Physical Training in Patients with Valvular Heart Disease after Surgery

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The necessity, the methodology and clinical benefit of physical training were evaluated in 85 patients with valvular heart surgery. In 21 patients who had undergone the exercise stress test before surgery, corrective valvular surgery increased maximal oxygen uptake (max·VO₂) from 15.4 before to 18.9 ml/min/kg, while 11 (52%) of them failed to increase exercise capacity over 5 METs. Of the total 85 patients, 41 (58%) again showed reduced exercise capacity in the initial postoperative stress test, suggesting that a return to work might be difficult without rehabilitation in these patients.

We then compared two training programs: program A of short duration and frequent exercise and program B of longer duration and less frequent exercise, both using a bicycle exercise set at an intensity of 70% of the max·VO₂. Both programs similarly increased max·VO₂, while patients preferred program A, suggesting that exercise of longer duration could not be tolerated because of de-conditioning. Program A was then prescribed to 62 patients, and it increased max·VO₂ from 18.2 to 20.7 ml/min/kg after 4 weeks training without any complication. In 9 patients who served as controls undergoing no physical training, no spontaneous improvement in exercise capacity was observed. Of the 76 patients who received either program A or B, 28 patients failed to increase the max·VO₂ by 10% or more. These patients presented atrial fibrillation, a cardiothoracic ratio ≥60% or exercise-induced ST depression more frequently, suggesting that residual cardiac dysfunction might inhibit the training effects. These observations indicated that physical training is beneficial to patients after valvular heart surgery, by increasing exercise capacity, promoting an earlier return to daily activities and to work and improving generally, the quality of life.

DURING the last decades, physical training has been widely accepted as a therapeutic approach in the rehabilitation for patients with heart disease.¹⁻³ However, training programs have mostly been offered to patients with coronary heart disease. The majority of patients undergoing corrective valvular heart surgery have long studied heart problems and have been forced to rest in bed. Surgical intervention inevitably causes deterioration in their general condition. This eventually leads to deconditioning in the working skeletal muscles and in the neuro-hormonal system of patients after valvular heart surgery. Rehabilitation programs for such patients, therefore, are needed to improve physical capacity and increase the rate of return to normal life. However, insufficient interest has been shown in physical training after valvular heart surgery, and no rehabilitation program compatible with the socio-economic conditions in Japan has been established. In an attempt to rehabilitate patients after valvular heart surgery and to

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Key words:
Valvular heart disease
Valve replacement
Physical training

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Exercise Therapy in the Field of Circulation

Program A

Exercise Prescription
Type of exercise: Bicycle ergometer
Intensity: 70% of VO₂ max.
Duration: 6 min (72 min/week)
Frequency: Twice a day
Place: Training room in hospital
Supervision: Under supervision

Exercise protocol

Warm-up Stimulus Cool-down

3 min 6 min 3 min

Program B

Exercise Prescription
Type of exercise: Bicycle ergometer
Intensity: 70% of VO₂ max.
Duration: 24 min (72 min/week)
Frequency: Every other day
Place: Training room in hospital
Supervision: Under supervision

Exercise protocol

Warm-up Stimulus Cool-down

3 min 24 min 3 min

Fig.1. Two programs for exercise training used in the present study.

TABLE 1 EFFECTS OF CORRECTIVE VALVULAR SURGERY ON EXERCISE CAPACITY

<table>
<thead>
<tr>
<th></th>
<th>Before surgery (n=21)</th>
<th>After Surgery (n=21)</th>
<th>#After surgery (n=85)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. oxygen uptake (ml/kg/min)</td>
<td>15.4±4.2</td>
<td>18.9±3.4*</td>
<td>18.2±5.3</td>
</tr>
<tr>
<td>Ex. capacity ≤ 4 METS</td>
<td>8 (38%)</td>
<td>2 (10%)*</td>
<td>15 (18%)</td>
</tr>
<tr>
<td>Ex. capacity ≤ 5 METS</td>
<td>15 (71%)</td>
<td>11 (52%)</td>
<td>41 (58%)</td>
</tr>
<tr>
<td>Symptoms and signs terminating exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extreme fatigue</td>
<td>7 (33%)</td>
<td>14 (67%)*</td>
<td>41 (48%)</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>8 (38%)</td>
<td>2 (10%)*</td>
<td>10 (12%)</td>
</tr>
<tr>
<td>Serious arrhythmia</td>
<td>1 (5%)</td>
<td>0</td>
<td>3 (4%)</td>
</tr>
</tbody>
</table>

* p<0.05 as compared with exercise testing before surgery.
Values are mean±SD or number of patients (%),
# Patients who did not undergo the pre-operative exercise tolerance test are included.
Max. = Maximal, Ex. = Exercise

promote an earlier return to normal life, we
have been conducting physical training pro-
grams since 1961. The present report de-
scribes our experience, and sets out the
necessity, methodology and clinical benefits
of our programs.

SUBJECTS AND METHOD

Study patients
The subjects consisted of 85 patients with
valvular heart disease who underwent valvu-
lar heart surgery. There 42 men and 43
women with an average age of 48±10 years.
Preoperative diagnosis were mitral stenosis
(MS) in 31 patients, mitral regurgitation
(MR) in 11, MS+MR in 3, aortic stenosis
(AS) in 3, aortic regurgitation (AR) in 5,
AS+AR in 6, MS+ASR in 23, and MR+
ASR in 3. Open mitral commissurotomy
(OMC) was performed in 9 patients, mitral
valve replacement (MVR) in 41 patients,
aortic valve replacement (AVR) in 13 pa-
tients, double valve replacement (DVR) in
18, and OMC+AVR in 4. Thirty five pa-
tients had sinus rhythm, while the other 50
presented atrial fibrillation. Patients having
symptoms and signs of overt congestive heart
failure, inflammation, dysfunction in the
lung, liver, or kidney were excluded from

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Fig. 2. Changes in maximal oxygen uptake after training in program A (left) and B (right). Both programs increased maximal oxygen uptake to a comparable degree.

Program A

Program B

Fig. 3. Self-assessment of the patients for the two programs.

The control subjects were 9 patients who did not receive exercise prescription because of the development of post-transfusion liver dysfunction after having undergone the initial exercise stress test at around 50 days postoperatively. They consisted of 4 men and 5 women with an average age of 49 ± 5 years. Preoperative diagnoses were MS in 4 patients, MR in one, AR in one, and MS + AR in 3. OMC was performed in one, MVR in 4, AVR in one, and DVR in 3. Three patients had sinus rhythm, while 6 presented atrial fibrillation. These control patients were allowed to move about freely in the ward, although they did not receive any special exercise prescription.

Exercise stress test

Multi-stage, symptom-limited exercise stress testing was performed in the sitting position by using an electrically-braked bicycle ergometer. Exercise began at a 25 watts work-load and was increased by 25 watts every min stepwisely. Exercise was terminated when patients complained of symptoms such as chest pain, dyspnea or extreme fatigue, or developed severe arrhythmias, a fall in systolic blood pressure of more than 20 mmHg or ST depression of more than 2 mm, or when they attained a target heart rate (85% of age-predicted maximal heart rate). The initial exercise test was performed one month or more after surgery (mean 53 days) to avoid the direct effects of the surgery and a similar test was repeated after training. In 21 patients, the exercise test was additionally performed before surgery.

Training protocol

Two training programs were used in the present study (Fig. 1). Program A was of short-duration (6 min) and performed frequently involving 6 min of exercise twice every day. Program B prescribed a longer duration and less frequent training (24 min of exercise every other day). In both programs A and B, every 3 min of exercise was interposed with one minute of resting, and they were carried out using a bicycle set at an intensity of 70% of the maximal oxygen uptake determined by the initial exercise test. The total exercise duration was 72 min per week in both programs. Both training were performed in the ward under the super-
TABLE II  EFFECTS OF PHYSICAL TRAINING ON EXERCISE CAPACITY

<table>
<thead>
<tr>
<th></th>
<th>Training group (n: 62)</th>
<th>Control group (n: 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Second</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rest 82±13</td>
<td>80±12</td>
</tr>
<tr>
<td></td>
<td>max. 139±23</td>
<td>146±20**</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rest 123±17</td>
<td>123±18#</td>
</tr>
<tr>
<td></td>
<td>max. 166±23</td>
<td>170±25#</td>
</tr>
<tr>
<td>Max. RPP (\times 10^2)</td>
<td>230±54</td>
<td>246±51**</td>
</tr>
<tr>
<td>Max. (\dot{V}O_2) (ml/min/kg)</td>
<td>18.2±3.5</td>
<td>20.7±4.1*</td>
</tr>
<tr>
<td>Max. work load (watts)</td>
<td>61±20</td>
<td>72±23* #</td>
</tr>
</tbody>
</table>

*: p<0.05, **p<0.01 as compared with initial test,
#: p<0.05 as compared with control group,
RPP = rate pressure product, Max. = Maximal

Fig.4. Relationship between oxygen uptake and heart rate before and after exercise training. Each line connects values at rest and peak exercise respectively. Exercise training increased maximal oxygen uptake and maximal heart rate (left), showing a right-downward shift of the line. There was neither increase in maximal oxygen uptake nor increase in maximal heart rate (right).

vision of a physician. Exercise stress testing was repeated after a 4 week interval to determine the efficacy of training. Self-assessment of the programs was done by patients using a questionnaire.

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### TABLE III RELATIONSHIP BETWEEN CLINICAL PROFILE AND EFFECTS OF PHYSICAL TRAINING

<table>
<thead>
<tr>
<th></th>
<th>Poor improvement group</th>
<th>Improvement group</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of patients</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male/female</td>
<td>28/15 (13)</td>
<td>48/23 (25)</td>
<td></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>49.4±9.6</td>
<td>47.8±10.1</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Duration of disease (years)</strong></td>
<td>6.4±5.8</td>
<td>5.7±8.1</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Atrial fibrillation</strong></td>
<td>21 (75%)</td>
<td>24 (50%)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td><strong>CTR (%)</strong></td>
<td>58.5±4.3</td>
<td>54.6±3.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Patients with CTR ≥60%</strong></td>
<td>16 (57%)</td>
<td>3 (6%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Initial exercise test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Max. oxygen uptake (ml/kg/min)</strong></td>
<td>18.6±3.9</td>
<td>18.2±3.5</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Exercise-induced ST depression</strong></td>
<td>13 (46%)</td>
<td>3 (6%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are mean±SD or number of patients (%).
†Poor improvement group: patients who increased the maximal oxygen uptake by less than 10% after exercise training.
‡Improvement group: patients who increased the maximal oxygen uptake by 10% or more after exercise training.

**Statistical analysis**

Values are presented as mean±SD. Student’s t-test for paired observations was used for comparison of the data before and after surgery and for before and after training. Comparisons between groups were performed by the unpaired t-test or chi-square analysis. Statistical significance was determined at p value <0.05.

**RESULTS**

(1) Effects of valvular surgery on exercise capacity (Table I).

In 21 patients who underwent the preoperative exercise stress test, the corrective valvular surgery increased the mean maximal oxygen uptake from 15.4 to 18.9 ml/min/kg. The percentage of patients who terminated exercise by developing cardiac symptoms and signs decreased from 43% to 10%. Nevertheless, the maximal oxygen uptake was 5 METs or less in 52% of patients in the initial postoperative exercise test. The percentage of those with impaired exercise tolerance before training was similar (58%) in the total 85 patients of the present study. These observations suggested that direct return to work without exercise training might be difficult in more than half of the postoperative patients.

(2) Comparison of program A and program B

To compare the usefulness of program A and B, 18 patients were randomly allocated to program A and 14 patients to program B. Both programs increased maximal oxygen uptake to a comparable degree; from 18.2 to 20.6 ml/min/kg in program A and from 17.8 to 20.4 ml/min/kg in program B (Fig. 2). In the self-assessment by the patients using a questionnaire, 83% of patients said program A was satisfying. In contrast, program B was satisfying in only 14%, with the remaining patients complaining of discontent (42%) or fatigue (36%), as shown in Fig. 3.

(3) Effects of physical training

Based on the above results, program A
was then performed by 62 patients, and the effects of the physical training were assessed by comparing them with those in 9 control patients who did not receive any exercise prescription. The training and control groups did not differ in their baseline profiles, including age, frequency of atrial fibrillation, cardiothoracic ratio, and surgical procedures. The two groups underwent the initial exercise test at a comparable time after surgery and gave similar results in maximal heart rate, maximal oxygen uptake, and in symptoms at peak exercise (Table II). After physical training, the resting heart rate tended to decrease while peak exercise heart rate increased significantly. Maximal oxygen uptake also significantly increased from 18.2 to 20.7 ml/min/kg. Thus the line representing the correlation between the oxygen uptake and the heart rate showed a rightward shift after training and the heart rate at the same level of oxygen uptake tended to decrease in the training group (Fig. 4). Seventy-four percent of patients attained exercise capacity of 5 METs or more which allowed return to work. No complications were observed during the physical training. On the other hand, no significant changes in exercise capacity were observed in the control group on the second exercise test performed 3-17 weeks after the initial test.

(4) Factors inhibiting the effects of physical training

Of 76 patients in the training groups using either of the two programs, 28 patients (35%) failed to increase the maximal oxygen uptake by 10% or more after the training. These were designated as the "poor improvement group". In an attempt to determine factors that might inhibit the effects of physical training, the clinical characteristics of the poor improvement group were compared with those of the 48 patients who showed an increased maximal oxygen uptake of 10% or more: the "improvement group" (Table III). The two groups did not differ in age or interval between the onset of cardiac symptoms and surgery. However, the percentage of patients with atrial fibrillation and of those with a cardiothoracic ratio of 60% or more, were significantly higher in the poor improvement group. The maximal oxygen uptake at the initial postoperative exercise test did not differ between the two groups, while the exercise-induced ST depression was more frequently noted (46% vs 6%) in the poor improvement group.

DISCUSSION

Surgical intervention for valvular heart disease is an established therapeutic modality to correct cardiac function. However, improvement in exercise capacity sufficient to permit normal daily activities or return to work may not always be achieved shortly after surgery. This may be due to a structural change in the heart, such as hypertrophy or dilatation, that may be difficult to regress rapidly after corrective valvular surgery, thus preventing improvement in the cardiac function. Some patients could have irreversible myocardial dysfunction. Additionally, the majority of patients undergoing heart surgery has been required to take bed rest prior to and after operation, which could result in neuro-hormonal dysfunction. Long-term congestive heart failure could lead to atrophy in the working skeletal muscles due to disturbed perfusion and malnutrition. Surgical intervention further ameliorates the overall general condition and nutrition. The deconditioning of the working skeletal muscles and the neuro-hormonal system from these factors would be an additional and important mechanism for decreased exercise capacity in the early phase after valvular surgery. In the present study, exercise capacity significantly improved after surgery, while the increase was not sufficient for daily activities or a return to work in 58% of patients, with exercise capacity remaining at 5 METs or less. This supports the need for physical training in patients after valvular heart surgery aiming to improve their physical capacity.

Nevertheless there has been no established exercise prescription for patients with valvular heart disease after surgery. For physical training of patients with coronary artery disease, exercise programs involving 20-30 min of exercise at an intensity of about 70% of the maximal exercise capacity 3-4 times weekly have been generally recommended. Since the program usually requires specific facilities and instruments which are not readily available in Japan, we have alterna-
tively proposed a short-duration frequent training program using a two-step exercise and have reported the effectiveness and safety of this program in patients with coronary artery disease. In the present study, we examined two exercise programs: one of short duration (6 min) and greater frequency (twice every day), and the other of longer duration (24 min) and less frequency (every other day). Both programs employed bicycle exercise training set at an intensity of 70% of the maximal oxygen uptake. While the maximal oxygen uptake similarly increased in both programs, program A appeared to be preferred from the self-assessments of the patients. This would imply that patients shortly after valvular heart surgery could not tolerate well exercises of longer duration because of deconditioning of the working skeletal muscles. We would therefore suggest that a training program of short duration and greater frequency is better suited for the rehabilitation of patients shortly after valvular heart surgery.

Physical training using program A was then conducted on an additional 62 patients. The training increased maximal work load by 16% and maximal oxygen uptake by 14%. The heart rate at rest or at the same rate-pressure-product (RPP) level during exercise tended to decrease, while peak heart rate and RPP increased significantly after training. Seventy-four percent of these patients attained exercise capacity of 5 METs or more which permitted their return to work. In contrast, the control subjects did not present any improvement in exercise capacity. Although they were suffering from liver dysfunction and thus were not randomly selected, the results suggested that their spontaneous improvement in exercise capacity after surgery occurred only very slowly. These observations therefore suggested that physical training after valvular heart surgery is useful in improving both the cardiac function and capacity of working skeletal muscle during exercise. Newell et al and Sire et al have performed physical training for patients after aortic valve replacement and have demonstrated that the training was effective for improvement in exercise capacity and an earlier return to work. In their control subjects, spontaneous improvement of exercise capacity was minimal. Their findings are thus largely consistent with the present observations that physical training could effectively improve exercise capacity and promote an earlier return to work in patients after valvular heart surgery.

It was of note, however, that physical training was less effective in 35% of the postoperative patients in the present study involving 76 patients with program A or B. These patients with poor improvement presented higher frequencies of atrial fibrillation, enlarged cardiothoracic ratio ≥ 60% and an exercise-induced ST depression on baseline examinations. A large cardiac volume and atrial fibrillation may indicate residual cardiac dysfunction after surgery. Although the mechanism for exercise-induced ST depression in patients with valvular heart disease remains ill-defined, Takahashi from our laboratory has suggested that this could be a sign indicating deterioration in the cardiac function during exercise. Patients with poor improvement could thus be regarded as those who could not attain an adequate improvement in the cardiac function through surgery. These observations suggest that patients with persistent cardiac dysfunction after surgery might benefit little from physical training. This does not imply, however, that physical training is always contraindicated in these patients with cardiac dysfunction, since no serious complications developed even in these in the present study. In an effort to attain maximal rehabilitation for patients after surgery, we have been assessing physical training to these patients with cardiac dysfunction by using a less strenuous exercise with intensive caution in case of development of heart failure or serious arrhythmia.

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