ST Segment Changes Post-Infarction:
Predictive Value for Multivessel Coronary Disease
and Left Ventricular Aneurysm

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SUMMARY To ascertain whether exercise testing might predict multivessel coronary disease and left ventricular aneurysm after a myocardial infarction, 154 patients with a single documented myocardial infarction who had both exercise testing and coronary angiography were grouped according to whether they had $\geq 1$ mm ST depression, $\geq 1$ mm ST elevation, or neither during exercise testing: 83 patients developed ST depression alone (group 1); 22 patients had ST elevation with concomitant ST depression in other leads (group 2); 19 patients had ST elevation alone (group 3); and 30 patients had no ST changes (group 4). Multivessel disease, defined as $\geq 70\%$ luminal narrowing in two or more coronary vessels, was present in 76\% (63 of 83) of group 1, 91\% (20 of 22) of group 2, 21\% (four of 19) of group 3, and 13\% (four of 30) of group 4. A left ventricular aneurysm was present in 31\% (26 of 83) of group 1, 68\% (15 of 22) of group 2, 79\% (15 of 19) of group 3, and 40\% (12 of 30) of group 4. We conclude that ST changes during exercise testing in patients after a myocardial infarction can reliably predict the extent of coronary disease and the presence of a left ventricular aneurysm; ST depression with or without ST elevation predicts multivessel disease; ST elevation alone or a negative exercise test suggests single vessel involvement; and ST elevation with or without ST depression predicts left ventricular aneurysm.

AFTER A MYOCARDIAL INFARCTION, exercise testing is frequently used as a guide to cardiac rehabilitation or to aid in the detection of cardiac arrhythmias. Few studies have correlated the ST segment response on the exercise test post-infarction with catheterization data. In this study, we have analyzed a group of patients with previous myocardial infarction to determine whether specific ST segment responses to exercise could predict subsequent catheterization findings.

Methods

The patient population consisted of 154 consecutive patients who had a single myocardial infarction documented by history, serial electrocardiographic changes, and/or characteristic enzyme changes, and who also underwent an exercise test in conjunction with coronary arteriography and left ventriculography. The patients were studied because of symptoms or to assess prognosis in a time period ranging from two to 36 months after infarction (mean 13.6 months). Graded exercise testing was performed on a bicycle ergometer or treadmill, the latter using the Bruce Protocol. To assure interpretable tracings on each patient, the skin was briskly scrubbed using acetone-soaked gauze in the specific areas where the silver-silver chloride electrodes were to be attached. To further secure the electrodes, Velcro straps were snugly wrapped around the chest and lower abdomen covering the electrodes. A 12-lead electrocardiogram was then recorded using a 3-channel Hewlett Packard machine (HP-1514B) at rest, at 3-minute intervals during exercise, immediately post-exercise, and at 1, 2, 3, 6 and 9 minutes during the recovery period. During the exercise period itself, two leads were simultaneously and continuously monitored. All patients were exercised to an end point consisting of self-limited exhaustion, severe dyspnea, dizziness, moderately severe angina, hypotension, repetitive ventricular arrhythmias or $>4$ mm ST segment depression on the monitoring electrocardiogram. Significant ST segment deviations were interpreted as 1 mm of horizontal or downsloping ST segment depression or $1$ mm of ST segment elevation beyond the isoelectric baseline, lasting for at least 80 msec after the J point, either during exercise, recovery or both. If the resting electrocardiogram already displayed ST segment deviations, an additional 1 mm of ST segment directional change was required. There were 41 patients with baseline ST segment depression and 14 patients with baseline ST segment elevation in the population.

Eliminated from the study were patients with multiple infarctions, those on digitalis, those with valvular heart disease, and those whose resting electrocardiogram showed bundle branch block or ventricular hypertrophy. Patients without exercise-induced ST segment abnormalities who did not achieve 85\% predicted maximal heart rate during exercise were also excluded.

Coronary cineangiography and left ventriculography were performed in all patients, usually the day after the stress test; in no instance were the two studies...
performed more than one month apart. The decision
to perform cardiac catheterization was made before
the exercise test, which was done as part of the routine
evaluation of these patients. The cineangiograms of
each major vessel were reviewed in multiple projec-
tions. Multivessel coronary disease was defined as
present if two observers estimated the luminal diam-
eter narrowing to be greater than 70% in at least two
major coronary vessels. Cineventriculograms in the
right anterior oblique projection were obtained in all
patients, and the majority (72%) had left anterior
oblique view available for analysis as well. Left ven-
tricular aneurysm was defined as a well-demarcated
area of akinesia or dyskinesia that showed loss of the
usual ventricular trabeculation.

Group comparisons were carried out using the chi
square test or analysis of variance followed by
Scheffe's test.

Results

Patient Groups — General Characteristics

The patients were divided into four groups on the
basis of the results of their exercise tests: group 1 con-
sisted of 83 patients who, during exercise testing,
developed ST segment depression alone (fig. 1); group
2 consisted of 22 patients who developed both ST seg-
ment elevation and concomitant ST segment depres-
sion in other leads, excluding lead aVR (fig. 1); group 3
consisted of 19 patients who developed ST segment
elevation alone (fig. 1); and group 4 consisted of 30 pa-
tients who did not develop any significant ST segment
changes at or above 85% maximal predicted heart rate
(fig. 1).

The mean age of the 154 patients was 51.3 years
(range 25–65 years). There were 136 males and 18
females in the group. Anterior wall infarctions had oc-
curred in 85 patients, and 50 of the infarctions were
transmural; inferior wall infarctions had occurred in
69 patients, and 63 of the infarctions were transmural.

Angiographic Correlations

Multivessel coronary disease was observed in 91 of
the patients (59%). When each group was analyzed
separately (fig. 2), multivessel coronary disease was
present in 76% of group 1, 91% of group 2, 21% of
group 3, and 13% of group 4. Thus, ST segment
depression with or without ST elevation (groups 1 and
2) predicted multivessel coronary disease to a
significantly greater degree than ST segment elevation
alone (group 3) or a negative exercise test (group 4).
Moreover, the prevalence of multivessel disease in pa-

tients with exercise-induced ST segment depression
(79%, 83 of 105) was significantly greater ($P < 0.001$)
than in the total population (59%, 91 of 154). Exercise-
induced ST segment depression occurred with similar

![Figure 1](http://circ.ahajournals.org/) Representative examples of the 12-lead rest and exercise electrocardiograms of individual pa-
tients in groups 1–4.
frequencies in both patients with anterior infarctions (65%, 55 of 85) and those with inferior infarctions (72%, 50 of 69).

Ventriculography

Left ventricular aneurysm was present in 31% of group 1, 68% of group 2, 79% of group 3, and 40% of group 4 patients (fig. 3A). Patients were then segregated according to the presence or absence of ST elevation (fig. 3B). Aneurysm was present in 73% of patients with exercise-induced ST segment elevation (groups 2 and 3) but was seen in only 34% in the absence of exercised-induced ST elevation (groups 1 and 4). Thus, exercise-induced ST segment elevation was more highly predictive of a left ventricular aneurysm than was ST segment depression alone or a negative exercise test.

The mean ejection fraction was analyzed in each group and the differences between groups are shown in fig. 4. The mean ejection fraction was significantly lower in the groups showing ST segment elevation

![Figure 2](image1.png)

**Figure 2.** Prevalence of multivessel coronary disease (n = 91) in each patient group (n = 154). *P < 0.001 when compared to either groups 1 or 2.

![Figure 4](image2.png)

**Figure 4.** Mean ejection fraction in each group. *P < 0.05 (Scheffe's procedure) when compared to either groups 2 or 3. **P < 0.05 when compared to group 3.

![Figure 3](image3.png)

**Figure 3.** A) Prevalence of aneurysm (n = 68) in each patient group (n = 154). *P < 0.005 when compared to either groups 2 or 3. **P < 0.025 when compared to group 3. B) Prevalence of aneurysm (n = 68) comparing groups 1 and 4 with groups 2 and 3.
FIGURE 5. Prevalence of chest pain (n = 70) in each patient group (n = 154). *P < 0.005 when compared to either groups 1 or 2.

than in the groups showing either ST segment depression alone or a negative exercise test.

Stress Test Data

Analysis of associated anginal chest pain (of at least grade 2 out of 4 severity) during the exercise test (fig. 5) revealed that patients with ST segment depression had a significantly greater prevalence of exercise-induced anginal chest pain than did patients with ST segment elevation alone or a negative exercise test.

Discussion

The prognosis of patients with coronary artery disease has been shown to correlate with the number of diseased coronary vessels and upon the state of left ventricular function.\textsuperscript{6-10} It is important to identify those patients surviving a myocardial infarction who have multivessel coronary artery disease without left ventricular dysfunction whose prognosis might be improved by coronary bypass grafting.

Many previous studies have indicated that the majority of patients surviving an acute myocardial infarction have diffuse coronary artery disease.\textsuperscript{11-14} However, some patients do not, and our data agree with previous studies\textsuperscript{15-17} in suggesting that the absence of post-infarction ST segment depression on the exercise test is a marker for single vessel coronary artery disease. This finding also is supported by previous studies\textsuperscript{18-20} which found that subsequent coronary events occurred more frequently in patients with exercise-induced ST segment depression after a myocardial infarction, although in none of the latter studies was coronary angiography performed.

The presence of ST segment elevation during the exercise test after an infarction has also previously been correlated with the presence of a left ventricular aneurysm,\textsuperscript{21,22} although these studies used 1-3 lead exercise electrocardiograms and did not comment upon the concomitant appearance of ST segment depression. One previous study has, however, used an exercise protocol similar to ours. Haïat,\textsuperscript{23} using 12-lead exercise electrocardiograms, felt that exercise-induced "pure" ST segment elevation was indicative of localized left ventricular dysfunction; however, exercise-induced ST segment elevation, when accompanied by reciprocal ST segment depression, was more indicative of left ventricular dysfunction and/or myocardial ischemia. He based his conclusion on the higher frequency of associated exercise-induced angina in the latter group, although less than half of his patient population underwent cardiac catheterization. We also found that exercise-induced ST segment elevation alone post-infarction predicted severe segmental myocardial dysfunction, but was rarely associated with multivessel coronary artery disease unless concomitant ST segment depression was also present in other leads on the exercise electrocardiogram.

The value of exercise-induced ST segment elevation for predicting the presence of a left ventricular aneurysm was less for patients with inferior wall infarctions (50%, seven of 14) than with anterior wall infarctions (85%, 23 of 27). Moreover, when an aneurysm was demonstrated, it was localized to the inferior or posterior-basal segment in 86% (six of seven) of patients with inferior ST segment elevations and to the anterior or apical segment in 100% (23 of 23) of patients with anterior ST segment elevations.

Exercise-induced chest pain occurred more frequently in the present study in patients with ST segment depression on the exercise electrocardiogram, implying that active myocardial ischemia was frequently present in the presence of multivessel disease. Exercise-induced chest pain was rarely present in the groups with a high prevalence of single vessel disease post-infarction whether or not an aneurysm was present (groups 3 and 4).

The ejection fraction in patients post-infarction is related to the amount of viable myocardium remaining. As expected, we found that the ejection fraction correlated more closely with the presence of severe segmental left ventricular dysfunction, as predicted by the exercise test, rather than with the presence of multivessel coronary disease. This confirms an earlier study by Gorlin,\textsuperscript{24} who found no statistical correlation between the number of diseased coronary vessels and the ejection fraction.

Possible sources of error in interpretation of the present study should be considered. It is theoretically possible that the presence of a ventricular aneurysm might produce opposing vectorial forces to those resulting from concurrent ischemia in adjacent myocardium, thus leading to cancellation of forces and an isoelectric baseline. This possibility may have been minimized in our study through use of 12-lead exercise electrocardiograms. Moreover, only one of the 33 patients with a negative exercise test in this study had both a ventricular aneurysm and multivessel coronary artery disease.
disease. Thus, it appears that most patients without exercised-induced ST segment changes post-infarction have decreased coronary blood flow only to the area of infarction, without additional areas of ischemia being present.

We also found that, contrary to prior studies, the majority of patients in our series have exercise-induced ST segment changes after a myocardial infarction. Only 19% of patients in this study had a negative exercise test. This may prove helpful in predicting subsequent catheterization findings: exercise-induced ST segment depression predicts multivessel coronary disease; ST segment elevation alone suggests a ventricular aneurysm and single vessel disease; and a negative exercise test is correlated with single vessel coronary disease alone.

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