copyright © 2018 Published by Elsevier on behalf of the American College of Cardiology Foundation. All rights reserved.
German Ross Registry Experience

- 1014 patients (root replacement and subcoronary technique) between February 1990 and July 2006
- 0.78% hospital mortality
- Overall survival
  - 1 year – 98.7%
  - 5 years – 96.4%
  - 8 years – 93.2%
- Freedom from reoperation on autograft (no difference b/w techniques)
  - 1 year – 99.1%
  - 5 years – 96.1%
  - 8 years – 93.9%
- Freedom from allograft re-intervention
  - 1 year – 99.5%
  - 5 years – 97.3%
  - 8 years – 96.1%
- 0% reoperative mortality

(Circulation. 2007;116[suppl 1]:I-251–I-258.)
Long-term outcomes after **autograft versus homograft** aortic root replacement in adults with aortic valve disease: a randomised controlled trial

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

- 228 Male and female patients (>18 and <69 years)
- Excluded aortic root/ascending aneurysms, bicuspid aortic valve, decreased EF, active endocarditis, redo, rheumatic disease
- Perioperative death
  - Homograft – 3%
  - Ross – <1%
- 10 year actuarial survival
  - Homograft – 83%
  - Ross – 97%
- Hazard ratio for death in homograft group – 4.61
- Survival in Ross group was similar to age and sex-matched British population (96%)

*Figure 2: Actuarial survival after autograft versus homograft aortic root replacement*
90% of patients were age 18-60
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
Key points

- Excluded aortic root/ascending aneurysms
- Excluded decreased EF, endocarditis, rheumatic, and bicuspid valves (?), urgent/emergent cases
- ~65% were NYHA I-II
- Oversizing pulmonary allograft
- Seated autograft within native aortic annulus for fibrous support
- Strict BP control post-op (SBP <100-110 mmHg) for 6-12 mos
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

- 160 patients with prospective data collection by single surgeon
- Mean age 42.0 +/- 11 years
- 58.1% had preoperative AI
- Vast majority were bicuspid valves

**RESULTS**

- 7.5 year survival – 92.9%
- 9.4% required reoperation on autograft
- Patients with AI required more reoperations
- Risk factors – **female gender, aortic dilatation, 3-cusp valve, annuloplasty**
The Ross procedure: Outcomes at 20 years

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

- 212 patients prospectively followed, single surgeon
- Mean age 34 +/- 9 years, 66% men, 82% with congenital AV disease

RESULTS
- 1 operative mortality
- 20 years survival – 93.6% (similar to age and sex matched population)
- 27 patients required reoperation
  - 15 on autograft
  - 8 on homograft
  - 4 other cardiac procedures

Freedom from reoperation
- Autograft – 81.8%
- Homograft – 92.7%
- Both – 79.9%

Risk factors for reoperation
- Preoperative AI
- Aortic annulus > 15 mm/m^2
- men

(J Thorac Cardiovase Surg 2014;147:85-94)
The Ross procedure: Outcomes at 20 years

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

**TABLE 2. Freedom from morbid events at various time intervals**

<table>
<thead>
<tr>
<th>Freedom from event</th>
<th>5 y (95% CI)</th>
<th>10 y (95% CI)</th>
<th>15 y (95% CI)</th>
<th>20 y (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-cause mortality</td>
<td>98.6 (95.7-99.5)</td>
<td>97.5 (94.0-98.9)</td>
<td><strong>93.6 (88.1-96.6)</strong></td>
<td><strong>93.6 (88.1-96.6)</strong></td>
</tr>
<tr>
<td>Alive and reoperation-free on the AV or PV</td>
<td>93.7 (87.7-96.7)</td>
<td>90.4 (83.3-94.5)</td>
<td>84.4 (75.2-90.2)</td>
<td>77.9 (61.7-87.9)</td>
</tr>
<tr>
<td>Thromboembolism</td>
<td>99.1 (96.3-99.8)</td>
<td>98.6 (95.6-99.5)</td>
<td>98.6 (95.6-99.5)</td>
<td>96.8 (89.9-99.0)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>No event</td>
<td>99.0 (96.0-99.7)</td>
<td>96.8 (92.4-98.7)</td>
<td>96.8 (92.4-98.7)</td>
</tr>
<tr>
<td>Reoperation on AV</td>
<td>97.6 (94.3-99.0)</td>
<td>96.5 (92.8-98.3)</td>
<td><strong>93.0 (87.3-96.1)</strong></td>
<td><strong>81.8 (60.3-92.3)</strong></td>
</tr>
<tr>
<td>Reoperation on patients with aortic insufficiency</td>
<td>95.2 (88.8-98.0)</td>
<td>94.1 (87.4-97.3)</td>
<td>87.3 (77.0-93.2)</td>
<td>75.5 (52.0-88.7)</td>
</tr>
<tr>
<td>Reoperation on PV</td>
<td>No event</td>
<td>97.9 (94.5-99.2)</td>
<td><strong>95.5 (90.5-97.9)</strong></td>
<td><strong>92.7 (85.6-96.4)</strong></td>
</tr>
<tr>
<td>Aortic insufficiency*</td>
<td>93.1 (88.6-95.8)</td>
<td>90.3 (85.2-93.7)</td>
<td>88.7 (83.1-92.6)</td>
<td>62.6 (28.6-89.3)</td>
</tr>
<tr>
<td>PV dysfunction†</td>
<td>93.0 (88.4-95.8)</td>
<td>84.8 (78.8-89.2)</td>
<td>74.6 (78.8-89.2)</td>
<td>53.8 (30.7-72.2)</td>
</tr>
<tr>
<td>Aortic root ≥44 mm</td>
<td><strong>99.5 (96.6-99.9)</strong></td>
<td><strong>96.6 (92.5-98.5)</strong></td>
<td><strong>90.9 (84.2-94.9)</strong></td>
<td><strong>75.7 (42.5-91.4)</strong></td>
</tr>
</tbody>
</table>

CI, Confidence interval; AV, aortic valve; PV, pulmonary valve. *Greater than mild. †Moderate or severe pulmonary valve insufficiency and/or peak systolic gradient ≥40 mm Hg.
Late Results of the Ross Procedure
David et al.

- Median age 34 (28-41)
- Probability of Ross-related reoperation at 20 years 16.3%
- Autograft reoperation 11.5%
- Pulmonary homograft reoperation 8.2%
Take Away

- Bioprosthetic AVR
  - 45-60% risk of reoperation (age 35-55)
  - 7-15 year shorter life expectancy than sex and age matched population (age 35-55)
  - ~30% mortality at 15 years (age 45-54)
- Mechanical AVR
  - ~26% mortality at 15 years (age 45-54)
  - Higher incidence of lifetime bleeding and thromboembolic event
- Ross Procedure
  - Essentially equal survival to sex and age matched populations
  - 93-97% 10 year survival (David-94% 20 yr)
  - 90-97% freedom from reop on autograft at 10 years (David-89% at 20 yrs)
  - 82-98% freedom from reop on homograft at 10 years (David-92% at 20 yrs)
  - Vast majority of autograft failures from AI/root aneurysm
Ross Procedure versus Bioprosthetic AVR and Valve-in-valve TAVR
Valve-in-Valve TAVR?

- Survival and durability for bioprostheses is highly dependent on age.
- High lifetime risk of reoperation in younger adults with bioprostheses.
- Valve-in-valve TAVR has demonstrated suboptimal outcomes at one year in the elderly population (especially with small bioprostheses).
- Outcomes of valve-in-valve in younger patients with larger surgical valves is largely unknown.
- TAVR durability still unknown.
- Potential need for multiple interventions in young adults.
Why does the Ross procedure fail?

- **Pulmonary autograft failure**
  - Annular dilatation $\rightarrow$ AI
  - Sinotubular junction dilatation $\rightarrow$ AI
    - Valve deterioration
      » Leaflet thinning
      » Cusp stretching
      » Free margin elongation and prolapse
      » Cusp tears at commisures

- **Pulmonary homograft failure**
  - Intimal hyperplasia at distal anastomosis $\rightarrow$ PS
  - Inflammatory-mediated external fibrous compression $\rightarrow$ PS
  - Leaflet degeneration $\rightarrow$ PS/PI
How do we avoid failure?

• **Patient selection?**
  - Aortic annulus <27 mm
  - Aortic stenosis rather than AI
  - Gender?

• **Post-operative management?**
  - Strict BP control (SBP <100-110 mmHg) for 6-12 months

• **Surgical Technique?**
  - Subcoronary or inclusion technique?
  - Technically difficult, easy to distort valve geometry
  - Appropriate for select patients
  - Reinforcement of autograft in annulus and distally
  - Oversize pulmonary homograft
  - Meticulous distal pulmonary anastomosis
  - **Suspension of pulmonary autograft within a Dacron Valsalva graft**
Case Example #1

- 45M with severe symptomatic bicuspid aortic stenosis
  - Mean AV gradient 42 mmHg, peak velocity 4.3 m/s, calculated AVA 1.1 cm$^2$
- Works in the oil industry and spends 2 weeks each month in remote Alaska on oil rigs. No access to healthcare.
- Plays competitive ice hockey
Pre-operative TEE
Post-operative TTE
Case Example #2

- 29M, bicuspid aortic valve
- s/p BAV age 12
- Moderate Aortic Stenosis
  - $V_{\text{max}}$ 3.3 m/s, mean gradient 25 mmHg, AVA 1.3 cm²
- Ascending Aorta 5.5 cm
- Construction worker
- Recent history of Epistaxis requiring cauterization
Pre-Op TEE
Post-Op TEE
Mobilize Coronaries
Proximal Neo-Root
Reimplant Coronary Arteries
Distal Neo-Root
Proximal Homograft
Completed Ross
Conclusion

• The Ross Procedure provides excellent freedom from death and valve-related complications in appropriately selected patients in experienced centers.

• The Ross Procedure (modified) can be considered in younger adults (<55), those contemplating pregnancy, high levels of physical activity, and those who have a contraindication or preference for avoiding anticoagulation.

• Valve-in-valve TAVR may provide additional options in younger AVR populations, but outcomes are still largely unknown.

• Matching the patient to the most appropriate valve replacement therapy is critical!