Research Highlight

Aortic valve sparing operations in aortic root aneurysms: remodeling or reimplantation?

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Introduction

Over the past two decades, there has been a significant paradigm shift towards aortic valve sparing (AVS) operations over the more traditional method of prosthetic replacement for suitable aortic pathologies. Such operations, by virtue of preserving the patient's native aortic valvular anatomy, carry numerous benefits, most notably the obviation of life-long anticoagulation medication and the reduced need for reoperation when compared to mechanical and biosynthetic valves.

Two main valve-sparing operations have dominated modern surgical practice: the David 'reimplantation' technique, whereby the entire aortic valve is preserved and securely sewn within a synthetic tube graft (1), and the Yacoub 'remodeling' technique, which replaces all three sinuses by means of a triple-tongue-shaped graft (2). Whether one technique is superior than the other has polarised the surgical community.

The present article summarises the recent evidence comparing remodelling and reimplantation techniques (3).

Search strategy

A thorough literature search was conducted using Medline and EMBASE for studies published between 1990 to December 2010 for the terms: valve-sparing.mp OR valve-preserving.mp OR valve reimplantation.mp OR valve remodeling.mp. Included studies must present selected outcomes of interest (such as aortic valve reoperation, postoperative aortic insufficiency, and/or survival) separately for each of the two techniques. Only the most complete set of outcomes was included from centres that publish duplicating results.

Results

In total, 392 papers were found using the reported search criteria. From these, 14 papers were identified to have provided the best information comparing the two valve-sparing techniques (4-17). No randomised controlled trials (RCT) or meta-analyses were found.

A total of 1,338 patients from 13 centres were included in this study. Operative technique was Yacoub for 606 patients and David for 732 patients (*Table 1*).

Early mortality ranged from 0-6.9% for the Yacoub technique and 0-6% for the David technique. In the largest available series of 289 patients reported by David and colleagues in 2010 (4), early mortality was 1.6% in the Yacoub cohort and 1.7% in David group. In a series of 30 patients with acute type A dissection managed with either Yacoub or David technique, the overall early mortality was 17% (14). Cardiopulmonary bypass and aortic cross clamp times were longer or equal for the David technique in all studies that reported these results (4,7,9-11,15-17).

In several series, the freedom from moderate or severe aortic insufficiency (AI) within the follow-up period was more frequent for the David technique (4,7-12,15), although it seldom reached statistical significance (4,11).

Discussion

Over the past two decades, surgical approaches to aortic

Table 1 Best evidence papers comparing the Yacoub technique to David technique

Author, year, country, study type	Patient group	Outcome	Key results	Comments
David *et al*., (2010), Canada (4) Cohort study	- 289 consecutive patients (Y: 21%; D: 79%) - Prospective 1988-2007 - Age (Y: 48.6; D: 47.2) - Acute type A aortic dissection (Y: 12%; D: 8%) - Chronic type A aortic dissection (Y: 15%; D: 4%) - BAV (Y: 3.3%; D: 10%) - MFS (Y: 42%; D: 34%) - Preoperative moderate or severe AI (Y: 55%; D: 51%) - Follow-up (Y: 10.1; D: 6.5 years*)	- CPB time (min) - Cross clamp time (min) - Size of Dacron graft - Early mortality - Moderate and severe AI postoperative - Freedom from moderate or severe AI 4 years 8 years 12 years - Independent predictor of AI - Reoperation on the aortic valve - Freedom from reoperation 4 years 8 years 12 years - Independent predictor of death - Late mortality (n) - Survival (%)	Y: 129; D: 140 Y: 103; D: 116 Y: 27.1; D: 30.7 Y: 1.6%; D: 1.7% Y: 18%; D: 3.5%* Y: 96.0%; D: 98.3% Y: 93.6%; D: 97.4% Y: 82.6%; D: 91.0% Age by 5-year increments (HR: 1.2, 95% CI 1.01-1.40) Y: 5; D: 2 Y: 100%; D: 99.6% Y: 95.8%; D: 99.6% Y: 90.4%; D: 97.4% Age by 5-year increments (HR: 1.4; 95% CI 1.2- 1.6), aortic dissection (HR: 3.2; 95% CI 1.3- 8.3) 26 5 years: 94%; 10 years: 88%	- Longer CPB and cross clamp time in D - Technique type was not a predictor of mortality or postoperative AI - Long-term moderate to severe AI more common in Y than D, but reoperation rate comparable - Authors believe remodeling provides excellent results for older patients with normal aortic annulus but may not be appropriate for MFS - Authors consider aortic annulus >27 mm in men and >25 mm in women as dilated for which they prefer D technique - Regardless of technique, restoration of normal cusp geometry is important in AVS
Matalanis *et al*, (2010), Australia (5) Retrospective study	- 61 patients (Y: 13%; D: 87%) - Age: mean 61 years - AI ≥ grade III: 47 (77%), 11 with normal leaflet and 36 with leaflet prolapse - Leaflet prolapse: 42 (69%) - MFS: 9 - Follow-up 28 months	- Early mortality - Survival at 5 years - Recurrent AI - Actuarial freedom from AI at 5 years - Actuarial freedom from AVR at 5 years	4.9% 95% Y: 0; D: 5 Y: 100%; D: 85% (NS) 93%	- Y was associated with more freedom from AI, although not statistically significant. However, Y was only used for patients with normal leaflet in this study

Table 1 *(continued)*

Table 1 (continued)

Author, year, country, study type	Patient group	Outcome	Key results	Comments
Badiu *et al*, (2010), Austria (6) Retrospective study	- 102 patients (earlier 28 had Y, later 74 had D with Valsalva graft) - Age: 47 - BAV: (Y: 10.8%; D: 10%) - Tricuspid valve with severe AI: (Y: 30%; D: 39.2%) - MFS: 20.6% - Type A dissection: 8.8% - Follow-up: 2.8 years	- Diameter of used conduit (mm) - Early mortality - Reoperation (AVR) - Estimated 5-year freedom from re-operation - Actuarial freedom from severe AI at 5 years - Survival within the period of follow-up	Y: 30.9; D: 25.4 1 with CVA Y: 5; D: 1 92.2% 100% (reoperated patients excluded) 97.8%	- No significant difference in outcomes in patients with preoperative severe AI or BAV - Y in MFS may be associated with higher risk of reoperation than D
Hanke *et al*, (2009), Germany (7) Prospective study	- 191 patients (Y: 57%; D: 43%) - Prospective 1993-2006 - Age (Y: 55.9; D: 49.2*) - Type A aortic dissection (Y: 29%; D: 42%) - BAV (Y: 14%; D: 11%) - MFS (Y: 13%; D: 20%) - AI ≥ grade II (Y: 43%; D: 59%*) - Diameter of aorta (Y: 60 mm; D: 59 mm) - Echocardiographic follow-up 3.1 years (completed in 95.3%)	- CPB time (min) - Cross clamp time (min) - Open distal anastomosis - Mean graft size (mm) - Additional cusp intervention - Additional annulus intervention - GRF glue used - Echocardiographic findings at last follow-up: Aortic valve area (cm^2) Annulus dimension (mm) Mid sinus dimension (mm) STJ dimension (mm) Ascending aorta dimension (mm) Maximal pressure gradient LVOT (mm) Mean pressure gradient LVOT (mm) AI ≥ grade II - Estimated increase of AI within 10 years (grade) - Estimated increase of AI within 10 years in MFS subgroup (grade) - Factors associated with AI over time	Y: 185.2; D: 221.2* Y: 138; D: 165* Y: 65%; D: 68% Y: 28.2; D: 28.7 Y: 13%; D: 19% Y: 20%; D: 0%* Y: 13%; D: 19% Y: 3.0; D: 2.2* Y: 23; D: 22 Y: 30; D: 26* Y: 25; D: 25 Y: 30; D: 29 Y: 9.3; D: 12.6* Y: 4.9; D: 6.0 Y: 12%; D: 6% Y: 1.0; D: 0.4 Y: 1.32; D: 0.75 MFS, cusp intervention, preoperative annulus diameter	- Both techniques adequately preserve aortic valve function in those with aneurysms of the ascending aorta or root, type A aortic dissection, and MFS - Patients with preoperative large annulus diameters and MFS may benefit from D than Y - Authors suggested annulus diameter of 28-30 mm as a cut-off below which Y technique and above which D technique may be superior - Central plication of prolapsing cusps is disadvantageous over time

Table 1 *(continued)*

Table 1 (continued)

Author, year, country, study type	Patient group	Outcome	Key results	Comments
Patel *et al*, (2008), USA (8) Retrospective study	- 84 patients with MFS (earlier 40 had Y, later 44 had D with Valsalva graft) - Retrospective 1997-2006 - Age: 29.2 - Aortic dissection: 12.5% - AI ≥ grade III: 9.5% - BAV: 1.2%	- CPB time (min) - Cross clamp time (min) - Early mortality - Survival at 8 years - Freedom from re-operation on the aortic root at 5 years - Postoperative AI ≥ grade III - Reoperation for AI	141.7 102.6 0 100% Y: 86.1%; D: 100% Y: 9; D: 0 Y: 5; D: 0	- Earlier during study period authors preferred Y technique, but switched to D since 2002 because of high rate of late AI requiring AVR - D was associated with less likelihood of AI in MFS than Y
Erasmi *et al*, (2007), Germany (9) Retrospective study	- 164 consecutive patients (Y: 59%; D: 41%) - Retrospective 1993-2005 - Age (Y: 56; D: 50.2*) - Type A aortic dissection (Y: 22%; D: 41%) - BAV (Y: 13; D: 6) - MFS (18%) - AI (Y: 86%; D: 85%) - Diameter of aorta (Y: 6.0; D: 5.9 cm) - Follow-up (Y: 54.7; D: 48.4 months)	- CPB time; median (min) - Cross clamp time; median (min) - Circulatory arrest time; median (min) - Early mortality - Reoperation - Freedom from reoperation during follow-up time - AI > grade II at last follow-up - Late mortality during follow-up (in 143 patients; 98.6%) - Overall mortality	Y: 180; D: 212* Y: 135; D: 159* Y: 22; D: 30* Y: 4%; D: 6% Y: 7; D: 1 Y: 89%; D: 98% Y: 1.3%; D: 0% Y: 9% of survivors; D: 5% of survivors Y: 12.5%; D: 10.3%	- Both AVS techniques can be performed safely in elective patients with root aneurysms - D required longer CPB and cross clamp time than Y - Authors suggested pathologies that impair root integrity (like MFS, acute type A dissection, excessive annular dilatation) might benefit from D technique to support annulus.
Jeanmart *et al*, (2007), Belgium (10) Retrospective study	- 114 consecutive patients (Y: 42%; D: 58%) - Retrospective 1995-2005 - Age (Y: 54; D: 51) - BAV (Y: 23%; D: 36%) - MFS (Y: 10%; D: 6%) - Endocarditis (Y: 3; D: 0) - Moderate to severe AI (Y: 42%; D: 62%) - EF 0.30-0.50 (Y: 4%; D: 12%) - Follow-up 50 months (93% complete)	- CPB time (min) - Cross clamp time (min) - Associated AV leaflet correction - Early mortality - Re-exploration for mediastinal bleeding - Early reoperation for AVR - Hospital length of stay (days) - Late deaths - Late reoperations - 5-year survival - 5-year freedom from AS or AI (moderate or severe) in survivors - 5-year freedom from reoperation in survivors	Y: 120; D: 133 Y: 98; D: 110 62% Y: 2.1%; D: 0% Y: 14.6%; D: 13.6% Y: 1; D: 1 Y: 9; D: 10 10 (4 cardiac related) 2 for recurrent AI, 1 for AS Y: 87%; D: 92% (NS) Y: 97%; D: 83% (NS) Y: 97%; D: 85% (NS)	- Short-term and midterm results were comparable between the two techniques - Authors stated that they opted for D technique in recent years to prevent long-term recurrence of AI although their short- and mid-term results were comparable between the two techniques

Table 1 *(continued)*

Table 1 (continued)

Author, year, country, study type	Patient group	Outcome	Key results	Comments
David *et al*, (2006), Canada (11) Prospective study	- 220 consecutive patients (Y: 24%; D: 76%) - Prospective 1988-2005 - Age (Y: 47.7; D: 45.5) - Type A aortic dissection (Y: 10%; D: 11%) - BAV (Y: 0; D: 9%*) - MFS (Y: 45%; D: 38%) - Preoperative AI (Y: 71%; D: 65%)	- CPB time (min) - Cross clamp time (min) - Early mortality - Re-exploration for mediastinal bleeding - Postoperative AI - Severe AI postoperative - Freedom from moderate or severe AI (%) 5 years 10 years - Reoperation for AVR - Freedom from reoperation at 10 years - Late mortality (n) - Survival (%)	Y: 130; D: 140 Y: 104; D: 115* Y: 1.9%; D: 1.2% Y: 13.2%; D: 7.8% Y: 66%; D: 29%* Y: 8%; D: 2% Y: 98%; D: 99% Y: 75%; D: 94%* by log-rank statistics Y: 3; D: 2 Y: 93%; D: 96% 13 5 years: 94%; 10 years: 88%	- D required longer CPB and cross clamp time than Y - Y associated with a higher risk of late AI than D (by log-rank statistics) - Authors suggested D provides more stable valve function than Y did during first 10 years of follow-up - Long-term survival after AVS operations was excellent
Bethea *et al*, (2004), USA (12) Retrospective study	- 65 patients (Y: 89%; D: 11%) - 19 children mean age 13.7, 46 adults mean age 41.8 - Retrospective 1994-2005 - MFS (total 44) - Acute type A aortic dissection (total 2) - Preoperative AI ≥ grade III (adults: 17.8%; children: 15.8%)	- Early mortality - AI ≥ grade III at 1-year follow-up - Reoperation (AVR) for AI in adults - Reoperation (AVR) for AI in children - Late mortality - Actuarial survival at 3 years	0 7/45 adults (Y: 6; D: 1), 3/19 children (all in Y) Y: 3 (2 had significant annular dilatation); D: 1 (no annular dilatation) Y: 2 (both had significant annular dilatation) 1 adult with meningitis 98% for adults and 100% for children	- Both techniques had satisfactory outcomes - Y technique accompanied with higher risk of late annular dilatation and AI both in adults and children (no statistical comparison available in this study)

Table 1 *(continued)*

Table 1 (continued)

Author, year, country, study type	Patient group	Outcome	Key results	Comments
Burkhart *et al*, (2003), USA (13) Retrospective study	- 71 patients (Y: 27%; D: 73%) - Retrospective 1994-2000 - MFS: 20 (28.1%) - Preoperative moderate or severe AI: 40 (56.3%) - Aortic annulus mean diameter: 25 mm - Follow-up time: median 22.5 months	- CPB time (mean) - Moderate postoperative AI - Re-exploration for mediastinal bleeding - Early mortality - Five-year actuarial survival - Reoperation (AVR) - Freedom from reoperation - Predictors of reoperation (univariate analysis)	146 min 8.4% 7.0% 2.8%; 84.1% Y: 10.5%; D: 21.2% 88.8% at 1 year and 78.9% at 3 years Aortic annulus >25 mm, necessity of aortic cusp repair, male gender	- Almost double reoperation rate compared to Y, but difference was not significant - Selection of operation technique not clear
Leyh *et al*, (2002), Germany (14) Retrospective study	- 30 patients with acute type A aortic dissection (Y: 27%; D: 73%) - Retrospective 1995-2000 - Age (Y: 62; D: 52) - MFS (Y: 12.5%; D: 9%) - Cystic medial necrosis (Y: 37.5%; D: 36.4%) - Aortic root dissection (Y: 87.5%; D: 86.4%) - Follow-up (Y: 32.7; D: 22.2 months)	- CPB time (min) - Cross clamp time (min) - Circulatory arrest time (min) - Overall 30-day mortality - Late mortality - Long-term survivors - Reoperation - Freedom from reoperation - Freedom from reoperation because of structural aortic valve failure	Y: 212; D: 212 Y: 143; D: 157 Y: 29; D: 35 17% 4% Y: 75%; D: 82% Y: 3 for acute severe AI Y: 38%; D: 95% Y: 38%; D: 100%*	- Small series making statistical comparison between groups inaccurate - Longer follow-up time in Y group than D group (although not statistically significant) could have affected results - Y technique may be associated with a higher failure rate than D technique in mid-term in acute type A dissection
Graeter *et al*, (2002), Germany (15) Retrospective study	- 119 patients (Y: 82%; D: 18%) - Retrospective 1995-2001 - Age (Y: 61; D: 47) - Type A aortic dissection (Y: 26; D: 8)	- CPB time (min) - Cross clamp time (min) - Early mortality - Need for reoperation within first year - Freedom from AI > grade II in 4 years - Freedom from proximal reoperation	Y: 121; D: 143 Y: 87; D: 113 Y: 3.1%; D: 0 Y: 0%; D: 0% Y: 86%; D: 94.7% Y: 97.8%; D: 100%	- Insignificant difference between both groups; however, there is a tendency towards shorter CPB and cross clamp time; D: and higher freedom from AI and reoperation

Table 1 *(continued)*

Table 1 (continued)

Author, year, country, study type	Patient group	Outcome	Key results	Comments
Ninomiya *et al*, (2001), Japan (16) Case series	- 8 patients (Y: 3; D: 5) - Retrospective 1998-2001 - Age (Y: 46; D: 29) - MFS (Y: 0; D: 4) - Preoperative moderate to severe AI (Y: 2; D: 3) - Diameter of the aortic annulus (Y: 21.3 mm; D: 25.4 mm) - LVDd/Ds (Y: 58.3 mm/38.0 mm; D: 57.2 mm/39.8 mm) - Follow-up 18 months	- CPB time (min) - Postoperative moderate to severe AI at discharge - Postoperative moderate to severe AI at follow-up - Pressure gradient through aortic valve (mmHg) at follow-up - Postoperative LVDd/Ds - Postoperative complication - Mortality or reintervention during follow-up period	Y: 291; D: 384 Y: 0; D: 0 Y: 0; D: 1 Y: 5.3; D: 15.4 Y: 46.7 mm/29.3 mm; D: 53.0 mm/37.2 mm Y: 0; D: 1 re-exploration for bleeding None	- Small series - All patients with MFS were operated using D technique - Authors suggested D technique in aortic root dilatation and in MFS - Superior haemodynamic achievement after Y rather than D in this series although patients with MFS all group
Schäfers *et al*, (1998), Germany (17)	- 40 patients (Y: 73%; D: 27%) - Retrospective 1995-1997 - Age (Y: 64; D: 49*) - Acute type A aortic dissection (Y: 41%; D: 27%) - BAV (Y: 5; D: 0) - MFS (3) - AI grade (Y: 2.7; D: 2.8) - AV diameter (Y: 25; D: 33*) - Sinotubular diameter (Y: 43; D: 56*) - Follow-up mean: 11 months	- CPB time (min) - Cross clamp time (min) - Circulatory arrest time (min) - Postoperative AI (grade mean) - Peak AI gradient (mm Hg) early postoperative 6 months 12 months - Postoperative AI ≥ grade II	Y: 133; D: 145 Y: 87; D: 112 Y: 18; D: 19 Y: 0.5; D: 0.5 Y: 6.5; D: 4.9 Y: 6.5; D: 5.0 Y: 6.3; D: 4.8 Y: 6.9%; D: 9.1%	- Authors chose Y technique for root dilatation with normal AV junction and D for root dilatation with dilated AV junction including MFS - Authors merely used Y technique for BAV - No significant difference in the percentage of AI > grade I between the two groups

* P<0.05 (at least); AI, aortic insufficiency; AS, aortic stenosis; AV, aortoventricular; AVR, aortic valve replacement; AVS, aortic value sparing; BAV, bicuspid aortic valve; CI, confidence interval; CPB, cardiopulmonary bypass; D, reimplantation technique (David procedure); HR, hazard ratio; LVDd/Ds, left ventricular end-diastolic/-systolic diameter; LVOT, left ventricular outflow tract; MFS, Marfan's syndrome; NS, not significant; POD, postoperative day; STJ, sinotubular junction; Y, remodeling technique (Yacoub procedure)

root aneurysms have been repeatedly refined and improved, with progressively more complicated techniques that promised greater patient outcomes. The introduction of the composite graft procedure by Bentall in 1966 (18) has been challenged by valve-sparing techniques of David and Yacoub. These operations have surmounted the issues faced by prosthetic valves, but not without introducing limitations of their own. Such shortcomings have led to conflicting opinions regarding the suitability of these two techniques, which has yet to be thoroughly addressed.

One main issue thus far is that the selection criteria for each technique are not well established. However, based on limited evidence and personal experience, a number of surgeons have developed their own preferences over time. Some surgeons have switched from the Yacoub to the David technique (6,8) or opted for the David technique (10) over time, believing in the longer durability of this procedure. For example, Patel and associates (8) preferred the Yacoub technique for patients with the Marfan's syndrome (MFS) up until 2002, after which they switched to the David technique due to high rate of late AI requiring reoperation. The adverse association between MFS and the remodelling method has been noted by several other authors, who suggested that using the Yacoub technique in MFS might be associated with a higher risk of reoperation for AI (4,6-9,16,17). In addition, the anatomy of the aortic valve has also impacted upon procedural choice. David *et al*. (4) prefers the David technique when the aortic annulus is >27 mm in men and >25 mm in women, while believing that the Yacoub technique is suitable in older patients with a normal aortic annulus. Hanke *et al*. (7) further suggested an annulus diameter of 28-30 mm as a dichotomous cut-off for technique selection, advocating the Yacoub technique for annuli of narrower diameters and the David technique for wider diameters.

Other factors that impact on technique selection includes acute aortic dissections, structural deficiencies, and congenital abnormalities. In a small series of 30 patients with acute type A aortic dissection managed with AVS operations, Leyh and colleagues reported a 30-day mortality rate of 17% (14). In this study, freedom from reoperation due to structural aortic valve failure was 38% in the Yacoub and 100% in the David group (P=0.04), suggesting that the Yacoub technique is associated with a higher rate of failure in mid-term acute type A dissections. Similarly, pathologies that impair root integrity (such as MFS, acute type A aortic dissection, and excessive annular dilatation) may benefit from the David rather than the Yacoub technique to support the annulus (9). Although some authors merely preferred the Yacoub technique for bicuspid aortic valve (BAV) (17), the accumulated evidence in the current study indicates comparable results for both Yacoub and David technique in BAV pathologies.

Marfan syndrome, cusp intervention, and preoperative annular diameters were also factors associated with postoperative AI in a study of 191 patients (7). In another study, an aortic annulus >25 mm, necessity of aortic cusp repair, and male gender were predictors of reoperation (13). However, David *et al*. (4) only identified older age as an independent predictor of postoperative AI. Taken together, this indicates that careful selection of patients for each technique and successful restoration of normal cusp geometry might omit the diameter of the aortic annulus as a predictor of postoperative AI.

The results from the present analysis demonstrate comparable outcomes for both techniques. However, there is a tendency for less freedom from significant long-term AI in the Yacoub group than the David group, which does not necessarily result in a higher reoperation rate in Yacoub group compared to the David group.

A key limitation in the present review is the difficulty in making comparisons between the two techniques. To date, no RCT has investigated the topic and there were no clear selection criteria described in most of the available reports. A concerted effort is required to more aptly compare the two techniques, so as to better improve patient selection.

In conclusion, current evidence is in favour of the David technique over the Yacoub technique in pathologies such as MFS, acute type A aortic dissection, and excessive annular dilatation, which may impair aortic root integrity. Careful selection of patients for each technique and successful restoration of normal cusp geometry are the keys to success in AVS operations.

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