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## Revival of the Ross Procedure in Adults: a Narrative Review

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### Abstract

Despite considerable advances in percutaneous aortic valve implantation in the elderly, the choice of aortic valve substitute in young patients requires thoughtful consideration and the ideal choice is one that will last several decades with favourable haemodynamics, quality of life, and low reintervention rates. More recent reports from multiple valve centres, including ours, have shown excellent long-term durability into the third decade in adults, compared to conventional aortic valve replacement. The current best available evidence in the field suggest that Ross procedure should be considered in young adult patients- if performed in high volume centres by an experienced team.

#### Key Words:

Ross Procedure, Pulmonary Autograft, Adult Cardiac Surgery, Aortic Valve Disease

### Best Available Evidence

#### The Ross Procedure

In 1967 Donald Ross pioneered the eponymous Ross procedure in which a pulmonary autograft is used to replace a diseased aortic valve and the pulmonary valve is replaced with a homograft (Figure 1).<sup>1</sup> Since its inception, the use of the Ross procedure has shown significant promise in a wide range of patients suffering from aortic valve disease. The late 90s and early 2000s saw a precipitous drop in the absolute and relative number of Ross procedures in adults performed for fear of longer operation duration, higher transfusion rates, and a considerably high perioperative mortality rate.<sup>2</sup> Whereas the paediatric population saw a gradual, sustained increase in the use of the Ross procedure since its inception and remains today a well-established option for aortic valve disease. As a living valve, it is able to undergo somatic growth in the paediatric population and hence its popularity.<sup>3</sup> In recent years, however, there has been a revival in the young adult population (18-60-year-old group) given compelling evidence showing excellent long-term survival and improved quality of life as the technique has increased in popularity. Particularly, there is evidence to suggest young adult patients return to a good quality of life post procedure and enjoy survival beyond the third decade often free from re-intervention.<sup>4-7</sup>

Risk mitigation strategies, improved peri-operative care, surgeon experience and centralisation of the procedure have all acted to improve outcomes. This has led to outcomes and perioperative risk of complications that one would associate with isolated aortic valve replacement.<sup>3,8</sup>

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There is a recognised learning curve associated with any complex or niche cardiac surgical technique.<sup>3</sup> However, good outcomes can be achieved with sufficient case volume and dedicated expertise. The 2021 ESC/EACTS guidelines for the management of valvular heart disease say that the Ross procedure may be an alternative to valve replacement when performed by experienced surgeons.<sup>9</sup> In 2020, the American College of Cardiology/American Heart Association class IIb recommended the Ross procedure in young adults (under 50 years of age) with aortic valve disease.<sup>10</sup>

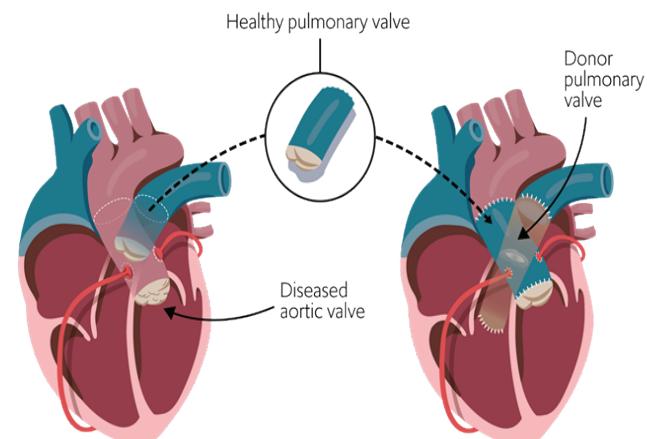


Figure 1: The Ross procedure: aortic valve replacement with a pulmonary autograft and pulmonary homograft implantation.<sup>11</sup>

## Aortic Valve Substitute- Spoilt for Choice?

For aortic valve replacement there are several options including: mechanical prosthesis, bioprostheses, homograft, and autograft (Table 1). The factors governing the choice of prosthesis for replacement can be broadly considered into patient factors (age, consideration of pregnancy, anticoagulation contra-indication) and surgical factors (durability of prosthesis, surgeon experience and pathology). The two commonest prostheses in the under 60 cohort are tissue and mechanical valves, twenty-year comparisons of these two choices show survival superiority of mechanical valve.<sup>12</sup> There is a growing trend in the young adult patients to choose bioprosthetic valve and then opt for a transcatheter aortic valve in valve implantation following structural valve degeneration.<sup>13</sup> However, life expectancy in patients under 40 is 17 years after bioprosthetic aortic valve replacement and those under 60 rarely experience re-operation free survival.<sup>14</sup>

Patients with either mechanical valves or bioprostheses in the aortic position have a reduced life expectancy when compared to the normal population.<sup>15</sup> Reoperation increases mortality risk as valves degenerate particularly in the bioprosthetic cohort.<sup>16</sup> Residual gradients may persist and act as an early warning sign for diastolic heart failure and arrhythmias also contribute to increased morbidity and mortality.

## Survival and Reintervention

The Ross procedure has unique features. It is the only operation that has been shown to consistently restore survival in adolescence and young adults up to 60 years of age.<sup>4,7,17,18</sup> The survival advantages when compared to mechanical prosthesis and tissue valve are significant. Long term survival of over 15 years have been demonstrated in a randomised controlled trial, propensity matched studies and multicentre cohort studies.<sup>19-21</sup> Reintervention free survival has been demonstrated for three decades in selected patients using the Ross procedure.<sup>22</sup>

At 15 years, 15% of patients will experience the need for reintervention in either their autograft or homograft.<sup>23</sup> With regards to risk factors for this, aortic regurgitation, and large annular diameter pre-operatively appear to be risk factors for a shorter time to reintervention. This corresponds to a risk of 1.3% per year, in mechanical valves it is approximately 0.5% per year whereas biological valves see a risk of 2% per year.<sup>23-25</sup>

## Quality of Life and Haemodynamics

Quality of life endpoints have been shown to be superior in the Ross procedure when compared to those undergoing isolated mechanical aortic valve replacement.<sup>25</sup> These patients enjoy life free from anticoagulation, thromboembolic rates similar to normal population, physiological exercise haemodynamics and pregnancy unhindered by warfarin.<sup>4,8</sup> Fewer post-operative complications that are associated with artificial valves such as stroke, thrombosis, or infection have also been demonstrated.<sup>5,24</sup> This in combination with the liberation from the noise of their mechanical prosthesis often translate to improved quality of life.<sup>26,27</sup> Four-dimensional magnetic resonance imaging has shown flow patterns across the aortic root of Ross patients at 10 years follow up to closely represent a normal aortic root.<sup>28</sup> The pulmonary autograft itself can withstand high stress, e.g., heart rates in excess of 170 bpm, at which point mechanical valves become less efficient.<sup>29,30</sup> Clinically, this translates to a normal physiological response to exercise and a normal exercise capacity for Ross patients.

## Technique and Standardisation

The performance of the Ross procedure has been confined to a relatively small number of centres world wide.<sup>18</sup> Historically, this has been related to a wide variation in the techniques used by different surgical groups to implant the pulmonary autograft in the aortic root. More recently, there has been the identification and the

Table 1: Advantages and limitations of the aortic valve replacement options available in young populations

Aortic Valve Replacement	Advantages	Disadvantages
Bioprostheses	<ul style="list-style-type: none"><li>Widely available</li><li>Option for in-valve TAVI</li><li>Standardised techniques</li><li>No need for anticoagulation</li></ul>	<ul style="list-style-type: none"><li>Risk of structural valve deterioration</li><li>Low durability</li><li>High risk of reintervention in younger cohorts</li></ul>
Mechanical	<ul style="list-style-type: none"><li>Good durability</li><li>Standardised techniques</li><li>Low risk of re-intervention</li></ul>	<ul style="list-style-type: none"><li>Anticoagulation</li><li>Bleeding and thromboembolism</li><li>First trimester of pregnancy contra-indication</li></ul>
Aortic homograft	<ul style="list-style-type: none"><li>Favourable haemodynamics in the early post-operative period</li><li>Useful in extensive endocarditis</li></ul>	<ul style="list-style-type: none"><li>Structural degeneration</li><li>Lack of long-term evidence</li></ul>
TAVI	<ul style="list-style-type: none"><li>Least invasive</li><li>Early improvement in QoL</li></ul>	<ul style="list-style-type: none"><li>High incidence of paravalvular leak</li><li>Higher permanent pacemaker rate</li><li>Lack of suitability in bicuspid valves</li></ul>
Ross Procedure	<ul style="list-style-type: none"><li>Excellent long-term survival</li><li>Superior haemodynamics</li><li>Return to good quality of life</li><li>Low rate of valve-related complications</li></ul>	<ul style="list-style-type: none"><li>Complex with notable learning curve</li><li>Two valve surgery risk</li><li>Complex reintervention</li></ul>

adoption of a handful of successful techniques to prevent late dilation of the aortic root leading to more reproducible results.<sup>4,7</sup>

Different approaches all aim at ensuring normal autograft root dynamism, whilst protecting it from dilation in the long term. The pulmonary valve lacks a true fibrous annulus, and the leaflets are attached to the infundibular muscle of the RVOT, therefore, implantation of the autograft into the LVOT is imperative for its integrity and blood supply.<sup>31</sup> In patients with aortic regurgitation, it is recommended to perform an extra-aortic annuloplasty ring to reduce dilation risk. The autograft is thinner than the aortic wall but remodels over a 6-12-month period, during this period blood pressure control is pivotal and some centres advise a maximum systolic of less than <115 mmHg. Reinforcement can also be achieved by surrounding the autograft in a Dacron graft (Figure 2). The use of Personalised External Aortic Root Support (PEARS) is also a good option.

When considering stabilising the sinotubular junction it is important to cut the autograft right above the commissures to prevent dilation. Generally, lower thresholds for concomitant ascending aorta replacement are accepted in adult Ross patients, a proposition of >3.5-4cm has been adopted by certain groups performing the Ross.<sup>31</sup> This ensures dilation and size increase does not compromise the integrity of the autograft over time.

## The Ideal Patient

The Ross procedure is not a key that unlocks every door and careful consideration should be made when selecting the right patients for the procedure. Factors that are important include type of valvular dysfunction, performance status of the patient, and comorbidities. In young adults under 60, the anticipated life expectancy is arguably the most significant factor to consider. Those with life expectancy greater than 15 years should be considered and would benefit from the Ross.

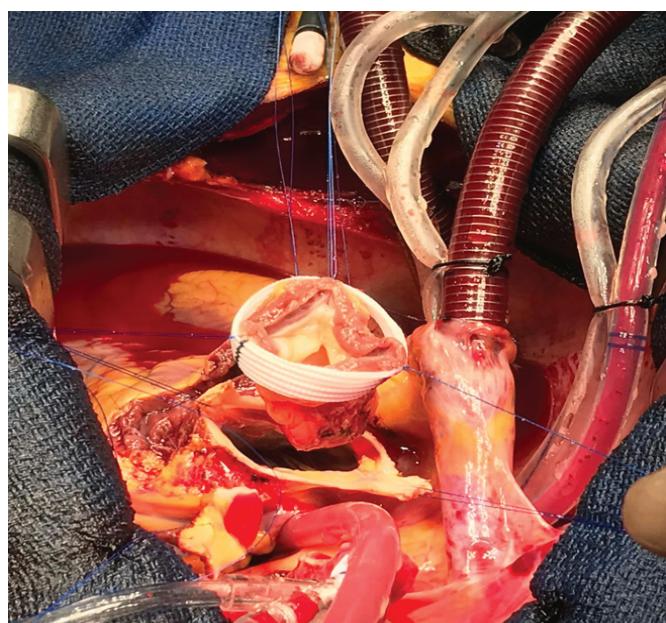


Figure 2: Intraoperative image of Dacron reinforcement of the autograft just before implantation in the aortic position.

## Conclusion

### Take Home Message

- The Ross procedure has excellent survival rates into the third decade after surgery.
- Quality of life after the Ross procedure is superior to mechanical and bioprosthetic aortic valve replacement.
- Few expert centres offer the Ross procedure in adults.
- All patients under the age of sixty should consider the Ross procedure as alternative to conventional aortic valve replacement.

### Disclosure Statement

Mario Petrou is a member of the Editorial Board of the Journal of the Best Available Evidence in Medicine.

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