Biological vs. mechanical aortic root replacement


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Abstract

Objectives: Although age and co-existing coronary disease are major determining factors when deciding valve choice (mechanical vs. biological) in simple aortic valve replacement, no studies have documented selection criteria for biological (BIO) vs. mechanical (MECH) aortic root prosthesis. Methods: Two hundred and twenty-one consecutive patients underwent elective aortic root replacement with either BIO (homograft, n = 111, Freestyle®, n = 25) or MECH composite grafts (n = 85). Median age in BIO was 53 years and in MECH 54 years (P = NS). Groups were similar in gender, NYHA class and ejection fraction (BIO, EF = 59% vs. MECH, EF = 55%), but the need for concomitant coronary artery bypass grafting (CABG) did differ between groups (MECH = 35% vs. BIO = 17%, P = 0.003). Mean follow-up was 42 ± 28 months for mortality and 39 ± 28 months for morbidity. Results: Full root replacement was performed in 213 patients (96%) and hemi-root in eight (4%). The most common underlying etiologies were annulo-aortic ectasia (n = 82, 37%), calcified-degenerative (n = 73, 33%) and bicuspid/congenital aortic valve disease (n = 39, 18%). Operative mortality was 1.5% for BIO and 2.4% for MECH (P = 0.5). By univariate analysis there was a trend towards greater 5-year survival in BIO (92.4% vs. 88.2%, P = 0.068). By multivariate analysis, increasing age (HR = 2.4, P = 0.003), previous valve replacement (HR = 4.7, P = 0.024), concomitant CABG (HR = 3.7, P = 0.032), and perioperative stroke (HR = 9.9, P = 0.0005) were all independent predictors of late death. The 5-year freedom from valve-related complications was similar in both groups (BIO = 93% vs. MECH = 86%, P = 0.5). Conclusions: Elective aortic root replacement is an exceedingly safe operation. At mean follow-up of 4 years, there is no meaningful difference in early or mid term valve-related results between BIO and MECH aortic root replacement. Continued evaluation for late valve-related complications in this cohort will be necessary to determine the advantages, if any, of one prosthesis over the other.

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Keywords: Aortic root replacement; Valve choice

1. Introduction

In deciding the choice of prosthesis in simple aortic valve replacement (AVR), most surgeons recommend a mechanical valve in the younger patients and a stented bioprosthesis in older individuals. The precise age at which one prosthesis is preferred over the other is a matter of controversy, but recent studies indicate that patients younger than 65 years or whose life expectancy is at least 15 years should receive a mechanical valve [1]. However, with co-morbidities, especially coronary artery disease (CAD), where life expectancy is limited, the age cut-off favoring a bioprosthesis is lower [1,2]. The decision of which prosthesis to use for aortic root replacement is even more difficult than that for isolated AVR, because there are no studies directly comparing mechanical and biological conduits. Also, most studies of aortic root replacement include heterogeneous groups of patients, making comparisons difficult. In this retrospective study, biological vs. mechanical aortic root prostheses were compared in an attempt to identify predictors of outcome, specifically age and co-morbidities that may favor one prosthesis over the other.

2. Materials and methods

From January 1992 to May 2001, 369 consecutive patients underwent aortic root replacement at Brigham and Women’s Hospital. Because the choice of prosthesis was strongly influenced by underlying pathology, patients with acute endocarditis, where homograft was preferred, or acute dissection of the ascending aorta, where mechanical valve was preferred, were excluded (n = 148). The elimina-
Forty-nine patients (22.2%) underwent a partial sternotomy common in the MECH group. Preoperative atrial aneurysms and CAD requiring coronary artery bypass grafting (CABG). Preoperative atrial fibrillation was also more common in the MECH group as were aortic arch aneurysms and CAD requiring coronary artery bypass grafting (CABG). Preoperative atrial fibrillation was also more common in the MECH group.

All operations were performed through a sternotomy. Forty-nine patients (22.2%) underwent a partial sternotomy as part of a ‘minimally-invasive’ procedure. The ascending aorta and right atrium were cannulated for cardiopulmonary bypass (CPB) in 77% of the patients, otherwise the femoral artery and/or the femoral vein were used. For the reoperative procedures both femoral artery and vein were routinely exposed before sternotomy. CPB was undertaken at a median temperature of 28 °C (range 11–33 °C). Myocardial protection was accomplished with antegrade and or retrograde cardioplegia as well as local and systemic hypothermia.

The aorta was transected at the sino-tubular junction. The coronary ostia were excised with a cuff of aortic wall and mobilized to facilitate re-implantation. The root and aortic valve was then replaced based on the surgeon’s preference with a bioprosthesis (cryopreserved homografts, n = 111; Freestyle®, n = 82, 37%), calcified degenerative (n = 73, 33%) and bicuspid congenital aortic valve disease (n = 39, 18%). Eight patients (3.6%) had healed endocarditis, three (1.4%) had rheumatic valve disease and two (0.9%) had chronic dissection. Six patients (2.7%) had ‘other’ pathology, one each of fibrotic aortic valve, myxomatous or leaking aortic valve, sinus valsalva, structural or nonstructural valve disease.

Twenty-five patients (11.3%) had clinical manifestations of Marfan’s syndrome, one patient (0.5%) had Ehlers-Danlos syndrome, one patient (0.5%) had hereditary telangiectasia and two patients (0.9%) had cystic medial necrosis.

### Table 1

Preoperative patient characteristics

<table>
<thead>
<tr>
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<th>BIO (N = 136)</th>
<th>MECH (N = 85)</th>
<th>P value</th>
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<tbody>
<tr>
<td>Age (years, median)</td>
<td>53</td>
<td>54</td>
<td>NS</td>
</tr>
<tr>
<td>Female (%)</td>
<td>36 (26)</td>
<td>18 (21)</td>
<td>NS</td>
</tr>
<tr>
<td>Ejection fraction (median)</td>
<td>59</td>
<td>55</td>
<td>NS</td>
</tr>
<tr>
<td>NYHA III/IV (%)</td>
<td>44 (33)</td>
<td>22 (26)</td>
<td>NS</td>
</tr>
<tr>
<td>Preoperative atrial fibrillation (%)</td>
<td>4 (3)</td>
<td>9 (11)</td>
<td>0.035</td>
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<tr>
<td>Reoperations (%)</td>
<td>15 (11)</td>
<td>13 (15)</td>
<td>NS</td>
</tr>
<tr>
<td>Previous valve surgery (%)</td>
<td>10 (7)</td>
<td>9 (11)</td>
<td>NS</td>
</tr>
<tr>
<td>Marfan’s (%)</td>
<td>5 (4)</td>
<td>20 (24)</td>
<td>0.001</td>
</tr>
<tr>
<td>Aortic arch aneurysm (%)</td>
<td>3 (2)</td>
<td>13 (15)</td>
<td>0.001</td>
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</table>

because of CAD and in four patients (1.8%) for myocardial dysfunction detected while or after weaning from CPB.

All patients received aspirin postoperatively and in those patients with a mechanical conduit warfarin was started to maintain the INR ratio between 2.5 and 3.0.

In-hospital complications were defined and registered according to standardized definitions [3]. Postoperative data were obtained from hospital and autopsy records. Information about mortality was gained from the National Death Index and in the case of late mortality a death certificate was obtained.

Perioperative myocardial infarction was defined as patients with new postoperative CK-MB over 50 IU/l and a CK-MB/CK ratio >10%, and/or EKG changes. Renal disease was identified when the postoperative creatinine level was greater than 2.0 mg/dl. Pulmonary insufficiency was defined as the need for ventilation beyond the 2nd postoperative day. Thromboembolism, any hemorrhage, aortic valve reoperations or endocarditis were considered to be valve-related morbidity. Endocarditis was defined clinically.

Statistical analysis was performed with STATA 6.0 Intercooled (College Station, TX). The Fisher’s exact test and Mann-Whitney U-test were used for the univariate analysis of dichotomous and continuous independent variables, respectively. Long-term survival in months was ascertained from the time of operation to the end of September 2001 using Kaplan–Meier curves. Multivariate analysis was performed using logistic regression. All the statistical analyses were conducted with α = 0.05, one-sided for mortality and two-sided for all other observations.

### 3. Results

Full root replacement was performed in 213 patients (96%) and hemi-root in eight (4%). Of the full root replacements, the button technique was used in 199 patients (90%), while in 22 patients (10%) deviations from the standard technique were necessary because of either CAD and/or the inability to directly re-implant the artery. These included interposition grafts and performance of bypass grafts.

The most common underlying pathologic etiologies were annulo-aortic ectasia (n = 82, 37%), calcified degenerative (n = 73, 33%) and bicuspid congenital aortic valve disease (n = 39, 18%). Eight patients (3.6%) had healed endocarditis, three (1.4%) had rheumatic valve disease and two (0.9%) had chronic dissection. Six patients (2.7%) had ‘other’ pathology, one each of fibrotic aortic valve, myxomatous or leaking aortic valve, sinus valsalva, structural or nonstructural valve disease.
Median CPB and aortic cross-clamp duration were 169 min (range 92–558 min) and 129 min (range 31–442 min), respectively. Concomitant procedures for the entire cohort included CABG (n = 53, 24%) and aortic arch replacement (n = 16, 7.2%), both of which were significantly more common in the MECH group (P = 0.001). Concomitant mitral valve surgery was performed in 12 patients (5.4%), including seven valve replacements, three repairs with ring and two repairs without ring.

Early postoperative complications are shown in Table 2. The incidence of postoperative respiratory insufficiency, renal failure, stroke or peri-/postoperative myocardial infarction was not significantly different between groups. Similarly, there were no significant differences in the incidence of postoperative deep vein thrombosis (1.4%), atrial fibrillation (28.6%), deep infections/mediastinitis (0.9%), sepsis (0.9%), endocarditis (0.5%) or wound dehiscence (0.5%).

Overall hospital mortality was 1.8% with two deaths in each group (P = NS). Estimated late survival for the entire cohort is shown in Fig. 1. Five-year survival was 91.4%. Fig. 2 shows estimated late survival with BIO or MECH aortic root conduit. There was a trend towards greater 5-year survival in the BIO vs. the MECH group (92.4% vs. 88.2%, P = 0.068).

Mean follow-up was 42 ± 28 months for mortality (100% complete) and 39 ± 28 months for morbidity (86% complete). Late postoperative complications are shown in Table 3. Follow-up revealed ten late deaths, none related to the cardiac operation. Reoperation was required in three patients (for valve-root dehiscence, structural valve degeneration, and thoracic aortic aneurysm, respectively). Endocarditis occurred in two patients, bleeding complications requiring hospital admission occurred in seven patients, and four patients suffered a stroke. Two patients suffered myocardial infarction.

The 5-year freedom from valve-related complications did not differ between groups (BIO = 93% vs. MECH = 86%, P = 0.5) (Fig. 3). By multivariate analysis, increasing age (HR = 2.4, CI = 1.34–4.37, P = 0.003), previous valve replacement (HR = 4.7, CI = 1.23–18.24, P = 0.024), concomitant CABG (HR = 3.7, CI = 1.23–18.24, P = 0.032), and perioperative stroke (HR = 9.9, CI = 1.23–18.24, P = 0.0005) were all independent predictors of late death.

4. Discussion

The principal finding in this study is that elective aortic root replacement is an exceedingly safe operation with an operative mortality (OM) of 1.8% which is close to the OM found in the STS-database for simple AVR [4]. Furthermore, at mid term, there are no meaningful differences in valve-related outcomes between BIO and MECH. In other comparable aortic root series, the OM ranges between 1.7 and 18%, averaging 7–8% in recent studies [5–13]. Our low OM reflects a highly selected patient population because
patients with acute aortic dissections or active endocarditis were excluded, a subgroup in whom OM approaches 30% [6].

There were four hospital deaths in our series: three patients had left ventricular dysfunction with secondary multiorgan failure, likely related to myocardial protection failure. The other patient succumbed to coagulopathy after circulatory arrest. These hospital deaths are similar to other reports in the literature [6,8,12].

Late mortality in our series was low in both groups but without significant difference (BIO = 2.4%, MECH = 8.3%). There was a tendency towards greater late mortality in the MECH group which is likely related to the greater coexistence of CAD requiring CABG.

Our 10-year postoperative follow-up revealed that the majority of patients were generally doing well in both groups and we could not find any meaningful differences regarding overall mortality, freedom from valve-related complications or early and late complications between groups. This was confirmed with multivariate analysis where age, previous valve replacement, concomitant CABG and perioperative stroke were independent predictors of late death but the type of conduit was not. Other adverse late valve outcomes, specifically anticoagulation-related bleeding, thromboembolic events, cerebrovascular assaults and reoperations for structural valve deterioration, were not different between groups. There was, however, a trend towards both better survival and freedom from valve-related complications in the univariate model for the BIO group, but this should be viewed in context of the more extensive surgery performed in the MECH group (more aortic arch procedures and more CABG operations).

It is not obvious to us why previous valve replacement (mitral or aortic) was found to be an independent predictor of poor late survival, in contrast to the other predictors, i.e. increased age, perioperative stroke and concomitant CABG. These factors were corrected for other potential confounding factors that were identified with univariate analysis, and included EF, NYHA class, Marfan’s syndrome, aortic arch aneurysm, preoperative atrial fibrillation, cross-clamp time and reoperations.

Anticoagulant-related hemorrhage was uncommon in the MECH group (seven patients during the entire follow-up period). This was lower than reported in most studies involv-

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Late postoperative complications</th>
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<tbody>
<tr>
<td></td>
<td>BIO (N = 136)</td>
</tr>
<tr>
<td>Embolic/ischemic stroke (%)</td>
<td>2 (1.5)</td>
</tr>
<tr>
<td>CNS bleeding (%)</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>Other bleeding complications (%)</td>
<td>4 (2.9)</td>
</tr>
<tr>
<td>Reoperation (%)</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>Endocarditis (%)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Myocardial infarction (%)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Late mortality (%)</td>
<td>5 (3.7)</td>
</tr>
</tbody>
</table>
ving mechanical AVR (1–2%/pt-y) [1,14–16]. Our explana-
tion could be that the patients in our study were younger
than in most of the simple AVR series. Other complicati-
on were also uncommon with the exception of perioperative
myocardial infarction (12%) and reoperations for bleeding
(8%). Of significance is that our definitions of peri-/post-
operative myocardial infarction were strict compared to
other studies. Most of these patients had only moderate
enzyme elevations, and only few manifested clinical low
cardiac output.

Complications related to thromboembolism were not seen
in any patient and endocarditis occurred in only two
patients; both were in the MECH group.

Generally homograft durability is good for the first
decade postoperatively. It has been reported that about 9%
will degenerate at 12 years in patients over 20 years old
[17], which leads to a higher rate of reoperation, especially
in those with longer life expectancy. Reoperations in
general can double the OM (2.6 vs. 5.6%) [4]. However,
in many cases reoperative AVR with a stented BIO or
MECH can be performed into the neoannulus of the homograft
and the conduit itself does not have to be replaced [18].
It is clear, however, that the increased risk of reoperation
with BIO must be weighed against the life-long risk of anti-
coagulant-related bleeding with MECH. Although mechanical
conduits have high structural durability, two patients in
our series did require reoperation. One of the patients had
a dehiscence of the proximal anastomosis of the mechanical
conduit and the other was reoperated for an aortic aneurysm
above the conduit.

A limitation of our study was that the two groups were not
randomized. The demographic data were, however, compar-
able with the exception of Marfan’s syndrome, aortic aneu-
rysms and CAD being more common in the MECH group.
Atrial fibrillation preoperatively was also more common in
the MECH group. Most of these patients were already
taking coumadin and a MECH prosthesis was therefore a
logical choice. No randomized studies are available regard-
ing aortic root replacements and, for obvious reasons, such
studies would be difficult to conduct, especially at a single
institution. Another limitation is that late postoperative
echocardiographic data are not available for these patients.
It is therefore possible that some of the patients in the BIO
group had subclinical valve dysfunction.

These data demonstrate that, in experienced centers,
replacement of the aortic root, valve and the ascending
aorta with a valved conduit can be performed with approxi-
mately the same mortality and morbidity as isolated AVR.
Further evaluation of valve-related complications in this
cohort is necessary to determine the advantages, if any, of
one prosthesis over the other. In order to identify differences
between these conduits, longer follow-up of the cohort will
be needed.

Acknowledgements

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Research Fund of Brigham and Women’s Hospital.

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Appendix A. Conference discussion

Dr J. Roquette (Lisbon, Portugal): In your patients that you implanted mechanical valves, they had much more concomitant coronary bypass grafts. Was there any explanation?

Dr Mihaljevic: There was no apparent explanation for that. What we have to stress is that looking at the patients who needed coronary artery bypass surgery in conjunction with an aortic root replacement, I think what is important to differentiate, there are two subgroups of patients: those who you really intended to do the CABG to begin with and those where the bypass surgery needed to be done for the compromise of a coronary circulation secondary to the technical problems. Two of those patients that had their coronary artery bypass surgery were those that we had to do the bypass because we had problems weaning those patients from the heart-lung machine. So I think that is certainly a bad predictor for survival.

Dr V. DiSesa (West Chester, PA, USA): This obviously was not a prospective study, so that the decision about which prosthesis to use was made by the surgeon, I presume.

Dr Mihaljevic: That is true.

Dr DiSesa: What factors did you consider, and has this look at your intermediate term follow-up caused an evolution in your thinking about which prosthesis to use?

And then maybe a related question, at times, at least, it is easier to obtain hemostasis when you are sewing biologic tissue to biologic tissue, and did you use things like BioGlue in order to facilitate hemostasis?

Dr Mihaljevic: To start out with the first question first, what we tried to do is essentially to extrapolate the data and experience that we had from the elective aortic valve replacement to the patient population who needed an elective aortic root replacement, and I think that at least in our group, surgeons have been increasingly willing to use a homograft for elderly patients, regardless of an indication.

Regarding your question about bleeding, the rate of bleeding has not been significantly different between these two groups, and partly because of the BioGlue. We have been using it a lot, and essentially the reoperative rate for bleeding as well as the intraoperative problems with bleeding have not been a major problem regardless of the choice of the prosthesis.