REVERSIBILITY OF THE LEFT VENTRICULAR FUNCTION 
AFTER AORTIC VALVE REPLACEMENT FOR 
AORTIC REGURGITATION 

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Ten patients with aortic regurgitation underwent aortic valve replacement using a Björk-Shiley valve prosthesis. They ranged from 27 to 58 years of age. The studies were centered around the postoperative hemodynamics, especially concerning the function of the left ventricle during a follow-up period which averaged about 8 months. The left ventricular end-diastolic volume (LVEDV) returned to the normal range, and the muscle mass of the left ventricle decreased remarkably after surgery. The ejection fraction and mean velocity of the circumferential fiber shortening both increased up to the normal range. The left ventricular end-diastolic pressure exhibited normal values with a decrease of the LVEDV. The depressed left ventricular function was largely reversible after surgery. 

The function of the left ventricle has been studied considerably. However, there are a number of points remaining to be resolved. Since little work has been done to study left ventricular function after aortic valve replacement, there remain many problems to be solved. This is especially true in reference to the amount of time that can be safely allotted for the operation and to whether or not the reduced left ventricular function is reversibly improved during the late postoperative period. 

The purpose of the present paper is to confirm the presence of postoperative reversibility of the preoperatively reduced left ventricular function. It also includes the determination of limits of the preoperative impairment of the cardiac function and hemodynamics in order to make the cardiac function reversible. 

PATIENTS AND METHODS 

Patients 

Twelve patients who were examined had a history of an aortic valve replacement using the Björk-Shiley tilting disc valve prosthesis. Two of these patients were eliminated: one patient was found to have perivalvular leakage through aortography postoperatively, and in the other the sinus rhythm developed into atrial fibrillation during the postoperative study. Full studies were performed on the remaining 10 patients. There were 8 men and 2 women. Each patient had a pure AR without any measurable systolic pressure gradient across the aortic valve. The age of these patients at surgery ranged from 27 to 58 with an average age of 39. 

Key Words: 
Aortic regurgitation 
Aortic valve replacement 
Left ventricular function 
Reversibility 

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TABLE I  CLINICAL AND HEMODYNAMIC DATA

<table>
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<th>Case No.</th>
<th>Age</th>
<th>Sex</th>
<th>Follow-up months</th>
<th>CTR (%)</th>
<th>RV&lt;sub&gt;s&lt;/sub&gt; + SV&lt;sub&gt;1&lt;/sub&gt; (mV)</th>
<th>HR (min&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>CI (L/min/m&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>SVI (ml/m&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>LVEDP (mmHg)</th>
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<tr>
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<td>Pre Post</td>
<td>Pre Post</td>
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<td>2.07 4.34 4.49</td>
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<td>22 12 6</td>
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Mean     39   | 8 61 53 | 6.6 3.9 | 80 83 112 | 2.43 3.36 5.71 | 32 44 51 | 21 7 9 |
SD       10   | 3 6 15 | 1.5 1.4 | 15 19 20 | 0.67 0.81 1.26 | 7 12 6 | 10 3 3 |
p value  <0.002 <0.001 ns <0.001 <0.02 <0.001 <0.02 ns <0.001 ns

Abbreviation: CTR = cardiothoracic ratio; RV<sub>s</sub> + SV<sub>1</sub> = RV<sub>s</sub> + SV<sub>1</sub> on electrocardiogram; HR = heart rate; CI = cardiac index; SVI = stroke volume index; LVEDP = left ventricular end-diastolic pressure; M = male; F = female; Pre = preoperation; Post = postoperation; R = at rest; Ex = during exercise; ns = not significant

**Methods**

The patients were studied preoperatively using right and retrograde or transseptal left heart catheterization. The pressures and cardiac output were measured at rest and during exercise prior to angiography at an average of about 8 months (from 4 to 15) after the operation. The left ventricle was catheterized by the transseptal technique postoperatively. The exercise was carried out using a bicycle ergometer for 5 to 7 min in the supine position. The pressures were measured using a Statham P23Db transducer and were recorded on an H-P 8 channel polyacorder. The cardiac output was measured using the green dye dilution method.

Left ventricular angiography at the right anterior oblique (RAO) view was carried out pre- and post-operatively by injecting 50 ml of 76% Urografin (Renograin) at 50 frames per sec on 35 mm film. The left ventricular volumes were calculated by the area-length method.

Premature and postpremature beats were excluded and the earliest satisfactory beat was used. The left ventricular free wall's thickness was measured at end-diastole at the RAO projection. The left ventricular mass (LVM) was determined according to the method of Rackley and his associates using the following equations:

\[ V_M = (V_{C+W} - V') \times 1.05 \]

\[ V_{C+W} = \frac{4}{3} \pi \left( \frac{L}{2} + h \right) \left( \frac{M}{2} + h \right)^2 \]

where \( V_M \) = left ventricular mass,
\( V_{C+W} \) = volume of left ventricular chamber plus wall,
\( V' \) = volume of chamber,
\( h \) = left ventricular wall thickness at end-diastole,
\( L \) = long axis,
\( M \) = minor axis, and
1.05 = specific gravity of the myocardium.

The mean velocity of the circumferential fiber shortening rate (mVCF) was calculated using the following equation:

*Japanese Circulation Journal Vol. 47, June 1983*
TABLE II ANGIOGRAPHIC AND HEMODYNAMIC DATA

<table>
<thead>
<tr>
<th>Case No.</th>
<th>LVESV (ml/m²) Pre</th>
<th>LVEDV (ml/m²) Pre</th>
<th>h (cm) Pre</th>
<th>LVM (g/m³) Pre</th>
<th>EF Pre</th>
<th>mVCF (circ/sec) Pre</th>
<th>Stress (10⁵ dyne/cm²) Pre</th>
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</table>
| p value  | < 0.001          | < 0.001           | ns       | < 0.001        | < 0.001 | < 0.001 | < 0.001<br>Where LVESV = left ventricular end-systolic volume; LVEDV = left ventricular end-diastolic volume; h = left ventricular wall thickness; LVM = left ventricular mass; EF = ejection fraction; mVCF = mean velocity of circumferential fiber shortening; Stress = left ventricular peak wall stress. Other abbreviations are the same as in Table I.

\[
mVCF = \frac{M_D - M_S}{M_D} \times \frac{1}{\text{ejection time}}
\]

where \( M_D \) = diastolic minor equator, \( M_S \) = systolic minor equator.

The peak left ventricular equatorial wall stress was calculated using the thick wall ellipsoid formula of Falsetti

\[
\text{Stress} = \frac{PM_D (2L^2 - M_D^2)}{4h (L^2 + M_Dh)}
\]

where \( P \) = pressure in dynes/cm².

Result were expressed as mean ± standard deviation. Statistical analysis was performed by Student's t-test for paired values. A probability (p) value of < 0.05 was considered significant.

RESULTS

The pre- and post-operative hemodynamic data is listed in Tables I and II.

Residual aortic prosthetic pressure gradients after surgery were less than 10 mmHg at rest and during exercise in every patient.

The mean left ventricular end-systolic volume (LVESV) decreased from 156 ± 79 to 47 ± 36 ml/m² (p < 0.001). The mean left ventricular end-diastolic volume (LVEDV) decreased from 272 ± 101 to 115 ± 36 ml/m² (p < 0.001) (Fig. 1).

The preoperative and the postoperative left ventricular wall thicknesses (h) were 1.3 ± 0.3 and 1.3 ± 0.3 cm, respectively.

The left ventricular mass (LVM) decreased significantly from 303 ± 168 to 179 ± 104 g/m² (p < 0.001) (Fig. 2). The mean ejection fraction (EF) increased significantly from 0.44 ± 0.10 to 0.63 ± 0.13 (p < 0.001). The EF returned to normal in every patient but one. That patient's EF decreased inversely from 0.33 to 0.30 (Fig. 3). The mean velocity of circumferential fiber shortening (mVCF) increased from 0.67 ± 0.25 to 1.46 ± 0.37 circ/sec (p < 0.001). The mean peak wall stress decreased after surgery from 434 ± 10³ ± 10³ to 351 ± 10³ ± 62 × 10³ dyne/cm² (p < 0.005). The mean left ventricular end-diastolic pressure (LVEDP) decreased significantly from 21 ± 10 to 7 ± 3 mmHg (p < 0.001). The mean cardiac index (CI) increased from 2.43 ± 0.67 to 3.36 ± 0.81 L/min/m² (p < 0.02) and the mean stroke volume index (SVI) increased from 32 ± 7 to 44 ± 12 ml/m² (p <
DISCUSSION

This report is an evaluation of the effectiveness of surgery to eliminate aortic regurgitation. The factors evaluated were as follows:

1) A preoperative evaluation of the LVM, the LV volume and the status of LV contractility,
2) a postoperative evaluation of these indices,
3) an evaluation of the cardiac reserve during exercise load and
4) the final evaluation concerning postoperative reversibility of the left ventricular function.

It was implied that the enlarged left ventricular volume decreased remarkably when the volume overload was removed postoperatively.

The LVM decreased postoperatively. Little change was noticed after surgery in respect to the wall thickness. The left ventricular wall remained slightly thickened in spite of a decrease in the LVM postoperatively. Accordingly, the degree of the LVM reduction was less than that of LVEDV, and the decrease of the LVM depended upon the decrease of the LVEDV (Fig. 4).

The LVEDP which had a high value preoperatively decreased remarkably after the operation with the decrease of the LVEDV (Fig. 5).

Pantley et al.\(^2\) have reported that in patients with aortic stenosis, the EF was improved postoperatively, but no remarkable improvement was noticed in patients with aortic regurgitation. Gault et al.\(^3\) have reported that the diameter of the left ventricle did not shorten after surgery in severely affected patients.

However, the coronary blood supply increased after surgery\(^12,13\) because the left ventricular
mass decreased and the aortic diastolic pressure elevated with a subsequent decrease in the LVEDP. Therefore, the left ventricular muscle contraction increased and the ejection fraction returned to normal.

The relationship between the exercise-induced changes in the LVEDP (ΔLVEDP) and the stroke volume index (ΔSVI) is shown in Fig. 6. Eight patients exhibited an increase in SVI, among whom LVEDP increased in 6. This response was normal during exercise in the supine position. In a ninth patient the LVEDP increased in association with a decrease of the SVI. This response was abnormal. The LVEDP and the SVI decreased simultaneously in a tenth during exercise. In this patient cardiac output increased slightly. This response was also abnormal.

Pantley et al, Gault et al, and others have reported that the preoperatively reduced left ventricular function did not improve through a short-term follow-up. Kennedy et al and Gaash et al have also reported that even though the patients with a slightly reduced left ventricular function showed improvement, the cases with severely reduced left ventricular function did not show any improvement. Kennedy et al explained the matter in detail in his report on 2 cases showing an EF of less than 0.5. In these cases, the left ventricular volume and weight decreased postoperatively, but the EF did not improve postoperatively. Gaash et al conducted an
echocardiographic study on 19 patients, and they reported that the volume and weight became normal postoperatively in 12 of the patients who underwent suitable operations, but no improvement was noticed in the other 4 patients. The preoperative left ventricular dimensions at end-diastole in 4 patients were higher than those seen in the other 12 patients. Contrarily, Schwarz et al. and others have reported postoperative improvements.

Schwarz et al. have reported 4 cases who showed an EF of less than 0.5 (though one case showed an EF of less than 0.4). Every case demonstrated an improvement in the EF of more than 0.5. Their results are very similar to those of the authors', but their cases included those with a slightly reduced left ventricular function. The average preoperative values in their cases were 53% for the cardiothoracic ratio, 54% for the EF, 157 ml/m² for the LVEDV, 176 g/m² for the LVM and 0.9 circ/sec for the mVCF. Their cases were only slightly severe as compared with the cases in the present study.

These discrepancies mentioned above may be in part due to the differences of the preoperative left ventricular function. In our data, the postoperative left ventricular function was reversible in the patients with an ejection fraction of 0.35. Contrarily, its reversibility was only slight in the patient with an ejection fraction of 0.33. The differences of the preoperative hemodynamics between the patient with an ejection fraction of 0.35 and 0.33 were found in the left ventricular volume, the wall thickness and the mass. Therefore, the values of those parameters were higher in the patient with an ejection fraction of 0.33.

The enlarged left ventricular volume nearly returned to the normal range postoperatively in most patients with aortic regurgitation. The left ventricular mass decreased remarkably as compared with the preoperative value. The LVEDP fell into the normal range. The reduced ejection fraction and the mVCF became normal and the response during exercise was good.

The left ventricular function was considered fully reversible postoperatively, if values of the LVEDV, the wall thickness and the mass have lower values than 350 ml/m², 1.5 cm and 350 g/m², respectively.

REFERENCES


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