INFLUENCE OF SURGERY FOR ISCHEMIC HEART DISEASE ON EARLY POSTOPERATIVE LEFT VENTRICULAR FUNCTION

TAKASHI FUJIWARA, MASATAKA YAMANE, KATSUMI MOTOHIRO, IKUO TAKAHARA, MASAKI SATO, YOICHI KOUGASA, AKIMITSU KISO, AND TATSUKI KATSUMURA

The pre- and postoperative systolic time intervals, hemodynamics and serum catecholamines were studied in 30 patients with successful myocardial revascularization surgery or left ventricular aneurysmectomy and the influence of the surgery on the left ventricular function was evaluated.

1. Significant depression of left ventricular performance was recognized in the group of patients with left ventricular aneurysm as compared to the patients with angina pectoris with or without previous myocardial infarction before the operation.

2. At 2 hours after the operation, significant decrease of ET/PEP, cardiac index and stroke work index and marked elevation of systemic vascular resistance were seen in the group of patients with aortocoronary bypass surgery who had previous myocardial infarction and with left ventricular aneurysmectomy as compared to the group of patients without previous myocardial infarction.

3. At 2 hours after the operation, ET/PEP seemed to reflect the left ventricular stroke work and the depression of the left ventricular function was mainly affected by the elevation of systemic vascular resistance due to the hypersecretion of serum catecholamines.

4. Reduction of systemic vascular resistance by vasodilator brought an improvement of ET/PEP, cardiac index and stroke work index.

Myocardial revascularization surgery for ischemic heart disease has a significant influence on the left ventricular function which is often impaired preoperatively.

It is well-known that low cardiac output syndrome after open heart surgery resulting from myocardial injury is caused by diffused subendocardial ischemia during cardiopulmonary bypass.1,2,3 Recent advances in the study on myocardial protection during open heart surgery are remarkable and concurrently it is very important to evaluate the left ventricular function for the early postoperative care in ischemic heart disease.

There are various methods for the evaluation of cardiac performances. However, most of these methods are difficult to perform easily, frequently and non-invasively during early postoperative period.

Previously, we reported that an impairment of cardiac function, which was evaluated by systolic time intervals and postoperative hemodynamic

Key Words:
Ischemic heart disease
Aortocoronary bypass
Left ventricular function
Postoperative care
Vasodilator

(Received on March 28, 1979; Accepted on July 23, 1979)
Division of Thoracic and Cardiovascular Surgery, Department of Surgery, Kawasaki Medical School, Matsushima 577, Kurashiki, Okayama, Japan.
TABLE I LEFT VENTRICULAR FUNCTION BEFORE AND AFTER THE OPERATION

<table>
<thead>
<tr>
<th>group</th>
<th>before operation</th>
<th>2 hours after op</th>
<th>6 hours</th>
<th>24 hours</th>
<th>3 days</th>
<th>1 week</th>
<th>3 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET/PEP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=15</td>
<td>2.58±0.11</td>
<td>2.0±0.07</td>
<td>1.97±0.07</td>
<td>2.28±0.14</td>
<td>2.36±0.10</td>
<td>2.67±0.12</td>
<td></td>
</tr>
<tr>
<td>n=9</td>
<td>2.43±0.14</td>
<td>1.55±0.10</td>
<td>1.79±0.15</td>
<td>1.94±0.10</td>
<td>2.04±0.10</td>
<td>2.34±0.29</td>
<td>2.30±0.14</td>
</tr>
<tr>
<td>n=6</td>
<td>2.01±0.18</td>
<td>1.44±0.04</td>
<td>1.66±0.09</td>
<td>1.97±0.07</td>
<td>2.08±0.10</td>
<td>2.33±0.04</td>
<td>2.61±0.20</td>
</tr>
<tr>
<td>CI (1/m²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3.3±0.3</td>
<td>2.7±0.3</td>
<td>2.7±0.2</td>
<td>3.2±0.2</td>
<td>3.7±0.3</td>
<td>3.8±0.4</td>
<td>4.2±0.2</td>
</tr>
<tr>
<td>2</td>
<td>3.3±0.3</td>
<td>2.2±0.3</td>
<td>2.7±0.2</td>
<td>3.0±0.2</td>
<td></td>
<td></td>
<td>3.5±0.3</td>
</tr>
<tr>
<td>3</td>
<td>2.9±0.20</td>
<td>2.0±0.1</td>
<td>2.7±0.3</td>
<td>3.0±0.3</td>
<td>3.4±0.4</td>
<td>3.6±0.2</td>
<td></td>
</tr>
<tr>
<td>LVSWI (g·m²/l)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>61.2±5.0</td>
<td>37.4±3.9</td>
<td>41.3±5.5</td>
<td>38.8±3.0</td>
<td>45.7±4.3</td>
<td>50.0±4.5</td>
<td>55.1±3.3</td>
</tr>
<tr>
<td>2</td>
<td>66.6±4.9</td>
<td>27.2±1.7</td>
<td>29.9±2.2</td>
<td>29.6±2.7</td>
<td>36.0±2.8</td>
<td></td>
<td>50.0±6.2</td>
</tr>
<tr>
<td>3</td>
<td>49.4±7.3</td>
<td>34.7±3.5</td>
<td>41.7±7.3</td>
<td>46.7±7.6</td>
<td></td>
<td></td>
<td>50.3±5.5</td>
</tr>
<tr>
<td>SVR (mmHg/l)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>21.7±2.1</td>
<td>27.9±2.7</td>
<td>23.7±2.7</td>
<td>19.3±1.6</td>
<td>16.5±1.7</td>
<td>16.1±1.4</td>
<td>13.1±0.8</td>
</tr>
<tr>
<td>2</td>
<td>18.3±1.5</td>
<td>35.7±2.4</td>
<td>23.1±2.6</td>
<td>21.2±2.9</td>
<td>19.2±1.5</td>
<td></td>
<td>15.6±1.3</td>
</tr>
<tr>
<td>3</td>
<td>22.7±2.7</td>
<td>35.6±2.5</td>
<td>25.7±2.7</td>
<td>21.5±1.4</td>
<td>18.1±1.9</td>
<td>15.4±1.7</td>
<td>19.2±1.7</td>
</tr>
</tbody>
</table>

Values are expressed as Mean ± SE. ET/PEP: ejection time/pre-ejection period. CI: cardiac index. LVSWI: left ventricular stroke work index. SVR: systemic vascular resistance.

TABLE II SERUM CATECHOLAMINES

<table>
<thead>
<tr>
<th>before operation</th>
<th>Anesthesia during cardiopulmonary bypass</th>
<th>2 hours after operation</th>
<th>6 hours</th>
<th>24 hours</th>
<th>3 days</th>
<th>1 week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenaline (ng/ml)</td>
<td>0.05±0.01</td>
<td>0.48±0.14</td>
<td>0.29±0.07</td>
<td>0.43±0.17</td>
<td>0.30±0.12</td>
<td>0.06±0.02</td>
</tr>
<tr>
<td>Noradrenaline (ng/ml)</td>
<td>0.19±0.02</td>
<td>0.33±0.05</td>
<td>0.49±0.08</td>
<td>0.74±0.15</td>
<td>1.04±0.26</td>
<td>1.08±0.34</td>
</tr>
</tbody>
</table>

Values are expressed as Mean ± SE. Normal value of adrenaline: <0.12 ng/ml
Normal value of noradrenaline: 0.04—0.35 ng/ml

studies, was more prominent during early postoperative period and the recovery of cardiac function was slower in ischemic heart disease than in congenital septal defect in adults and open mitral commissurotomy.

The purpose of this study is to evaluate the effect of myocardial revascularization surgery or left ventricular aneurysmectomy on the left ventricular function which was determined by the analysis of pre- and postoperative systolic time intervals, hemodynamic data and serum catecholamines.

MATERIALS AND METHODS

Thirty patients with successful aortocoronary bypass surgery (A-C bypass) or left ventricular aneurysmectomy were studied. The patients were divided into three groups — (1) a group of patients with A-C bypass who had no previous history of myocardial infarction, (2) patients with A-C bypass who had an old myocardial infarction and (3) patients with left ventricular aneurysmectomy. There were 15 patients in group 1, 9 in group 2 and 6 in group 3. Four
patients in group 3 had both A-C bypass and aneurysmectomy. None of them had peri- or postoperative myocardial infarction.

ET/PEP was determined by indirect method (phono-carotid pulse method) using ECG, phonocardiogram and carotid pulse wave.$^6$

*Japanese Circulation Journal Vol. 43, October 1979*
Fig. 3. Left ventricular stroke work index before and after the operation.
○--○: Group 1. •--•: Group 2. ×--×: Group 3.

Fig. 4. Systemic vascular resistance before and after the operation.
○--○: Group 1. •--•: Group 2. ×--×: Group 3.

Japanese Circulation Journal Vol. 43, October 1979
Cardiac output was obtained by impedance cardiography and thermodilution method.

Systemic vascular resistance (SVR) and stroke work index (LVSWI) were calculated by the following formula:

$$SVR = \frac{\text{mean blood pressure}}{\text{cardiac output}} \times \frac{13.6}{\text{pulse rate}} \text{ mmHg/L}$$

$$LVSWI = \frac{\text{mean blood pressure} \times \text{cardiac index}}{\text{pulse rate}} \times \frac{13.6}{\text{g.m/m}^2}$$

Serum catecholamines were determined in 9 cases by the high performance liquid chromatographic method.

These data were obtained before and at 2, 6, 24 hours, 3 days, 1 week and 3 weeks after the operation.

RESULTS

The values of ET/PEP, CI, SVR, LVSWI and serum adrenaline and noradrenaline in three groups were shown in Table I and II.

1. ET/PEP (Figure 1)

The preoperative ET/PEP in groups 1 and 2 were within normal limits (2.58 ± 0.11 and 2.43 ± 0.14 respectively, mean ± SE), but significantly reduced in group 3 (2.01 ± 0.18) (P < 0.05). At 2 hours after the operation, ET/PEP reduced significantly in all the groups (P < 0.01) (1.68 ± 0.06 in group 1, 1.55 ± 0.01 in group 2 and 1.44 ± 0.04 in group 3). Then gradual improvement was noted, although it was slower in groups 2 and 3 than in group 1. There was no difference in the recovery of ET/PEP between group 2 in which preoperative ET/PEP was normal and group 3 in which it was significantly depressed.

2. Cardiac index (Figure 2)

There was no difference in the preoperative cardiac index in these three groups. Two hours after the operation, cardiac index decreased significantly in group 2 (2.2 ± 0.2 L/m², P < 0.05) and group 3 (2.0 ± 0.1 L/m², P < 0.05) as compared to group 1 (2.7 ± 0.3 L/m², P:NS). The postoperative improvement of cardiac index was excellent in group 1. Twenty-four hours after the operation, it recovered to the preoperative level. At 3 weeks after the operation, it increased to 4.2 ± 0.2 L/m². On the other hand, the improvement of cardiac index was not sufficient and slower in group 2 and 3. There was no difference in the postoperative recovery of cardiac index between group 2 and 3.

3. Left ventricular stroke work index (Figure 3)

The preoperative stroke work index in groups 1 and 2 were normal but significantly smaller in group 3. At 2 hours after the operation, the stroke work of the left ventricle was decreased in all the groups. Especially in group 2, significant depression and slower recovery were recognized.

4. Systemic vascular resistance (Figure 4)

Systemic vascular resistance was markedly elevated at 2 hours after the operation in each group, especially in groups 2 and 3 (P < 0.01). Then it rapidly decreased and returned to the preoperative level at 6 to 24 hours after the op-
Fig. 7. The effect of vasodilator on left ventricular function. (2 hours after the operation).

Fig. 8. Serum adrenaline and noradrenaline before and after the operation.

○—○: serum adrenaline
●—●: serum noradrenaline.

5. Relation between ET/PEP and left ventricular stroke work index at 2 hours after the operation (Figure 5)

At 2 hours after the operation when postoperative left ventricular performance was most depressed, there was a relatively close correlation \( r = 0.67 \) between ET/PEP and stroke work index. So it seems that ET/PEP reflects stroke work of the left ventricle.

6. Relation between ET/PEP and systemic vascular resistance at 2 hours after the operation (Figure 6)

There was a close correlation \( r = -0.72 \) between ET/PEP and systemic vascular resistance at 2 hours after the operation. The depression of the left ventricular function seemed to be related to the elevation of systemic vascular resistance in early postoperative period.

7. The effect of vasodilator on the left ventricular function at 2 hours after the operation (Figure 7)

In five cases with high systemic vascular resistance at 2 hours after the operation, the influence of vasodilator (Phentolamine, 3–5 \( \mu \)g/kg/min) on the left ventricular function was studied.

Mean blood pressure changed from 110 mmHg to 103 mmHg, systemic vascular resistance decreased from 46.4 ± 2.2 mmHg/L to 33.9 ± 1.8 mmHg (P < 0.01), ET/PEP improved from 1.69 ± 0.11 to 2.14 ± 0.17, cardiac index increased from 2.4 ± 0.3 L/m² to 3.2 ± 0.4 L/m² and stroke work index improved from 33.3 ± 6.4 g·m/m² to 40.6 ± 8.7 g·m/m². These findings seemed to demonstrate that marked elevation of systemic vascular resistance at 2 hours after the operation played an important role in the depression of the left ventricular function which was improved by vasodilator.

8. Serum adrenaline and noradrenaline (Figure 8) (Table II)

Serum adrenaline was rapidly increased from 0.05 ± 0.01 \( \mu \)g/ml preoperatively to 0.48 ± 0.14 \( \mu \)g/ml during the operation. And then it decreased rapidly to the preoperative level at 24 hours after the operation.

Serum noradrenaline increased similarly as serum adrenaline and reached to the peak at 24 hours after the operation and then decreased

*Japanese Circulation Journal Vol. 43, October 1979*
slowly.

DISCUSSION

In open heart surgery the cardiopulmonary bypass causes frequently ischemic impairment of the myocardium, and the deterioration of left ventricular function by the operation obviously produces an adverse effect on the postoperative course and prognosis in the myocardial revascularization surgery on the patients with preoperative left ventricular dysfunction or low cardiac reserve.

In this study, we analyzed the changes of postoperative cardiac performance which was evaluated by systolic time intervals and hemodynamics in 30 surgically treated patients with ischemic heart disease. The influence of the surgery on cardiac function was evaluated in the patients with A-C bypass with and without old myocardial infarction and those patients with left ventricular aneurysmectomy. All the patients had a successful aortocoronary saphenous vein bypass graft or left ventricular aneurysmectomy without producing postoperative myocardial infarction.

ET/PEP was calculated as an index of systolic time intervals because it is little influenced by the pulse rate.

Significant dysfunction was noted in the group with left ventricular aneurysm preoperatively as compared to the group without aneurysm. ET/PEP and cardiac index decreased in all the groups after the operation, especially in groups 2 and 3. The subsequent recovery of ET/PEP was slower in these groups than in group 1. However, there was no difference in the degree of impairment and recovery of cardiac function between group 2 in which preoperative ET/PEP was normal and group 3 in which it was significantly low. The advantage of left ventricular aneurysmectomy was recognized on the postoperative improvement of left ventricular function.

There was a good correlation between ET/PEP and stroke work index at 2 hours after the operation, and ET/PEP in early postoperative period seemed to reflect the stroke work of the left ventricle. Also a better correlation was seen between ET/PEP and systemic vascular resistance, and the left ventricular function was improved by vasodilator which reduced systemic vascular resistance at 2 hours after the operation. These findings seemed to demonstrate that the main cause of cardiac dysfunction at 2 hours after the operation was a marked elevation of systemic vascular resistance.

Replege and his colleagues have reported that serum catecholamines increased during open heart surgery and very high values of catecholamines after cardiopulmonary bypass were observed in the patients who succumbed in early postoperative period.

Systemic hypertension was frequently seen in the series of patients undergoing myocardial revascularization surgery, resulting from the elevation of systemic vascular resistance caused by the hypersecretion of serum catecholamines and renin.

Boudouas et al. have reported the subsequent changes of systolic time intervals and serum catecholamines after aortocoronary bypass surgery. Shortening of Q-II interval and elevation of PEP/ET were still recognized at 3 weeks after the operation and returned to the preoperative value 3 months after surgery. Prolongation of PEP, shortening of ET and further elevation of PEP/ET were noted in the patients with myocardial infarction as compared to those patients with no myocardial infarction during the operation.

Lewis et al. have reported that the shortening of Q-II interval indicated myocardial hypofunction and seemed to be related to the secretion of catecholamines in urine.

Our results, demonstrating shortening of Q-II interval and ET, and decrease of ET/PEP after the operation, also suggested some relations to the consecutive changes of serum catecholamines.

Although there was no case with marked myocardial dysfunction before the operation or peri- and postoperative myocardial infarction in our series, the new myocardial infarction during operation, if it occurs, would extremely deteriorate the postoperative left ventricular performance.

For the prevention of postoperative low cardiac output syndrome, it would be very important to evaluate the consecutive changes of cardiac performance and systemic vascular resistance after the operation.

If the depression of early postoperative myocardial function is considered due to the result from a marked elevation of systemic vascular resistance, vasodilator will be effective to improve the cardiac function, and when the improvement of cardiac hypofunction is not obtained 6 hours after the operation or later,
severe myocardial dysfunction and the extremely poor results will be anticipated, and much more intensive care will be required as to prevent low cardiac output syndrome.

REFERENCES


