Reoperation after previous Ross procedure

Victor Tsang

Society of Thoracic Surgeons of Thailand
2016
As a living autograft, the transplanted pulmonary valve has the prospect of long term or permanent survival.

Ross, Lancet 1967
Donald Nixon Ross

Cardiothoracic surgeon who did the UK’s first heart transplantation. Born on Oct 4, 1922, he died on July 6, 2014, aged 91 years.

Donald Ross scored a series of surgical firsts. In the early 1960s, when open heart surgery was in its infancy, he developed the Guy’s-Ross heart lung bypass machine. In 1962, he did the first homograft of an aortic valve believing biological tissue would last longer than its artificial equivalent. So it proved. 5 years later he expanded the greatest issue was overcoming rejection. “We stopped after the third transplantation because the problem of rejection had not been overcome.” With the development of immunosuppressant drugs in the 1970s, the UK’s heart transplant programme was relaunched in 1979 by Sir Terence English at Papworth Hospital, and a few months later by Sir Magdi Yacoub at Harefield Hospital, both of whom had worked with Ross. “Donald had superb hands. After I was appointed a consultant at Papworth I used to go down to London on Saturday mornings to work with him, unpaid. I was still learning from him. He was very good with patients too—he saw them before and after surgery. He was wonderful to work with”, recalls English. But of the publicity around the first transplant, English adds: “His mistake was to let himself be used by the media, with all the flag waving. He was naive. It rubbed the profession up the wrong way—he was seen as a self-publicist. But he weathered all these things. He had a wonderfully buoyant nature.”

Ross was born in Kimberley, South Africa, to Scottish parents and was a contemporary of Barnard’s at the University of Cape Town, where he graduated with first class honours in 1946. In 1949, he came to the UK, taking up an appointment in Bristol before moving to Guy’s Hospital where, in 1953, he was appointed a cardiovascular research fellow by Sir Russell (later Lord) Brock, a pioneer of cardiac surgery, who had recognised his superior technique and calm manner. According to Yacoub, “Donald was unflappable. I was amazed how quick and dextrous he was, and how he could get out of trouble. I admired him for it.” In 1958, Ross became a consultant at Guy’s alongside Brock, later dividing his practice between Guy’s and the National Heart Hospital. Brock even tried to get him to join him in the USA, but Ross declined. In 1971, the National Heart Institute became the world’s first fully dedicated cardiology centre, with Ross as its director. He stepped down in 1975 but continued to practice until he retired 10 years later. His career was punctuated by nine major medical breakthroughs, which earned him the nickname, ‘the Father of British Cardiothoracic Surgery’.

In 1976, Ross received the UK’s highest state award, the CBE, and was elected to the Royal Society of London in 1980. He was elected as a fellow of the Royal College of Surgeons of Edinburgh and was awarded the Freedom of the City of Edinburgh in 1999. Ross was also a member of the Royal College of Surgeons of England and was awarded the Royal Medal in 2008. He was knighted in 2010 for his services to surgery and was made a Companion of Honour in 2012. Donald Nixon Ross passed away on July 6, 2014, aged 91 years.

In summary, Donald Nixon Ross was a pioneer in cardiac surgery, with a long and distinguished career. His contributions to the field have been recognised with numerous awards and honours, and he remains an inspiration to those who continue to work in the field of cardiac surgery.
Ross operation

Not often enough in clinical practice?
1994-2010
STS database
648,541 AVR
3,054 (0.47%) Ross
Recent annual incidence < 0.1%

Brett Reece et al. Rethinking the Ross procedure in Adults. ATS 2014
**Figure: The Ross procedure**

The patient’s own pulmonary valve is used to replace the diseased aortic valve and a pulmonary homograft is inserted in the right ventricular outflow.
Outcome and Reintervention studies
Centre experience and expertise influence long term results

Charitos et al. JTCVS 2012
Sievers et al. JTCVS 2010
A living valve implanted in the aortic position can significantly improve the long term outcomes in patients

Yacoub, Lancet 2010
Better quality of life following pulmonary autografts compared with mechanical valves

- Aicher et al JTCVS 2011
- Notzold et al JACC 2001
To achieve a ‘living’ aortic valve with no anticoagulation and a good long term outcome
Inclusion cylinder method for aortic valve replacement utilising the Ross operation in adults with predominant aortic stenosis – 99 % freedom from reoperation on the aortic valve at 15 years

Skillington et al. Glob Cardiol Sci Pract 2013
1997-2012

630 patients

Mean follow-up
8.3 +/- 4.6 yrs

49 reoperations
11 early
38 late

Markus Liebrich et al., ATS 2014
Early reoperations (n=11)

Valve replacement (8)

• Endocarditis

Valve repair (3)

• Rupture of the proximal suture line
• Development of pseudo aneurysm
• Covered rupture of proximal autograft

Markus Liebrich et al., ATS 2014
Late reoperations (n=38)

15 without
dilatation of neo-aortic sinus
15 valve replacement

20 with
dilatation of neo-aortic sinus
16 valve sparing repair
4 Bentall / valve replacement

Markus Liebrich et al., ATS 2014
Timing and technique of surgery in the young
The majority of young patients at Ross have mixed aortic valve disease

- Previous BAV
- Previous surgical valvuloplasty
When should it be done in terms of **LVEDV** recovery?

Cheung et al., Cardiol Young, 2003
Cardiopulmonary exercise testing

Mean exercise capacity 87% +/- 22% of predicted

Puranik, Tsang et al. Heart 2010
Benefits the very young

- Borderline LV volume
- Critical aortic stenosis
- Arch hypoplasia
- Smallish mitral valve
Pulmonary autograft

Subannular interrupted 4/0 Tycron sutures

Strip of autologus pericardium
GOSH:

Annulus = 0.31 (range -2.9 to 3.2)
Sinus = 2.7 (range -3.1 to 5.4)
STJ = 3.1 (range -1.2 to 6.0)

Annulus = 3 to 4
Sinus = 7 to 7.5
STJ = 4 to 5
GOSH:

Annulus 0.14/y (95% CI 0.32 - 0.59)  Annulus = 0.31/y

Sara K. Pasquali et al., JACC 2007
Ross at GOSH

75 children
Age 10.2 yrs (range 0.44-18 years)
Follow-up 5.2 yrs (up to 13.2 years)

5 reoperations
  3 autograft re-intervention
  2 LVOT re-intervention
<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age at Ross</th>
<th>Time to reop</th>
<th>Indication/pathology</th>
<th>Operation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.2 years</td>
<td>50 days</td>
<td>Regurgitation</td>
<td>Repair</td>
<td>Good valvular function</td>
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<tr>
<td></td>
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<td>Dehiscence of the non coronary cusp, and suspected endocarditis</td>
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<tr>
<td>2</td>
<td>10.2 years</td>
<td>6.7 years</td>
<td>Regurgitation</td>
<td>Repair</td>
<td>Good valvular function</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pseudoaneurysm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dehiscence of posterior aspect of autograft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12.0 years</td>
<td>5.4 years</td>
<td>Regurgitation</td>
<td>Repair</td>
<td>Good valvular function</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Perforation of left coronary cusp at time of Ross</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case No.</td>
<td>Age at Ross</td>
<td>Time to reop</td>
<td>Indication/pathology</td>
<td>Operation</td>
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<tr>
<td>1</td>
<td>11 months</td>
<td>1.8 years</td>
<td>Stenosis. Borderline LVOT with an favourable angulation at time of Ross</td>
<td>Resection</td>
<td>6 years after reoperation: v-max 3.6 m/s</td>
</tr>
<tr>
<td>2</td>
<td>1.8 years</td>
<td>10.1 years</td>
<td>Development of subvalar membrane</td>
<td>Resection</td>
<td>2.5 yrs after reoperation: v-max 3 m/s</td>
</tr>
</tbody>
</table>
Use of cine CT images to characterise tissue

Calculate strain and distensibility

\[
\text{Distensibility} = \frac{(A_{syst} - A_{dias})}{A_{dias}(P_{syst} - P_{dias})}
\]
Dilated autografts (＞45 mm) after the Ross procedure are bigger than normal but maintain mechanical property, unlike aneurysmal tissue which is much stiffer.

Dilated autografts may need to be treated differently from dilated native aorta.

Torii, Yacoub, et al. QFARF 2012.
2 patients from the original Lancet series by Donald Ross operated in 1967 in London.
**NATIONAL HEART HOSPITAL**  
Westmoreland Street, W.I.

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Age</th>
<th>Hospital No.</th>
<th>Admitted</th>
<th>Discharged</th>
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<tbody>
<tr>
<td></td>
<td>18, Churchill Avenue, Hastings, Sussex.</td>
<td>21</td>
<td>9242</td>
<td>2.11.67</td>
<td>28.1.68</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Physician</th>
<th>Age</th>
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<th>Admitted</th>
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<tr>
<td>Richard Emanuel</td>
<td>21</td>
<td>9242</td>
<td>2.11.67</td>
<td>28.1.68</td>
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</table>

<table>
<thead>
<tr>
<th>Own Dr.</th>
<th>Surgeon</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterson</td>
<td>Donald Ross</td>
<td>Royal East Sussex Hospital, Hastings, Sussex.</td>
</tr>
</tbody>
</table>

**Transferred to St. Helen's, Hastings.**

**Referral by Dr. Bradford.**

**DIAGNOSIS**  
CONGENITAL AORTIC INCOMPETENCE

**OPERATION**  
ROSS OPERATION - 6.11.67.
<table>
<thead>
<tr>
<th></th>
<th>Patient 1</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at Ross op in 1967</td>
<td>32 yrs</td>
<td>21 yrs</td>
</tr>
<tr>
<td>Surgeons</td>
<td>D Ross</td>
<td>D Ross / M Yacoub</td>
</tr>
<tr>
<td>Ethiology</td>
<td>Congenital aortic valve incompetence</td>
<td>Endocarditis (susp. bicuspid valve)</td>
</tr>
<tr>
<td>Surgical technique</td>
<td>Subcoronary</td>
<td>Subcoronary</td>
</tr>
<tr>
<td>Time to valve explant post-Ross</td>
<td>42 yrs (moderate autograft stenosis and obstructed homograft -&gt; autograft repair, homograft replacement and CABGx4 , 2006, sudden death 2009)</td>
<td>44 yrs (mixed autograft disease with dominand regurgitation, impaired LV, and dilated aorta → Bentall, 2011)</td>
</tr>
<tr>
<td>Histology</td>
<td>Trilaminar structure, thickened aortic valve cusps, normal coaptation, satisfactory cusp mobility, endothelial cells observed on both sides of cusps</td>
<td>Trilaminar structure, aortic cusps showed calcification and degeneration, senile calcific aortic stenosis present</td>
</tr>
</tbody>
</table>
Explanted autograft 42 years old
Immuno-histological studies
Observations

The Ross procedure can offer 40 or more years of warfarin free survival.

The viability of the autograft as a functional unit is proven at 10 or more years in younger age group.
What remains to be proven in the young population?

Would the adapted neoaorta in a root replacement reach a steady state to function as a longer term (>20 years) stable aortic valve unit?
Thank you
Histochemical studies
Histology

- Preserved very long-term viability of the autograft valve after the Ross procedure (42 and 44 years)

- Illustrates the capacity of pulmonary autograft valves to adapt to their new biomechanical environment

- Preserved cellularity, particularly endothelial integrity, is a major factor in the resistance of pulmonary autografts to infection, calcification and other valve-related complications
RVOT reintervention
The Paediatric Ross
late outcomes

1) Surgical technique
2) Patient factors
3) Histology
4) Bioengineering perspective
Patient factors

• Young age
• Bicuspid aortic valve
• Preoperative AI with dilated aortic annulus is a marker for future dilation
Rheumatic valves

- Ross procedure confers survival advantages over mechanical valve in young patients with rheumatic aortic valve disease

- Impaired autograft durability in younger patients (<30 years) with rheumatic aortic regurgitation and concomitant MR

*Raja et al. Interactive Cardiovascular and Thoracic Surgery 2010*
GOSH
2000 – 2011
85 Ross op
(1 neonate and 7 infants)

1 late death (PHT)
Patient factors
Survival of neonates with critical aortic stenosis

- An expanding surgical cohort of survivors with restrictive left ventricle / EFE and persistent pulmonary hypertension

_Burch et al Heart 2004_
The Paediatric Ross
late outcomes

1) Surgical technique
2) Patient factors
3) Histology
4) Bioengineering perspective
Histology
(3-6 years post Ross)

- Explanted autografts are viable and have a near-normal trilaminar cuspal structure and collagen architecture
- Autograft walls show focal loss of normal smooth muscle cells, elastin, and collagen

Patient 2 (44 yr post Ross)

Autograft regurgitation

Homograft stenosis
The Paediatric Ross late outcomes

1) Concept and surgical technique
2) Patient factors
3) Histology
4) Bioengineering perspective
When to do Ross

1. Often enough in clinical practice?
2. Timing of surgery in the young?
Quadricuspid neoaortic valve
Insights from 40 years follow-up of a patient with the Ross Procedure

Showing Autograft Valve Regurgitation
Showing Homograft Stenosis
Figure 1  Histological section showing the triple layer architecture of a normal aortic valve. Endothelial cells form a monolayer on each side of the cusp. Interstitial cells, a mix of fibroblasts, smooth muscle cells (SMCs) and myofibroblasts fil...

Ismail El-Hamamsy, Adrian H. Chester, Magdi H. Yacoub

**Cellular regulation of the structure and function of aortic valves**

*Journal of Advanced Research Volume 1, Issue 1 2010 5 - 12*

http://dx.doi.org/10.1016/j.jare.2010.02.007
1. **Proximal suture line** (close interrupted sutures) anchored within the fibromuscular LVOT for support

2. **Outflow anastomosis** should not exceed the autograft diameter
Fig. 3—Steps in replacement of aortic valve with a pulmonary autograft.
Bicuspid aortic valve