Detection of Multivessel Coronary Disease After Myocardial Infarction Using Exercise Stress Testing and Multiple ECG Lead Systems

JULIO F. TUBAU, M.D., BERNARD R. CHAITMAN, M.D., MARTIAL G. BOURASSA, M.D., AND DAVID D. WATERS, M.D.

SUMMARY Different exercise ECG lead systems were evaluated for the detection of multivessel coronary disease in 118 male survivors of a transmural myocardial infarction. Patients were classified according to the location of myocardial infarction and angina functional class and test results were correlated with angiographic findings. The ECG criteria for a positive test in any lead were horizontal or downsloping ST-segment depression ≥ 1 mm for 0.08 second, and a slow, upsloping ST segment depressed ≥ 1.5 mm at 0.08 second after the J point compared with the rest tracing.

The sensitivity of the test for multivessel disease was greater using 14 ECG leads (72%) or leads CC4, CM4, and V5 (64%) than lead V4 alone (50%) (p < 0.05). Sensitivity was less when the site of infarction was anterior (64%) vs inferior (77%). The predictive value of a positive test ranged from 50–100% and that of a negative test from 24–80%, depending on angina functional class and lead positivity during exercise. Leads CC4, CM4, and V5 gave data similar to data from 14 ECG leads. The maximum diagnostic value of exercise testing after infarction was for patients in angina class 0 or 1. A positive test in this subset increased the likelihood of multivessel disease from 50–55% to 80–100%, and a negative test reduced the risk of three-vessel disease to less than 10%. In patients with more severe angina, the post-test risk was only slightly more than the prevalence of multivessel disease, and false-negative tests were common. A positive test predicted multivessel disease more frequently when the site of infarction was inferior (89%) than anterior (73%). Exercise-induced chest pain, the number of positive ECG leads, ST-segment elevation, treadmill work time and maximum depth of ST-segment depression provided additional diagnostic information.

We conclude that probability statements for multivessel disease from exercise test results after infarction are most useful in patients with few or no symptoms and that satisfactory results can be obtained by recording leads CC4, CM4, and V5.

THE PROGNOSIS of patients with coronary atherosclerosis is related to the extent of coronary disease and to left ventricular performance.14 Survivors of transmural myocardial infarction are a large, easily defined subgroup with impaired ventricular function and variable prevalence and extent of multivessel disease. The results of exercise testing in patients after infarction have shown that a positive test is associated with a greater likelihood of future coronary events and with multivessel disease.6-8 Probability statements based on exercise test results are influenced by the lead configuration monitored during effort and by the prevalence of coronary or multivessel disease in the population evaluated.10, 11 In the present study, we examined the potential of nine different lead systems to predict multivessel disease in 118 male survivors of a transmural myocardial infarction.

Methods

Patient Material

The study population consisted of 118 men with an isolated transmural myocardial infarction who had a multiple-lead exercise test performed 1 day before a coronary arteriogram. The indication for cardiac catheterization in 68 patients was incapacitating angina pectoris. Fifty patients with mild or no symptoms had cardiac catheterization to determine extent of coronary disease and left ventricular impairment in order to estimate long-term prognosis. Patients over 65 years old or with unstable angina, cardiomyopathy, malignant hypertension or valvular or congenital heart disease were excluded. The diagnosis of myocardial infarction was made from the clinical history and the resting 12-lead ECG. Myocardial infarction was classified using Minnesota code criteria.12, 13 Anterior myocardial infarction was coded when 1) the Q/R ratio was ≥ 1/3 and the Q wave was ≥ 0.03 second in leads V2 to V4, 2) Q waves ≥ 0.04 second present in leads V1 to V4 or 3) a QS pattern present in leads V2 to V4 when an R-wave pattern was present in adjacent precordial leads to the right. Inferior myocardial infarction was coded when 1) the Q/R ratio was ≥ 1/3 and the Q wave was ≥ 0.03 second in lead II and/or 2) Q waves ≥ 0.05 second and ≥ 1 mm in lead III and/or lead aVF. Patients with anterolateral or extensive anterior infarctions (Q waves from V1 to V4) were excluded; exercise testing in this subgroup has been shown to have a low diagnostic yield.9

No clinical history of previous myocardial infarction could be elicited from two patients, but in the remaining 116, a typical clinical history was documented. Of these 116 men, infarction occurred within the year before arteriography in 87 patients and more than 1 year previously in 29. Men with silent in-
farction or a long interval between infarction and sub-
sequent coronary arteriography had clinical elec-
trocardiographic and angiographic features that were
similar to those of the entire group and thus are not
analyzed separately.

The day before coronary arteriography, a complete
description of the patient’s symptoms was recorded by
two physicians. The severity of angina was classified
according to the Canadian Cardiovascular Society
Classification. Briefly, patients in class 0 were
symptom-free; in class 1 patients, angina occurred
only with unusual or major effort; in class 2 and 3
patients, angina occurred with ordinary and mild
effort, respectively. Patients in class 4, whose angina
also occurred at rest, were not exercised.

Other than nitroglycerin, b blockers and other
medications were stopped for at least 2 days before
the test. No patients were taking digitalis prepara-
tions.

Exercise Testing

All patients were exercised using a Bruce protocol
modified by a 3-minute warm-up at 1.7 mph and a 5%
grade. The ECG and blood pressure were recorded at
rest in the sitting and standing positions, at 1-minute
intervals during the test, and at 1-minute intervals for
5 minutes after exercise. Patients were exercised until
exhaustion, severe dyspnea, progressive angina pector-
is, ST-segment depression ≥ 3 mm in an asympto-
tomatic patient or a minimum of 85% of the maximal
age-predicted heart rate was achieved in patients with
a negative test.

A 14-lead ECG system was recorded, which in-
cluded a standard 12-lead ECG (aVR excluded) and
leads CcA, CMs and CL. Siemens’s exercise patient
cable, ECG junction box, and nondisposable elec-
trodes were used in conjunction with a Cambridge
three-channel direct-writing recorder (model 3038).
Technical details relating to the sequence of ECG
recordings and patient position after exercise have
been previously reported.

The ECG criteria for a positive test in any lead were
1) horizontal or downsloping ST-segment depression
≥ 1 mm for 0.08 seconds and 2) a slow, upsloping ST
segment depressed ≥ 1.5 mm at 0.08 second after the
J point in at least three consecutive complexes, com-
pared with the rest tracing. The latter criterion in-
creased the sensitivity for multivessel disease by 5%
without decreasing specificity. ST-segment elevation
≥ 1 mm was analyzed in comparison to the resting
ECG, but was not included in the criteria for a positive
test. When ST-segment elevation or depression was
present on the rest ECG, an additional 1-mm shift in
any lead was considered significant.

Cardiac Catheterization

Selective coronary arteriography was performed using
a percutaneous transfemoral approach and in-
cluded craniocaudal and caudocranial sagittal angula-
tion views of the left coronary artery, as previously
described. A stenosis ≥ 70% of the arterial in-
traluminal diameter was considered significant except
for left main coronary disease, where stenoses ≥ 50%
were considered significant. A proximal stenosis of a
large diagonal or marginal branch was considered as a
stenosis of the left anterior descending or circumflex
coronary arteries, respectively. Multivessel disease
was defined when stenosis ≥ 70% occurred in two or
more vessel systems. Proximal left coronary disease
was considered present when either a stenosis ≥ 50%
of the left main or a stenosis ≥ 70% of the proximal
preseptal left anterior descending coronary arteries
occurred.

The left ventricle was opacified in the 30° right
anterior oblique view. Left ventricular wall motion
was assessed qualitatively by an experienced car-
diovascular radiologist and coded as normal,
hypokinetic and akinetic or dyskinetic. In each case,
the visually assessed left ventricular contraction
pattern was compared with the traced end-diastolic and
end-systolic silhouette using extracardiac reference
points. This technique provides a more reliable assess-
ment of left ventricular contraction than the usual
qualitative visual appraisal of the cineangiogram. Ejection fraction was calculated
by the area-length method.

Statistics

The chi-square test was used to assess differences
between proportions and the t test to compare the
means of independent observations. The sensitivity,
specificity, predictive values of a positive and negative
test and efficiency of the exercise test to detect mul-
tivessel disease were determined for each lead
system. Sensitivity was defined as the percentage
of patients with multivessel coronary disease who had
a positive test. Specificity was defined as the percent-
age of patients without multivessel coronary disease
who had a negative test. The predictive value of a
positive or negative test was defined as the percentage
of patients who had or did not have multivessel cor-
ony disease according to the exercise test result.

Results

Seventy-five men had an inferior and 43 an anterior
myocardial infarction (table 1). The angina functional
class was 0 or 1 in 30 patients with inferior and in 20
with anterior infarction; it was 2 or 3 in 45 patients
with inferior and in 23 with anterior myocardial
infarction. Patients with more severe angina were older
(52 ± 8 and 49 ± 9 years, respectively, for patients
with inferior and anterior infarctions) than asympto-
tomatic or mildly symptomatic patients (46 ± 9
and 44 ± 7 years, respectively) (p < 0.05). In patients with
inferior infarction, the group of patients in angina
classes 2 and 3 had a higher prevalence of multivessel
disease (80% vs 50%; p < 0.03) and three-vessel dis-
ease (40% vs 10%; p < 0.01) than the subset of
patients in angina classes 0 and 1. In patients with
anterior infarction, the prevalence of multivessel,
three-vessel or proximal left coronary disease was
similar in both angina subsets. This finding may relate
to the fact that patients with unstable angina and/or
Heartwall and Left Ventricular Function

TABLE 1. Coronary Anatomy and Left Ventricular Function

<table>
<thead>
<tr>
<th>Subset</th>
<th>n</th>
<th>Age (years)</th>
<th>Ventricular function</th>
<th>Number of vessels with stenosis</th>
<th>Proximal LAD stenosis</th>
<th>Left main stenosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ant. apical</td>
<td>Inferior</td>
<td>Ejection fraction</td>
<td>0-1</td>
</tr>
<tr>
<td>Inferior myocardial infarction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional class 2 or 3</td>
<td>45</td>
<td>52 ± 8</td>
<td>2</td>
<td>62</td>
<td>0.49 ± 0.01</td>
<td>9</td>
</tr>
<tr>
<td>Functional class 0 or 1</td>
<td>30</td>
<td>46 ± 9*</td>
<td>17</td>
<td>50</td>
<td>0.46 ± 0.02</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>49 ± 1</td>
<td>8</td>
<td>57</td>
<td>0.47 ± 0.01</td>
<td>24</td>
</tr>
<tr>
<td>Anterior myocardial infarction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional class 2 or 3</td>
<td>23</td>
<td>49 ± 9</td>
<td>56</td>
<td>22</td>
<td>0.48 ± 0.02</td>
<td>9</td>
</tr>
<tr>
<td>Functional class 0 or 1</td>
<td>20</td>
<td>44 ± 7*</td>
<td>65</td>
<td>20</td>
<td>0.50 ± 0.02</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>47 ± 1</td>
<td>60</td>
<td>21</td>
<td>0.49 ± 0.01</td>
<td>18</td>
</tr>
</tbody>
</table>

*p < 0.05, functional class 2 or 3 vs functional class 0 or 1.
†p = 0.004, functional class 2 or 3 vs functional class 0 or 1.
Abbreviations: LV = left ventricle; LAD = left anterior descending coronary artery; ant = anterior.

extensive anterior myocardial infarction were excluded from analysis. Ejection fraction was 0.44 ± 0.02 in patients with inferior and 0.48 ± 0.02 in patients with anterior myocardial infarction. Left ventricular function was not related to the functional class of angina.

Predictive Value of ST-segment Shifts (table 2)

Inferior Myocardial Infarction

A positive test increased the likelihood of multivessel disease from 0.68 to 0.89–0.97, depending on the lead system used. Sensitivity was significantly increased using 14 leads compared with lead V5 alone (77% vs 55%; p < 0.05). The sensitivity of leads CC5, CM5, and V5 equaled that of 14 leads (30 of 35, 86%) for high-risk lesions; all patients with proximal left coronary and all but one patient with three-vessel disease were detected. The sensitivities of lead V5 alone was 55% (28 of 51) for multivessel disease, 67% (14 of 21) for three-vessel and only 50% (seven of 14) for proximal left coronary disease. A positive test in any of 14 leads predicted multivessel disease in 80% (12 of 15) of patients in angina classes 0 and 1 and 93% (27 of 29) of patients in angina classes 2 and 3. The predictive value of a positive test increased to 89% (8 of 9) and to 100% (20 of 20), respectively, when lead V5 was positive.

The predictive value of a negative test for absence of multivessel disease using 14 leads was 80% (12 of 15) for men in angina classes 0 and 1 and 44% (seven of 16) for men in angina classes 2 and 3 (p < 0.05). Thus, in men with more severe angina, a negative test did not eliminate the possibility of multivessel disease; it did, however, reduce the risk of three-vessel or proximal left coronary disease to 14% (four of 29).

Anterior Myocardial Infarction

A positive test increased the likelihood of multivessel disease from 0.58 to 0.73–1.00 depending on the lead system used. Sensitivity was 64% with 14 leads, 56% with leads CC5, CM5, and V5 and only 40% with lead V5.

The predictive value of a positive test for presence of multivessel disease was 73% (16 of 22) with 14 leads, 83% (14 of 17) with leads CC5, CM5, and V5, and 91% (10 of 11) with lead V5. The predictive value of a negative test for absence of multivessel disease was 70% (seven of 10) for patients in angina classes 0 and 1 and 45% (five of 11) for patients in angina classes 2 and 3. Among the nine men with a false-negative test for multivessel disease using 14 leads, five had three-vessel and four had two-vessel disease.

Predictive Value of Other Exercise Parameters

Chest Pain

Progressive angina was present in 45 patients during exercise and was the end point of exercise in 43 patients. Of 28 with an inferior myocardial infarction who had progressive angina, 26 (93%) had multivessel disease. Similarly, of 17 patients with an anterior myocardial infarction who had angina during exercise, 14 (82%) had multivessel disease. The absence of angina during exercise did not preclude multivessel disease, as 49% (36 of 73) of patients without angina had multivessel disease (p < 0.001).

Treadmill Work Time

Of 29 patients with an inferior myocardial infarction, a negative exercise test using 14 leads and a final treadmill time ≥ 540 seconds, 14% (four of 29) had three-vessel or proximal left coronary disease. A positive test and a final treadmill time ≤ 360 seconds was predictive of three-vessel or proximal left coronary disease in 67% (10 of 15) of patients (figs. 1 and 2).

Of 18 patients with an anterior myocardial infarction, a negative exercise test using 14 leads and a final
treadmill time \( \geq 540 \) seconds, 17\% (three of 18) had three-vessel disease. A positive test and a final treadmill time \( \leq 360 \) seconds was predictive of three-vessel disease in 45\% (five of 11) of patients (figs. 3 and 4).

Thus, treadmill work time was a useful predictor of disease severity in patients with inferior or anterior myocardial infarction. A final treadmill work time \( \geq 540 \) seconds and a negative 14-lead ECG predicted the absence of three-vessel disease in 85\% (40 of 47) of patients and a positive ECG and treadmill work time \( \leq 360 \) seconds predicted the presence of multivessel and three-vessel disease in 92\% (24 of 26) and 54\% (14 of 26) of patients, respectively.

**Depth of ST-segment Depression**

In patients with class 0 or 1 angina after an inferior myocardial infarction, the depth of ST-segment depression did not relate to the extent of disease (fig. 1). However, of 19 men with class 2 or 3 angina and ST-segment depression \( \geq 2 \) mm, 13 (68\%) had proximal left coronary or three-vessel disease (fig. 2).

In patients with an anterior myocardial infarction, three-vessel or proximal left coronary disease occurred in 77\% (10 of 13) of patients with ST-segment depression \( \geq 2 \) mm (figs. 3 and 4).

Thus, ST-segment depression \( \geq 2 \) mm predicts the presence of three-vessel disease or proximal left coronary disease in 60\% (24 of 40) of patients after myocardial infarction, with a specificity of 76\% (51 of 67).

**ST-segment Elevation**

Of 10 patients with an inferior myocardial infarction and exercise-induced ST-segment elevation \( \geq 1 \) mm in the inferior leads, nine had multivessel disease vs 65\% (42 of 65) of patients without ST-segment elevation.

---

**Figure 1. Correlation of ECG results with work capacity for patients with inferior myocardial infarction in angina class 0 or 1.** Clear symbols represent proximal left coronary disease. VD = vessel disease.

**Figure 2. Correlation of ECG results with work capacity for patients with inferior myocardial infarction in angina class 2 or 3.** Clear symbols represent proximal left coronary disease. VD = vessel disease.
Table 2. Diagnostic Value of Exercise Test Results in the Detection of Multivessel Disease After Myocardial Infarction

<table>
<thead>
<tr>
<th></th>
<th>Single leads</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_3$</td>
<td>$V_4$</td>
<td>$V_5$</td>
<td>$V_6$</td>
</tr>
<tr>
<td>Inferior myocardial infarction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity for MVD</td>
<td>11/51 (22%)</td>
<td>26/51 (51%)</td>
<td>28/51 (55%)</td>
<td>26/51 (51%)</td>
</tr>
<tr>
<td>Specificity for MVD</td>
<td>23/24 (96%)</td>
<td>22/24 (92%)</td>
<td>23/24 (96%)</td>
<td>21/24 (88%)</td>
</tr>
<tr>
<td>Predictive value of a positive test for MVD</td>
<td>11/12 (92%)</td>
<td>26/28 (93%)</td>
<td>28/29 (97%)</td>
<td>26/29 (90%)</td>
</tr>
<tr>
<td>Predictive value of a negative test for absence of MVD</td>
<td>23/63 (37%)</td>
<td>22/47 (47%)</td>
<td>23/46 (50%)</td>
<td>21/46 (46%)</td>
</tr>
<tr>
<td>Anterior myocardial infarction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity for MVD</td>
<td>1/25 (4%)</td>
<td>4/25 (16%)</td>
<td>10/25 (40%)</td>
<td>9/25 (36%)</td>
</tr>
<tr>
<td>Specificity for MVD</td>
<td>18/18 (100%)</td>
<td>18/18 (100%)</td>
<td>17/18 (94%)</td>
<td>17/18 (94%)</td>
</tr>
<tr>
<td>Predictive value of a positive test for MVD</td>
<td>1/1 (100%)</td>
<td>4/4 (100%)</td>
<td>10/11 (91%)</td>
<td>9/10 (90%)</td>
</tr>
<tr>
<td>Predictive value of a negative test for MVD</td>
<td>18/42 (43%)</td>
<td>18/39 (46%)</td>
<td>17/32 (53%)</td>
<td>17/33 (52%)</td>
</tr>
</tbody>
</table>

* $p < 0.05$, lead $V_5$ vs 14 leads.

Abbreviation: MVD = multivessel disease.

---

**Figure 3.** Correlation of ECG results with work capacity for patients with anterior myocardial infarction in angina class 0 or 1. Clear symbols represent proximal left coronary disease. $VD =$ vessel disease.

**Figure 4.** Correlation of ECG results with work capacity for patients with anterior myocardial infarction in angina class 2 or 3. Clear symbols represent proximal left coronary disease. $VD =$ vessel disease.
TABLE 2. (Continued)

<table>
<thead>
<tr>
<th>Single leads</th>
<th>Multiple leads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC₆, CM₄, V₄</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>32/35 (91%)</td>
<td>35/38 (92%)</td>
</tr>
<tr>
<td>21/24 (88%)</td>
<td>21/24 (88%)</td>
</tr>
<tr>
<td>32/51 (63%)</td>
<td>35/51 (69%)</td>
</tr>
<tr>
<td>21/40 (53%)</td>
<td>23/45 (51%)</td>
</tr>
<tr>
<td>11/25 (44%)</td>
<td>12/25 (48%)</td>
</tr>
<tr>
<td>16/18 (89%)</td>
<td>15/18 (83%)</td>
</tr>
<tr>
<td>11/13 (85%)</td>
<td>12/15 (80%)</td>
</tr>
<tr>
<td>16/30 (53%)</td>
<td>15/28 (54%)</td>
</tr>
</tbody>
</table>

Elevation. Five patients had ST-segment elevation ≥ 1 mm in the inferior leads and significant ST-segment depression in the anterior leads; all had multivessel disease and four (80%) had inferior akinesis or dyskinesis. Ejection fraction was lower in patients who had ST-segment elevation (0.41 ± 0.03) than in patients who did not have this finding (0.48 ± 0.01) (p < 0.1).

Of 11 patients with an anterior myocardial infarction and exercise-induced ST-segment elevation ≥ 1 mm in the anterior leads, three (27%) had multivessel disease compared with 69% (22 of 32) who did not have this finding (p < 0.05). Of three patients with ST-segment elevation in the anterior leads and significant ST-segment depression in the inferior or lateral leads, two had single-vessel disease and one had an akinetic anterior wall motion abnormality. Ejection fraction was similar in patients with ST-segment elevation and patients without ST-segment elevation (0.47 ± 0.03 vs 0.50 ± 0.02).

The presence of isolated ST-segment elevation in any of the 14 leads predicted a corresponding akinetic or dyskinetic wall motion abnormality in 92% (12 of 13) of cases.

Number of Positive Leads

A positive test occurred in 44 patients with an inferior myocardial infarction using 14 ECG leads. The average number of positive leads was 3 ± 2 (mean ± SD) in patients with single-vessel disease vs 4 ± 1.5 and 5 ± 1.5 for patients with two- and three-vessel disease, respectively. Proximal left coronary disease did not increase the number of positive leads (4.1 ± 1.6 vs 4.2 ± 1.8). When three or more leads were positive, 95% (35 of 37) of patients had multivessel disease vs 57% (four of seven) with less than three positive leads (p < 0.005) (fig. 5). Of 13 patients with proximal left coronary disease, eight with proximal left anterior descending stenosis and three with left main stenosis (85%), had three or more positive leads.

A positive test occurred in 22 patients with an anterior myocardial infarction using 14 ECG leads. The average number of positive leads was similar in patients with one-, two- and three-vessel disease (4.2 ± 1.2, 4.7 ± 2.2, 3.9 ± 1.9, respectively) and was not greater in patients with proximal left coronary disease (4.5 ± 2 vs 3.9 ± 1.2). Of 21 patients with three or more positive leads, 71% (15) had multivessel disease.

Discussion

The diagnostic value of an exercise test depends on the population, the number of leads, the ECG criteria used for positivity and the exercise work load required.6, 11, 24-28 Male survivors of a transmural myocardial infarction represent a selected, heterogeneous population of patients with impaired ventricular function. In patients with inferior myocardial infarction, the prevalence of multivessel disease is higher when severe angina is present. Recent data have shown that a priori knowledge of disease prevalence and severity of disease must be used to obtain maximum diagnostic information from an exercise test result.11, 26-28 In the present study, we evaluated the potential of nine lead systems to predict multivessel disease after myocardial infarction and correlated the results to pretest knowledge of angina functional class and site of myocardial infarction.

Inferior Myocardial Infarction

The prevalence of multivessel disease in patients with an inferior myocardial infarction was 68%, slightly less than the 69–86% reported by others.30, 31 Patient selection would account for the different prevalences, because 80% of our patients in angina class 2 or 3 had multivessel disease compared with only 50% of patients in angina class 0 or 1 (p < 0.001).
Patients with unstable angina after infarction were excluded from our study.

The predictive value of a positive test for multivessel disease was 80% in men with mild or no symptoms and 96% in men with more severe angina. The results of three recent studies have reported the predictive value of a positive test at 76–89%. The predictive value of a negative test for the absence of multivessel disease using 11 or 14 leads was 80% for men with mild symptoms and only 42–44% for men with more severe angina (p < 0.05). Clearly, angina class must be considered when analyzing exercise test results in men with previous inferior myocardial infarction.

The prevalence of three-vessel or proximal left coronary disease was 13% for men in angina class 0 or 1. A negative test in 14 leads reduced the likelihood of this finding to 4% and a positive test with a final treadmill time < 540 seconds increased the likelihood to 60%. Thus, the major diagnostic impact of an exercise test in patients after an inferior myocardial infarction was in patients in angina class 0 or 1.

Anterior Myocardial Infarction

The prevalence of multivessel disease in patients with an anterior myocardial infarction was 58%, less than the 60–82% reported in other studies. The prevalence of three-vessel disease was 28%, similar to the 24–36% reported in other series. The extent and prevalence of multivessel disease did not correlate with angina class.

The sensitivity of the 14-lead ECG for multivessel disease was less in patients with an anterior myocardial infarction (64%) than in patients with an inferior myocardial infarction (76%). Castellanet and co-workers have reported a sensitivity of 52% in patients with anterior infarction using leads CMs, III and VI. The predictive value of a positive test for multivessel disease using 14 ECG leads was 80% for men in angina class 0 or 1 and 67% for men in angina class 2 or 3. The predictive value of a negative test for absence of multivessel disease was 70% for men in angina class 0 or 1 vs only 45% for men in angina class 2 or 3. The decreased predictive potential of the exercise test in men with more severe angina could not be explained by the prevalence or severity of multivessel disease, which were similar in patients with mild or more severe symptoms.

The maximum diagnostic benefit of the exercise test was for men in angina classes 0 and 1. A negative test in 14 leads and a final treadmill time > 540 seconds decreased the likelihood of three-vessel disease to 10%.
and a positive test with 2 mm or more ST-segment depression and/or a final treadmill time <360 seconds increased the likelihood of this angiographic finding to 40–67%.

Exercise-induced ST-segment Elevation

The significance of ST-segment elevation was dependent on the site of myocardial infarction, whether it was an isolated event and whether it was associated with coincident ST-segment depression in other leads.

The presence of ST-segment elevation ≥1 mm as an isolated finding predicted an akinetic or dyskinetic wall motion defect in 88% of men with an anterior infarction and 100% of men with an inferior infarction. Weiner and colleagues7 and Chahine et al.9 reported akinetic or dyskinetic left ventricular contraction abnormalities in 79–86% of their patients with isolated exercise-induced ST-segment elevation ≥1 mm.

The predictive value of isolated ST-segment elevation for multivessel disease was 25% for men with an anterior and 80% for men with an inferior myocardial infarction, within the 21–81% range reported by Weiner et al.7 and Chahine et al.9 These studies show that the predictive value of an exercise test for multivessel disease after infarction is not improved by using ST-segment elevation ≥1 mm among the criteria for a positive test. The association of ST-segment elevation with ST-segment depression in other leads was found to have the same significance as ST-segment depression alone.

Choice of Lead System and ECG Criteria for Positivity

The sensitivity of an exercise test is significantly increased by recording multiple ECG leads during and after exercise.10, 11, 20 When disease prevalence is high, multiple leads increase the predictive power of a negative test, without decreasing the predictive value of a positive result. Survivors of myocardial infarction have a high prevalence of coronary and multivessel disease and are a subset of patients in whom multiple leads provide additional diagnostic information when an exercise test is performed.

In the present study, maximum sensitivity was obtained using 14 ECG leads. The predictive value of a positive test for multivessel disease ranged from 67–93% and was higher when individual leads were considered. The predictive value of a negative test was only slightly improved using 14 ECG leads. The most practical set of leads for routine clinical use in this subset of patients would be leads CC5, CM5, and V5, which are only 8% less sensitive than 14 leads and provide similar predictive information.

A slow, upsloping ST segment depressed ≥1.5 mm or ≥2 mm at 0.08 second after the J point has a similar predictive value to horizontal ST-segment depression in populations with a high prevalence of coronary disease.33, 34 Optimal ECG criteria that provide increased sensitivity without decreasing the predictive value of an abnormal test in patients after infarction are 1) horizontal or downsloping ST-segment depression ≥1 mm and 2) a slow, upsloping ST segment depression ≥1.5 mm at 0.08 second after the J point in any lead compared with the resting tracing.

Clinical Implications

The patient population evaluated in this study does not represent the total patient population that enters a coronary care unit. We did not study patients with subendocardial and mixed or extensive transmural myocardial infarction, nor did we study women or patients over 65 years old. The population we studied represents ambulatory, postinfarction patients commonly referred for coronary arteriography. Thus, the quantitative results of this study, for example, the exact percentage of multivessel disease associated with a certain parameter, may not be valid if applied to other patient populations (e.g., a consecutive series of patients studied within the initial weeks after acute myocardial infarction).

The maximum diagnostic value of exercise testing after infarction is for patients who are asymptomatic or in angina class 1. A negative test using multiple leads reduces the risk of three-vessel disease to less than 10% and a positive test increases the risk of multivessel disease to 80% or more. Profound ST-segment depression ≥2 mm or a final treadmill time <540 seconds increases the likelihood of finding more extensive coronary disease.

The diagnostic value of performing an exercise test in patients after infarction in angina class 2 or 3 is limited, even when 14 ECG leads are recorded. False-negative tests for multivessel disease are common, the prevalence of multivessel disease a priori is high, and coronary arteriography will be frequently performed to establish prognosis and identify "high-risk" lesions.

However, there is another dimension to exercise stress testing — its prognostic implication or prediction of future coronary events.5, 34–39 The use of the test in this manner is highly appropriate to patients with a previous myocardial infarction. Exercise testing could still be useful in the subgroup of postinfarction patients with class 2 or 3 angina, if it is shown that a positive test using multiple ECG leads is associated with a significantly increased incidence of long-term coronary events. This would lead to a better selection of high-risk patients for coronary arteriography and coronary artery surgery.

Acknowledgment

We thank Diane Roy and Claire Bertrand-St-Hilaire for secretarial assistance.

References

3. Friesinger GC, Page EE, Ross RS: Prognostic significance of
coronary arteriography. Trans Assoc Am Phys 83: 78, 1970
Detection of multivessel coronary disease after myocardial infarction using exercise stress testing and multiple ECG lead systems.
J F Tubau, B R Chaitman, M G Bourassa and D D Waters

Circulation. 1980;61:44-52
doi: 10.1161/01.CIR.61.1.44

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1980 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/61/1/44.citation

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/