Haemodynamics and left ventricular mass regression: a comparison of the stentless, stented and mechanical aortic valve replacement

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Abstract

Objective: Our objective was to compare the degree of change in hemodynamics and left ventricular mass (LVM) regression after aortic valve replacement (AVR) with stentless, stented and mechanical valves.

Methods: Patients greater than 59 years of age had AVR for aortic stenosis with the stentless xenograft (Cryolife–O’Brien, CLOB), stented xenograft (Carpentier–Edwards, C–E) or mechanical valve (ATS). One-hundred and forty-two patients received stentless, 40 stented, and 69 mechanical valves (mean age 74 ± 6 vs. 72 ± 7 and 67 ± 6 years, respectively). Serial echocardiography was performed.

Results: The left ventricular outflow tract diameter was similar pre-operatively in the stentless versus the stented versus the mechanical groups (2.2 ± 0.4 vs. 2.3 ± 0.2 vs. 2.2 ± 0.3 cm; P, n.s). The effective orifice area was larger immediately post-operatively in the stentless versus the stented or the mechanical group (2.4 ± 0.4 vs. 2.0 ± 0.6 vs. 2.0 ± 0.7 cm², P = 0.0001 for both comparisons). The peak aortic gradient at 6 months was significantly less in the stentless versus the stented and mechanical groups (15 ± 7 vs. 25 ± 9 vs. 22 ± 9 mmHg, P < 0.0001). LVM regressed over 6 months in all subgroups: stentless 272 ± 64 g vs. 220 ± 72 g, P = 0.0001, stented 257 ± 58 vs. 230 ± 74 g, P = 0.02, and mechanical 267 ± 95 vs. 204 ± 54 g, P = 0.003. The reduction in LVM was greater in the stentless versus the stented (P = 0.05) but similar to the mechanical group.

Conclusions: AVR with the stentless xenograft results in superior hemodynamics compared to the stented and mechanical valve replacements. AVR in all three groups leads to a significant regression of left ventricular hypertrophy within 6 months. However the reduction in LVM is greater in subjects with stentless and mechanical valves, which may have prognostic significance.

Keywords: Aortic valve replacement; Stentless porcine valve; Left ventricular mass

1. Introduction

Left ventricular hypertrophy occurs in aortic stenosis. It is believed to be a physiological response to an elevated left ventricular systolic pressure secondary to a gradient at the level of the aortic valve [1,2]. Ventricular hypertrophy is mediated by signal transduction mechanisms, requiring a sustained signal to maintain the process [3,4]. In the case of aortic stenosis, correction of the valve lesion produces regression of left ventricular hypertrophy [5,6].

Aortic valve replacement (AVR) with a stentless homograft was first reported by Ross in 1962 [7]. Initially the stentless aortic valve had poor clinical results due to both technical factors of implantation and to poor preservation. However with the development of improved methods for preserving tissue valves, there was renewed interest in stentless aortic valves of homologous and heterologous origins. In an attempt to improve the hemodynamic features and durability of heterologous tissue valves, stentless aortic xenografts have recently become the focus of much interest [8–11]. Because obstructing stents and sewing rings are eliminated, the stentless porcine aortic bioprostheses should result in superior haemodynamic function compared to stented xenografts and mechanical prostheses. In comparison with conventional stented AVR, it should be possible to implant significantly larger valves in patients matched for...
body surface area. There is evidence that the Toronto-stentless porcine valve (SPV) results in good haemodynamics and regression of left ventricular hypertrophy [8].

We have substantial experience with the Cryolife–O’Brien (CLOB) stentless aortic valve. This porcine xenograft is composed of three non-coronary cusps [9]. With removal of the muscle based right aortic valve leaflet, haemodynamic function and the size of the effective orifice should be maximised. Therefore we hypothesised that this stentless aortic valve replacement would result in improved haemodynamics and a greater regression in left ventricular mass (LVM) compared to that of the stented xenograft or that of the mechanical bileaflet prosthesis.

In this study, our objectives were to compare the degree of change in haemodynamics and LVM after AVR with (1) the stentless CLOB xenograft, (2) the stented supra-annular Carpentier–Edwards xenograft (C–E), and (3) the mechanical bileaflet ATS prosthesis.

2. Patients and methods

2.1. Patient characteristics

Patients included in this study were greater than 59 years of age, had predominant aortic stenosis preoperatively, and had an aortic valve replacement between December 1992 and February 1997 with either the CLOB or C–E xenografts or the ATS mechanical prosthesis. The choice of valve was determined by patient and surgeon preference. Patients were excluded if a concomitant myomyectomy was performed during surgery.

As shown in Table 1, 142 patients received the CLOB aortic valve replacement, 40 received the C–E aortic valve replacement, and 69 the ATS aortic valve. The mean age of the CLOB group was similar to the age of the patients receiving the C–E group (74 ± 6 vs. 72 ± 7 years; P, not significant (n.s.)) but significantly older than those receiving the ATS valve (74 ± 6 vs. 67 ± 6 years, P = 0.0001). The three groups were approximately sex matched.

Patients in the three groups had predominant aortic stenosis. The pre-operative peak aortic gradients and mean aortic gradients were similar. Aortic valve area was similar in the CLOB and the ATS groups (0.69 ± 0.20 vs. 0.71 ± 0.20 cm²; P, n.s.) but was slightly smaller in the CLOB group versus the C–E group (0.69 ± 0.20 vs. 0.81 ± 0.20 cm²; P = 0.005).

2.2. Size of valve implanted

The pre-operative left ventricular outflow tract diameter was similar in the CLOB, C–E and ATS groups (2.2 ± 0.4 vs. 2.3 ± 0.2 vs. 2.2 ± 0.2 respectively, P, n.s.). Despite the fact that the left ventricular outflow tract diameter was similar, it was possible to implant larger valves in the CLOB group than in the other two groups. The valve size in the CLOB group was 26.3 ± 2.4 vs. 23.7 ± 2.9 mm in the C–E group (P < 0.0001) versus 23.6 ± 2.4 mm in the ATS group (P < 0.0001).

2.3. Echocardiographic assessment

Echocardiography was performed pre-operatively, 1 week postoperatively and at 6 months. Measurements included peak and mean aortic gradients, effective orifice area (EOA), dimensionless performance index (DPI) and calculation of LVM. The competence of the valve was noted.

Effective orifice area was calculated using the continuity equation. This equation states that the effective orifice area is the product of the left ventricular outflow tract velocity time integral and left ventricular outflow tract area divided by the aortic velocity time integral [12,13].

DPI was calculated by dividing left ventricular outflow tract velocity by peak aortic valve velocity. DPI has the advantages of being more easily obtained than the valve area and being independent of cardiac output. It can be used as a finger print for an individual’s prosthesis and as a control for future follow-up.

LVM was calculated from M-mode using American Society of Echocardiology (ASE) criteria [14]: LVM × ASE formula = 1.04 [(intraventricular septum + posterior wall + left ventricular end diastolic dimension)² – (left ventricular end diastolic dimension)²]. LVM g × ASE corrected formula = 0.8[LVM × ASE] + 0.6.

2.4. Statistics

Data are expressed as mean ± SD. Statistical analysis was performed using the Student’s paired and unpaired t-test and by the χ² square test where appropriate. A P-value of < 0.05 was considered significant.

3. Results

3.1. Haemodynamics of aortic valve replacement

As shown in Table 2, the effective orifice area in the immediate post operative period was greater in the CLOB group than the C–E group (2.4 ± 0.4 vs. 2.0 ± 0.6, P = 0.001) versus 2.4 ± 0.4 vs. 2.0 ± 0.6, P = 0.001).
The peak and mean aortic valve gradients were significantly lower in the CLOB than in the C–E group at 6 months (peak gradients of 15 ± 7 mm Hg versus 25 ± 9 mm Hg, \( P < 0.0001 \) and mean gradients of 8 ± 4 versus 14 ± 5, \( P < 0.0001 \)). The peak and mean aortic valve gradients were also markedly less in the CLOB group than in the ATS at 6 months (peak gradients of 15 ± 7 vs. 22 ± 9 mm Hg, \( P < 0.0001 \) and mean gradients of 8 ± 4 vs. 12 ± 7, \( P < 0.0001 \))

The dimensionless performance index was higher in the CLOB group versus the C–E (0.51 ± 0.10 vs. 0.46 ± 0.10, \( P = 0.009 \)) and ATS groups (0.51 ± 0.10 vs. 0.46 ± 0.10, \( P = 0.003 \)).

3.2. Regression of left ventricular mass following aortic valve replacement

As shown in Table 3, LVM showed significant regression over a 6 month period in all three groups (CLOB, 272 ± 64 vs. 220 ± 72 g, \( P = 0.0001 \), C–E, 257 ± 58 vs. 230 ± 74 g, \( P = 0.02 \), and ATS 267 ± 95 vs. 204 ± 54 g, \( P = 0.003 \)).

Pre-operative LVM was not significantly different in the three different groups. The reduction in LVM was greater in the stentless versus the stented (\( P = 0.05 \)) but similar to the mechanical group.

4. Discussion

4.1. Haemodynamics following aortic valve replacement

This study shows that the CLOB stentless aortic xenograft results in superior haemodynamic function compared to stented supra-annular C–E xenograft and the bileaflet ATS mechanical prothesis. This is concordant with previous studies comparing the Toronto-SPV valve and stented xenografts [15]. It is likely that the superior haemodynamics are at least in part because obstructing stents and sewing rings are eliminated. In comparison with conventional stented aortic valve replacements and mechanical valves, it is possible to implant significantly larger valves in patients with similar left ventricular outflow tract diameters.

Table 2

<table>
<thead>
<tr>
<th>Haemodynamics</th>
<th>CLOB</th>
<th>CE</th>
<th>ATS</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOA</td>
<td>2.4 ± 0.4</td>
<td>2.0 ± 0.6</td>
<td>2.0 ± 0.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>AV mean gradient (mmHg)</td>
<td>8 ± 4</td>
<td>14 ± 5</td>
<td>12 ± 7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>AV peak gradient (mmHg)</td>
<td>15 ± 7</td>
<td>25 ± 9</td>
<td>22 ± 9</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

\( P \) Values are for the CLOB valve compared with both the CE and ATS valve. CLOB, CE and ATS as for Table 1. EOA, effective orifice area, AV, aortic valve.

4.2. Regression of left ventricular hypertrophy

Aortic valve replacement with the CLOB and C–E xenograft and ATS mechanical valve leads to a significant regression of left ventricular hypertrophy within 6 months. The reduction in LVM is greater in subjects with stentless and mechanical valves, which may have prognostic significance.

Because the stentless porcine aortic xenograft results in superior haemodynamic function and it is possible to implant larger valves in patients matched for body surface area, this suggested to us that this valve may result in a greater degree of regression of left ventricular hypertrophy compared with stented supra-annular C–E xenografts and with the ATS valve. Interestingly regression of LVM was greater in the CLOB aortic valve replacement than in the supra-annular C–E xenograft but was similar to that seen with the ATS valve.

4.3. Prognostic benefit conferred by regression of left ventricular hypertrophy

There is substantial evidence that the presence of left ventricular hypertrophy is a marker of poor prognosis with an increased risk of cardiovascular events [16,17]. The expected corollary of this is that regression of left ventricular hypertrophy results in an improvement in prognosis. We have yet to demonstrate an improvement in prognosis in patients with the greatest regression of left ventricular hypertrophy following aortic valve replacement, but we would speculate that this is likely.

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References


