EFFECT OF ISOMETRIC HANDGRIP EXERCISE ON LEFT VENTRICULAR FUNCTION IN THE PATIENT WITH ARTIFICIAL CARDIAC PACEMAKER

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The cardiovascular effects of isometric handgrip exercise were determined with a noninvasive method in the patient with artificial pacemaker. The arterial blood pressure was measured with mercury manometer as well as cardiac output by the dye dilution method with Indocyanin green before and after handgrip exercise.

Isometric handgrip exercise produced a significant increase in the left ventricular ejection time, the left ventricular ejection time/the prejection period, the ejection time index/the isometric contraction time, the arterial blood pressure and cardiac output and a significant decrease in the prejection time and the isometric contraction time.

Cardiac output was increased more remarkably in the negative Master two step test group than in the positive Master two step test group.

There was found a significant positive relationship between the increase in cardiac output and P wave rate upon handgrip exercise.

ELECTRIC pacing of the heart has been employed increasingly in the treatment of serious bradyarrhythmia during past 10 years, and therefore so many patients have been rehabilitated to social work after artificial pacemaker implantation.

The pacemaker which has been commonly employed is constant rate type which can not regulate the pulse rate of the patient on exercise.

The response of the cardiovascular system upon exercise in the patient with artificial pacemaker has been scarcely studied up to this time.

This study was performed to determine the effect of exercise on the left ventricular performance in the patient with artificial pacemaker by using noninvasive techniques.

MATERIAL AND METHOD

Twenty patients who have been completely paced by demand pacemaker using a monopolar or bipolar endocardial electrode were subjected to this study. Clinical data of those patients are shown in Table I.

The determination of the left ventricular systolic time intervals was performed with the patient in supine position, and included lead II of the electrocardiogram, the carotid pulse tracing (TY303, UA110, Fukuda, Japan) and the phonocardiogram taken with microphone (MA250,

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TABLE 1 CLASSIFICATION OF 20 PATIENTS

<table>
<thead>
<tr>
<th>Age</th>
<th>16–80 years (average 63)</th>
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</thead>
<tbody>
<tr>
<td>ECG findings</td>
<td></td>
</tr>
<tr>
<td>A-V block</td>
<td>10 cases</td>
</tr>
<tr>
<td>SSS</td>
<td>6 cases</td>
</tr>
<tr>
<td>AF &amp; bradycardia</td>
<td>4 cases</td>
</tr>
<tr>
<td>Master +</td>
<td>5 cases</td>
</tr>
<tr>
<td>Master −</td>
<td>15 cases</td>
</tr>
</tbody>
</table>

A-V = atrioventricular
SSS = sick sinus syndrome
AF = atrial fibrillation
Master + = positive Master two step test
Master − = negative Master two step test

UA310, Fukuda, Japan) applied at the near apex.

The tracing were recorded simultaneously
with mingogram (800, ET10, 10301D01, Elema-
Schoenander, Salva, Sweden) at the paper speed
of 100 mm/sec prior to and after isometric hand-
grip exercise. After control data was obtained at
rest, each patient was asked to squeeze a hand
dynamometer for 3 minutes at one third of the
predetermined maximum. At the end of the 3
minutes squeezing, the mechanocardiogram was
recorded and arterial blood pressure (BP) was
measured with mercury manometer at the fore-
arm. Cardiac output was also determined by
using the dye dilution technique of Indocyanine
green with earpease densitometer (DCR701,
Waters Instruments INC., USA) before and after
handgrip exercise.

The following phases of cardiac cycle were
measured; the left ventricular ejection time (ET)
as the interval from the beginning of the up-
stroke to the incisura of the external carotid
pulse tracing, the Q-S_H interval (Q-S_H) as the
interval from the beginning of the Q wave to the
first major vibration of the second sound.

The preejection period (PEP) was calculated
by subtracting ET from Q-S_H, the isometric con-
traction time (ICT) was derived by subtracting
ET from S_T-S_H interval and Q-S_H interval derived
by subtracting S_T-S_H from Q-S_H. The ejection
time index (ETi) was calculated as follows; ETi
for male = 1.7 x heart rate + ET and ETi for
female = 1.6 x heart rate + ET. In the patient
with remarkable P wave, those values were
obtained as an average random cardiac cycles with
the antecedent PR interval of 150 – 250 msec,
while in the patient without P wave the values
were obtained as an average of consecutive 10
cardiac cycles. Successively subjects were devided
into two groups, one group with negative Master
two step test and another group with positive
Master two step test. A comparative study was
made on the above mentioned measurements in
these two groups.

RESULTS

Changes in the left ventricular systolic time
intervals after handgrip exercise are shown in
Figure 1.

The ET before exercise was varied from 220
to 348 msec with an average of 263.5 msec. It
prolonged in all cases after the handgrip exercise
and its average reached to 276.5 msec (p < 0.05).
The PEP before exercise was varied from 115
to 185 msec with an average of 164.5 msec,
which decreased to 150.0 msec upon handgrip
exercise (p < 0.05). There was not observed any
relationship between changes in the ET and the
PEP upon exercise.

The ICT was varied from 30 to 70 msec with
an average of 51.0 msec, which decreased to 42.8
msec upon handgrip exercise (p < 0.05).

An average of the Q-S_H was 118.3 msec at rest
and decreased to 108.0 msec upon handgrip
exercise (p < 0.05). There was not observed
significant changes in Q-S_H upon handgrip
exercise.

The ET/PEP and the ETi/ICT decreased upon
handgrip exercise as shown in Figure 1.

The mean arterial blood pressure changed
from 94.6 mmHg to 111.5 mmHg upon handgrip
exercise (p < 0.05).

Cardiac output which was measured in 16
cases varied from 2.1 to 5.0 L/min with an aver-
age of 3.35 L/min at rest, which increased to

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3.96 L/min upon handgrip exercise (p < 0.05).

There was found a significant relationship between the changes in BP and cardiac output upon handgrip exercise, while there was not found any relationship between the changes in the cardiac output and the changes in ET, PEP, ET/PEP or ETi/ICT.

There was not observed any relationship between the patient's age and the changes in ET or PEP.

The average of % changes in ET, PEP, ETi/ICT, BP and cardiac output in the group of atrioventricular block (A-V block), sick sinus syndrome (SSS) and atrial fibrillation are shown in Figure
Fig. 2. Mean arterial blood pressure and cardiac output at rest and after handgrip exercise. 
Φ = mean ± standard error of the mean value.

Fig. 3. Relationship between % change in cardiac output and mean arterial blood pressure induced by handgrip exercise.

4. An increase in ET/ICT of the patient with SSS was most prominent among three groups, while there was not observed any significant difference in the other measurements.

The average of ET, PEP, ETi/ICT, BP and cardiac output in both groups of positive and negative Master two step test are shown in Figure 5. There was not found any significant difference in the changes in ET, PEP, ETi/ICT or BP, while there was observed definite difference of cardiac output between the two groups, namely, the rate of increase in cardiac output was 22.3% in the negative Master two step test group and 12.6% in the positive Master two step test group.

In the patient with marked P wave, there was found a significant relationship between the increase in cardiac output and P wave rate upon handgrip exercise. (Figure 6)

DISCUSSION

A great number of patients with bradyarrhythmia associated with Adams-Stokes syndrome have been treated increasingly with artificial pacemaker which has shown a dramatic effect.

It is well recognized that the patient with arti-
Fig. 4. The % changes in left ventricular ejection time (ET), pre-ejection period (PEP), ejection time/ isometric contraction time (ET/ICT), arterial blood pressure and cardiac output after hand-grip exercise in atrioventricular block (A-V block), sick sinus syndrome (SSS), atrial fibrillation (AF) and bradycardia.

Fig. 5. The % changes in left ventricular ejection time (ET), pre-ejection period (PEP), ejection time/ isometric contraction time (ET/ICT), arterial blood pressure and cardiac output after hand-grip exercise in the positive Master two step test (Master +) and the negative Master two step test (Master −) groups.

A medical pacemaker is able to tolerate moderate exercise even though his heart rate does not increase even during exercise. In the normal subjects, the cardiac output is increased by the increased heart rate during exercise, while there is no change in the pulse rate in those with artificial pacemaker.

Now, it is necessary to evaluate cardiac performance during exercise in the patient with artificial pacemaker besides estimation of the effect of life prolongation and prevention of Adams-Stokes syndrome by artificial pacemaker.

Recently, it has been found that sustained handgrip exercise is a valuable new stress test and also described that sustained isometric contraction of the flexor muscle of the forearm produced an increase in heart rate, arterial blood pressure and cardiac output and augmented myocardial contractility. Kovowitz and Jacobs reported that handgrip exercise were
valuable for the evaluation of reserve of cardiac performance in the patient with heart disease.

A noninvasive technique of the measurement of the left ventricular systolic time intervals has been employed lately for the evaluation of left ventricular function. Since Lind demonstrated that the ET/ICT after exercise correlated with the ejection fraction, the ET/ICT was considered as a good indicator of myocardial contractility.

Arrow and his associates demonstrated that ITT decreased and ET/ICT increased upon exercise in the normal subjects by external measurements. Pigott and Whittsett said that these changes might be attributed partly to increased adrenergic activity upon exercise.

This study was performed to see cardiac performance during exercise in the patient with artificial pacemaker using a noninvasive technique, mechanocardiogram. It was found that the ET prolonged and the PEP shortened after handgrip exercise, and that the ET/PEP, ET/ICT also increased upon handgrip exercise in the patient with artificial pacemaker. It means that contractile force of the heart increased upon handgrip exercise in the patient with artificial pacemaker.

Weissler and his associates described that an increase in ET and a decrease in PEP means an increase in stroke volume, while there was not found any significant relationship between the changes in cardiac output and the changes in the ET and PEP in this study.

In the normal subject, the cardiac output was increased mainly by an increase in the heart rate during exercise, while in the patient with artificial pacemaker, cardiac output might be increased as the result of an increase in the stroke volume upon exercise, because the heart rate does not increase upon exercise in them.

Sowton described that cardiac output increased by three times of that at rest during bicycle ergometer exercise in the patient with artificial pacemaker.

In this study, cardiac output increased by 17.6% of the control value upon handgrip exercise. An increase in cardiac output might be produced mainly by augmentation of the myocardial contraction and an increase in stroke volume.

There was also observed increased P wave rate upon handgrip exercise and positive correlation between the increase in P wave rate and cardiac output.

In the previous papers, it was described that properly timed atrial contraction made an important contribution to the enhancement of stroke volume. Upon exercise, frequency of properly timed atrial contraction increases and increased rate of properly timed atrial contraction might contribute to an increase in cardiac output in a part at exercise.

The patient with transvenous implantable artificial pacemaker shows commonly heart beat with left bundle branch block, and, therefore, original diagnostic criteria of Master two step test could not be indicated to the patient with artificial pacemaker. Cooksey and his associates established the diagnostic criteria of Master two step test in the patient with bundle branch block as positive in the case showing depression greater than 1.5 mm of the ST-T segment upon Master two step test.

In this series, the negative Master two step test group showed an increase in cardiac output by two times of that in the positive group upon handgrip exercise. This findings mean that the negative Master two step test group had a larger capacity of the cardiac function than the positive group and moreover that Master two step test might give a good information for decision of the grade of daily work. So it is understood that Master two step test is essential check procedure of the left ventricular performance before recovery to social work after pacemaker implantation.

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