CLINICAL SIGNIFICANCE OF EXERCISE-INDUCED ST CHANGES IN PATIENTS WITH PRIOR MYOCARDIAL INFARCTION

Comparison of Electrocardiographic and Angiographic Findings

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In order to investigate the clinical significance of exercise-induced ST changes in patients with prior myocardial infarction, we performed an exercise tolerance test using bicycle ergometer, coronary arteriography and left ventriculography in 77 patients with prior myocardial infarction and compared exercise-induced ST changes with coronary arteriographic and left ventriculographic findings. At end-point time in the exercise test, we observed abnormal ST elevation in 36 patients (46.7%), ST depression in 11 (14.3%) and no significant ST changes in the remaining 30 (39.0%).

After exercise, 29 out of 48 patients (60.4%) with prior anterior myocardial infarction had significant ST elevation, 9 (18.8%) had ST depression, and 10 patients (20.8%) had no significant ST changes. Of the 29 patients with exercise-induced ST elevation, 26 (89.6%) had no significant coronary lesion or simply had single vessel disease, and 6 of 9 patients with ST depression (66.7%) had multiple vessel disease. Furthermore, 18 of 29 patients with exercise-induced ST elevation (62.1%) had dyskinesia, 8 (27.6%) had akinesia and only 3 (10.3%) had hypokinesia. On the other hand, only 2 of 9 patients with exercise-induced ST depression (22.2%) had dyskinesia, 5 had akinesia, and 2 had hypokinesia.

Only 7 out of 29 patients (24.1%) with prior inferior myocardial infarction had ST elevation, 2 (6.9%) had ST depression, and no significant ST changes were observed in the remaining 20 (69.0%). No significant correlation was obtained between exercise-induced ST changes and coronary arteriographic and left ventriculographic findings.

These findings strongly suggest that exercise-induced ST elevation is commonly observed in patients with anterior myocardial infarction and correlated with the severity of abnormal left ventricular wall movement, and ST depression is related with the extent of coronary artery lesion.

Key Words:

Myocardial infarction
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ALTHOUGH exercise test in patients with prior myocardial infarction has been widely performed for evaluating the degree of physical activity and for predicting occurrence of arrhythmias during exercise and the prognosis of the

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patients,¹⁻⁶ only a few reports concerning the significance of ST changes during exercise were found in the literature.

In this study we attempted to assess the ST segment response to exercise, and compared it with the coronary arteriographic and left ventriculographic findings and elucidated the clinical significance of ST changes during exercise in patients with prior myocardial infarction.

MATERIALS AND METHODS

Patients

Seventy-seven patients, 67 men and 10 women with a mean age of 56.4 years (range 27 to 70) were studied. All patients had a single transmural myocardial infarction documented by history, serial electrocardiographic changes and characteristic serum enzyme changes. Forty-eight patients had anterior myocardial infarction and 29 patients inferior infarction. All patients underwent an exercise test using bicycle ergometer, coronary arteriography and left ventriculography from about two months after infarction.

Bicycle Ergometer Exercise Test

The patients were examined in fasting state and all medications were removed at least for 24 hours before the test. After resting 12-lead electrocardiogram was recorded, exercise test using bicycle ergometer started in supine position. Precordial leads (V₄₋₆) were monitored continuously for subsequent analysis. A standard 12-lead electrocardiogram was recorded at 3 minutes intervals during and after exercise. Blood pressure was measured with a cuff around the upper arm at rest and every one minute during and after exercise. Initial work load was 150 kpm/min and work load was increased by 150 kpm/min every 3 minutes. Exercise test was discontinued by the monitoring physicians when dyspnea, typical angina pectoris, leg fatigue precluded further exercise, or marked elevation of blood pressure occurred.

In this study, we analyzed ST segment changes in leads I, aV_L, V₁₋₆ in anterior infarction and II, III, aV_F in inferior infarction. A significant ST segment changes were defined by either 1 mm or more horizontal or down-sloping depression or elevation in precordial leads and 0.5 mm or more in limb leads with duration of at least 0.08 sec. The isoelectric point was taken as the junction of the PR segment with QRS complex.

TABLE I THE CAUSES OF DISCONTINUATION OF EXERCISE

<i>Causes of discontinuation of exercise</i>	<i>No. of Patients</i>
<i>Leg fatigue</i>	40
<i>Chest pain</i>	10
<i>Dyspnea</i>	2
<i>Extreme elevation of blood pressure</i>	9
<i>Extreme increase in heart rate</i>	13
<i>Arrhythmia</i>	3

In all patients, we quantified the work load during exercise as effort tolerance and calculated the product of heart rate and systolic blood pressure both at rest and at the end-point of the exercise test.

Cardiac Catheterization

Left and right heart catheterization and selective coronary arteriography were performed using Judkins technique. Coronary angiography was performed on 35 mm film with multiple views. Each coronary arteriogram was interpreted by two observers without knowledge of the results of the bicycle exercise test. A stenosis of 75% or more coronary artery was defined as significant narrowing. Left ventriculography was performed both in 30° right anterior oblique view and in 60° left anterior oblique view. Abnormalities of regional left ventricular wall movement was defined by the classification of Herman's criteria.⁷

Statistics

Student's *t* test was used to assess the differences between means of independent observations. The chi-square test was also used to assess the differences in proportions. The threshold of significance was $p < 0.05$.

RESULTS

Exercise Electrocardiographic Responses

The causes of stopping exercise test are described in Table I. Ten out of 77 patients (13.0%) stopped exercise test due to the appearance of anginal pain. The ST segment changes induced by exercise are also shown in Table II. ST elevation at the end of exercise test was observed in 36 patients (46.7%), ST depression in 11 (14.3%) and no significant ST change was observed in the

TABLE II EXERCISE-INDUCED ST CHANGES IN 77 PATIENTS WITH PRIOR MYOCARDIAL INFARCTION (No. of patients)

Infarct Site	ST elevation	ST depression	No change	Total
Anterior	29 (60.4)	9 (18.8)	10 (20.8)	48 (100.0)
Inferior	7 (24.1)	2 (6.9)	20 (69.0)	29 (100.0)
Total	36 (46.7)	11 (14.3)	30 (39.0)	77 (100.0)

The percentage is shown in the parenthesis.

TABLE III EXERCISE-INDUCED ST CHANGES IN 10 PATIENTS WHO HAD ANGINAL PAIN AT THE END-POINT OF EXERCISE

Infarct Site	ST elevation	ST depression	No change	Total
Anterior	0	5	1	6
Inferior	0	1	3	4

remaining 30 (39.0%).

Of 48 patients with prior anterior myocardial infarction, 29 patients (60.4%) exhibited significant ST elevation after exercise, 9 patients (18.8%) had ST depression and 10 (20.8%) had no significant ST changes. On the other hand, only 7 out of 29 patients with prior inferior infarction (24.1%) showed ST elevation, 2 (6.9%) had ST depression and 20 (69.0%) had no significant ST change at the end of exercise. Thus, exercise-induced ST elevation was more commonly observed in patients with prior anterior myocardial infarction than in those with inferior myocardial infarction ($p < 0.001$). Furthermore, among 10 patients who had chest pain during exercise test, no patient had ST elevation, 6 had ST depression and 4 had no significant ST change (Table III).

ST Change and Effort Tolerance

Exercise-induced ST changes and work load at the end of exercise test are summarized in Table IV. Work load at the end of exercise test was 433.9 ± 27.6 (mean $\pm$ SE, kpm/min) in 36 patients with exercise-induced ST elevation, 383.3 ± 53.6 in 11 patients with ST depression, and 375.0 ± 58.9 in 30 patients without significant ST change during exercise. Thus, no significant relationship between ST change and work load was observed.

Table IV also shows the product of heart rate and systolic blood pressure (rate pressure product, RPP) at the end of exercise test. RPP in 36 patients with exercise-induced ST elevation

was 201.0 ± 9.9 ($\times 10^2$, mean $\pm$ SE), 209.0 ± 21.5 in 11 patients with ST depression and 199.0 ± 19.7 in 30 patients without ST changes during exercise test. No significant relationship between exercise-induced ST change and RPP, was also observed.

Correlation of Exercise Test with Coronary Arteriographic Findings

1) Anterior Myocardial Infarction

Twenty-six out of 29 patients with exercise-induced ST elevation (89.6%) had no significant coronary artery lesion or simply had single vessel disease, and only 3 patients (10.3%) had multiple vessel disease, and only 3 patients (10.3%) had multiple vessel disease (Table V). Thus, ST elevation was more common in patients with no significant coronary artery lesion or with single vessel disease than in those with multiple vessel disease ($p < 0.01$). On the other hand, 6 out of 9 patients with ST depression (66.7%) had multiple vessel disease and the remaining 3 (33.3%) had no significant coronary lesion or had single vessel disease only.

2) Inferior Myocardial Infarction

Of 7 patients with exercise-induced ST elevation, 4 (57.1%) had single coronary artery disease, and 3 had multiple vessel disease. Of 2 patients with exercise-induced ST depression, one had single vessel disease and another had multiple vessel disease.

Correlation of Exercise Test with Left Ventricular Wall Movement

TABLE IV EXERCISE-INDUCED ST CHANGES, AND EFFORT TOLERANCE AND THE PRODUCT OF HEART RATE AND SYSTOLIC BLOOD PRESSURE (RPP) AT THE END-POINT OF EXERCISE (mean $\pm$ SE)

	ST elevation (36 patients)	ST depression (11 patients)	No change (30 patients)
Effort Tolerance (kpm/min)	433.9 $\pm$ 27.6	383.3 $\pm$ 53.7	375.0 $\pm$ 58.9
RPP ($\times 10^2$)	201.0 $\pm$ 9.9	209.0 $\pm$ 21.5	199.0 $\pm$ 19.7
(mean $\pm$ SE)			

TABLE V EXERCISE-INDUCED ST CHANGES AND CORONARY ARTERY LESION (No. of patients)

		OVD	SVD	MVD	Total
Anterior	ST elevation	5 (17.2)	21 (72.4)	3 (10.3)	29 (100.0)
	ST depression	1 (11.1)	2 (22.2)	6 (66.7)	9 (100.0)
	No change	3 (30.0)	6 (60.0)	1 (10.0)	10 (100.0)
Inferior	ST elevation	0	4 (57.1)	3 (42.9)	7 (100.0)
	ST depression	0	1 (50.0)	1 (50.0)	2 (100.0)
	No change	3 (15.0)	11 (55.0)	6 (30.0)	20 (100.0)

The percentage is shown in the parenthesis.

Abbreviations: OVD = No significant coronary artery lesion,

SVD = Single vessel disease,

MVD = Multiple vessel disease

TABLE VI EXERCISE-INDUCED ST CHANGES AND LEFT VENTRICULAR WALL MOVEMENT (No. of patients)

		Normal	Hypokinesis	Akinesis	Dyskinesis	Total
Anterior	ST elevation	0	3 (10.3)	8 (27.6)	18 (62.1)	29 (100.0)
	ST depression	0	3 (33.3)	4 (44.4)	2 (22.2)	9 (100.0)
	No change	0	4 (40.0)	3 (30.0)	3 (30.0)	10 (100.0)
Inferior	ST elevation	0	0	5 (71.4)	2 (28.6)	7 (100.0)
	ST depression	0	1 (50.0)	1 (50.0)	0	2 (100.0)
	No change	0	4 (20.0)	13 (65.0)	3 (15.0)	20 (100.0)

The percentage is shown in the parenthesis.

All patients in this study had asynergy (Table VI).

1) Anterior Myocardial Infarction

Among 29 patients with exercise-induced ST elevation, 18 (62.1%) had dyskinesis, 8 (27.6%) had akinesis and only 3 (10.3%) had hypokinesis. On the other hand, only 2 of 9 patients with exercise-induced ST depression (22.2%) had dyskinesis, 4 patients had akinesis, and 3 had hypokinesis. Thus, dyskinesis was more common in patients with ST elevation than in those with ST depression or no significant ST change.

2) Inferior Myocardial Infarction

In 7 patients with exercise-induced ST elevation, 2 had dyskinesis and the remaining 5 had akinesis. In 2 patients with ST depression, one had dyskinesis, and the other had akinesis.

DISCUSSION

Exercise test in patients with prior myocardial infarction has been a useful method for evaluating their physical activity, for predicting the occurrence of arrhythmia at chronic stage, for

obtaining an index of exercise load in rehabilitation program and for predicting the prognosis of those patients!¹⁻⁶

However, the clinical significance of exercise-induced ST change have not yet been agreed among investigators.⁸⁻¹¹ In this study, therefore, we performed exercise test in patients with prior myocardial infarction and compared the exercise-induced ST change with coronary arteriographic and left ventriculographic findings for evaluation of the significance of ST elevation.

Validity of the Method

For the assessment of exercise-induced ST change in patients with prior myocardial infarction, the following factors influencing on the exercise-induced ST change must be considered; 1) intervals between the onset of myocardial infarction and exercise test, 2) the differences in the work load among patients in symptom-limited exercise test, and 3) ECG monitoring system.

1) Intervals between the Onset of Myocardial Infarction and Exercise Test

Atterhög et al!¹² performed exercise test using bicycle ergometer in patients with prior myocardial infarction serially and studied the serial changes of electrocardiographic responses to the exercise test. They observed that the magnitude of ST elevation became smaller when the interval between the onset of myocardial infarction and the exercise test was longer. Thus, it was strongly suggested that the magnitude of ST change might depend on the interval between the onset of infarction and the exercise test.

In this study, exercise test was preformed 2 months after the onset of infarction in all patients. The influence of time interval between the onset of infarction and the exercise test on ST change, can be neglected.

2) Work Load

In our series, no significant differences were obtained in both work load and the rate pressure product (RPP) during exercise test among patients with exercise-induced ST elevation and ST depression, and those without significant ST change (Table IV). Thus, the influence of work load on the exercise-induced ST change can be neglected.

3) Monitoring ECG Leads

A standard 12-lead electrocardiogram was monitored during exercise and post-exercise in this study. And this multiple leads system was more sensitive for detecting ischemic electro-

cardiographic changes in the exercise study than single lead system.^{13,14}

Exercise-induced ST Change and Coronary Artery Disease

Among 36 patients with exercise-induced ST elevation, only 6 (16.7%) had multiple vessel disease and 7 out of 11 patients (63.6%) with exercise-induced ST depression had multiple vessel disease (Table V). Thus, multiple vessel disease was more common in patients with exercise-induced ST depression than in those with exercise-induced ST elevation ($p < 0.01$).

Weiner et al!¹⁵ performed the exercise test using bicycle ergometer or treadmill in 154 patients with single myocardial infarction. They observed that while only 4 patients out of 19 patients (21.1%) with exercise-induced ST elevation had multiple vessel disease, 63 out of 83 patients (75.9%) with exercise-induced ST depression had multiple vessel disease. And this finding agrees with our data.

Miller et al!¹⁶ also performed multiphasic graded exercise test using treadmill in 52 patients with inferior myocardial infarction and suggested that exercise-induced ST depression had correlated with multiple vessel coronary disease. Other investigator also suggested the positive correlation of exercise-induced ST depression and multiple vessel disease!¹⁷ Furthermore the patients who had exercise-induced ST depression were frequently complicated with sudden death and ventricular fibrillation, and prognosis of those patients was worse than that of those without exercise-induced ST depression!¹⁸ In our series, 10 patients stopped exercise test due to chest pain, and 6 patients had ST depression but no patient had ST elevation. And 4 patients had multiple vessel disease. Thus, it is suggested that exercise-induced angina pectoris was closely related to multiple vessel disease.

Exercise-induced ST Change and Left Ventricular Wall Movement

In anterior myocardial infarction, 18 out of 29 patients with exercise-induced ST elevation (62.1%) had dyskinesis, while only two of 9 patients with exercise-induced ST depression (22.2%) had dyskinesis. This finding strongly suggested that the exercise-induced ST elevation was well related with the severity of abnormalities of left ventricular wall movement.

Weiner et al!¹⁵ performed exercise test using bicycle or treadmill in 54 patients with single

myocardial infarction and observed that 30 out of 41 patients who had exercise-induced ST elevation (73.2%) had aneurysm. Paine et al¹⁹ also performed exercise test using treadmill, coronary angiography, and left ventriculography in 100 patients with prior myocardial infarction. Patients with exercise-induced ST elevation had more severe abnormalities in left ventricular wall movement and in lower left ventricular ejection fraction compared with the remaining 86 patients without ST elevation. Other investigators also reported close relationship between the exercise-induced ST elevation and left ventricular aneurysm.^{10,20} Cokkinos et al²¹ analyzed the influence of left ventricular aneurysm on electrocardiographic ST segment elevation and reported that after aneurysmectomy the magnitude of ST elevation became smaller. And this finding also suggests the close relationship between exercise-induced ST elevation and aneurysm.

Anterior Versus Inferior Myocardial Infarction

In this study, exercise-induced ST elevation was more commonly observed in patients with anterior myocardial infarction than in those with inferior infarction. In our series, no significant differences in coronary arteriographic findings were obtained between in patients with anterior infarction and in those with inferior infarction (Table V). On the other hand, the abnormality of left ventricular wall movement in patients with anterior infarction was more severe than in those with inferior infarction (Table VI). And this findings suggested that the difference in electrocardiographic response to exercise in patients with anterior and inferior infarction may be caused from the difference in the left ventricular wall movement.

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