Value of Left Ventricular Ejection Fraction During Exercise in Predicting the Extent of Coronary Artery Disease

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To determine the relation between left ventricular performance during exercise and the extent of coronary artery disease, the results of exercise radionuclide ventriculography were analyzed in 65 patients who also underwent cardiac catheterization. A scoring system was used to quantitate the extent of coronary artery disease. This system takes into account the number and site of stenoses of the major coronary vessels and their secondary branches. The conventional method of interpreting the coronary angiograms indicated that 26 patients had significant coronary artery disease (defined as 70% or more narrowing of luminal diameter) of one vessel, 21 had multivessel disease and 18 had no significant coronary artery disease.

Although the exercise left ventricular ejection fraction was significantly higher in patients with no coronary artery disease than in patients with one or multivessel disease (probability [p] < 0.001), there was considerable overlap among the three groups. With the scoring system, a good correlation was found between the coronary artery disease score and the exercise left ventricular ejection fraction (r = -0.70; p < 0.001). If the exercise heart rate was 130 beats/min or greater or the age of the patient was 50 years or less, an even better correlation was found (r = -0.73 and r = -0.82, respectively). The exercise ejection fraction (but not the change in ejection fraction, end-diastolic volume and end-systolic volume from rest to exercise) correlated with the extent of coronary artery disease.

The exercise ejection fraction is the most important exercise variable that correlates with the extent of coronary artery disease when the latter is assessed quantitatively by a scoring system rather than the conventional method of reporting coronary angiograms. Younger age and greater exercise heart rate strengthened the correlation. The change in ejection fraction from rest to exercise is useful in the diagnosis of coronary artery disease, but it was the absolute level of exercise ejection fraction that predicted the extent of disease.

Coronary arteriography for detecting coronary artery narrowing is useful in defining regions of potential ischemia. Because anatomic information may not provide an accurate physiologic assessment of the functional importance of coronary stenosis, regional and global left ventricular function during stress has emerged as a complementary aspect to arteriography (1). Radionuclide angiography permits noninvasive evaluation of left ventricular function at rest and during exercise, and detection of functional abnormalities in patients with coronary artery disease (2–5). The magnitude of exercise-induced left ventricular dysfunction has been correlated with the anatomic extent of disease; patients having multivessel disease show more deterioration in left ventricular function during exercise than do patients with one vessel disease (6).

Considerable individual variation is observed among patients grouped according to the number of stenosed vessels. Recently, it has been shown that proximal stenotic lesions in the left anterior descending artery resulted in more pronounced abnormality of left ventricular function during exercise than similar lesions located more distally (7). This has also been shown with proximal and distal lesions of the right coronary artery affecting right ventricular function during exercise (8). Individual variation in ventricular performance during exercise may result not only from differences in location of stenosis but also from variations in collateral vessels, severity of stenosis, cardiac medications, age, sex, level of exercise, associated cardiomyopathic and valvular processes, conditioning and other factors (9). This has been supported by the individual hemodynamic changes during

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exercise observed in patient groups with a similar anatomic extent of disease (5).

In this study, we evaluated left ventricular function at rest and during exercise, and determined the extent of coronary artery disease by using an angiographically computed scoring system. We undertook the study to determine which exercise variables correlate best with the extent of angiographic coronary disease.

Methods

Study patients. Between January 1980 and January 1982, approximately 800 patients underwent exercise testing, of these, 106 consecutive patients had radionuclide angiographic rest and exercise tests within 2 months of cardiac catheterization. Forty-one of these patients were excluded from this analysis because of previous cardiac surgery or concomitant valvular or congenital heart disease observed in patient groups with a similar anatomic extent of disease (5).

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Coronary arteriography. Left heart catheterization was performed by standard techniques. The coronary arteriograms were reviewed and interpreted by two experienced cardiologists. The three major coronary arteries were visualized in multiple projections, and were scored to determine the extent of disease by means of a modified scoring system (10). Each coronary artery was studied in three segments: proximal, middle, and distal; the left main artery was analyzed separately. The degree of narrowing was scored numerically from 1 to 5: 1, 25% diameter narrowing; 2, 25 to 49% narrowing; 3, 50 to 74% narrowing; 4, 75 to 99% narrowing and 5, total occlusion. This score was then multiplied by a factor that takes into consideration the location of disease, that is, 6, left main; 3, proximal disease; 2, middle and 1, distal disease. If a major diagonal or marginal branch was involved proximally, this factor was considered to be 1 and multiplied by the degree of narrowing. The total score could thus range from 0 (no coronary disease) to a maximal score of 45 (complete occlusion of all three vessels). Using the conventional method of reporting coronary arteriograms, at least 70% luminal diameter narrowing of a coronary vessel was used to diagnose significant coronary artery disease.

Radionuclide angiographic test. We performed radionuclide angiography with the patient in the upright position at rest and during exercise, using a variable-load bicycle ergometer (Quinton Instruments) and a computerized multiscrystal gamma camera (Baird-Atomic System-77) equipped with a 1 inch (2.54 cm) parallel-hole collimator positioned anterior to the precordium. A 20 gauge polyethylene catheter was inserted into a basilic vein. The radionuclide angiogram was obtained after administration of 15 millicuries (mCi) of technetium-99m pertechnetate dissolved in a volume of less than 1 cc. Precordial counts were recorded at 50 ms frame intervals for the rest studies and 25 ms frame intervals for the exercise studies during the initial pass of the radionuclide through the central circulation. Exercise was begun at a work load of 200 kpm/min and increased by 100 kpm/min increments every 1-1/2 minutes. The electrocardiogram was continuously monitored and blood pressure was recorded at 2 minute intervals during exercise and the recovery period.

Two electrocardiographic leads (CMz and aVF) were monitored constantly (11). The end points of exercise are defined as follows: severe angina pectoris, 2 mm or more ST segment depression with or without angina pectoris, excessive fatigue, leg weakness, shortness of breath, hypotension, dizziness and frequent premature ventricular complexes. At the onset of any of these end points, a second bolus of 15 mCi of technetium-99m pertechnetate was given and exercise was continued for the 30 seconds required for data acquisition.

The radionuclide angiograms were analyzed with computer software incorporated into a multiscrystal gamma camera. Left ventricular ejection fraction, end-diastolic volume and end-systolic volume were measured according to the method previously described by this and other laboratories (12-17). Validation data for measuring ejection fraction and volumes have been previously described by this laboratory (13). A normal response to exercise in our laboratory is defined as a 5% or greater increase in ejection fraction.

Regional wall motion was assessed using static images and a cinematic display of the entire representative cycle. Grading of three wall segments in the anterior view (anterior, apical, inferior) was as follows: 4, normal; 3, mild hypokinesia; 2, moderate hypokinesia; 1, severe hypokinesia and 0, akinesia or dyskinesia.

Statistical analysis. Differences in clinical characteristics for the group studied were compared by chi-square analysis or Student's t test. Individual changes in hemodynamic measurements from rest to exercise were compared by the paired t test. Standard regression analysis was used when appropriate. A probability (p) value of less than 5% was considered significant. Results are expressed as mean values + standard deviation (SD) when appropriate.

Results

Coronary angiographic and clinical findings. Of the 65 patients who underwent exercise radionuclide angiography, 11 (17%) had completely normal coronary arteries (coronary artery disease score of 0) and 7 (11%) had coronary stenosis that did not exceed 70% of the diameter of a major coronary artery (coronary artery score of 10.5 ± 7.0, range 1 to 22). The coronary artery score for these 18 patients was 4.2 ± 7.4. The remaining 47 patients had severe coronary artery disease (≥ 70% diameter narrowing of at least one major coronary vessel). There were 26 patients (40%) with one vessel disease (coronary artery disease score 14.8 ± 3.90, range 9 to 22) and 21 patients (32%) with multivessel disease (coronary artery score 30.4 ± 8.1, range 18 to 45). Four of the 21 patients with multivessel disease had left main coronary artery disease. Eight (17%) of the 47 patients (26 with one vessel disease + 21 with multivessel disease) had a documented history of myocardial infarction. The coronary artery score for the 65 patients was 16.9 ± 12.2 (range 0 to 45).
Thirty-four patients were in functional class I, 22 in class II and 9 in class III according to the New York Heart Association classification. Electrocardiographic evidence of previous transmural infarction (abnormal Q waves) was present in seven patients. Twenty-eight patients were on maintenance doses of propranolol at the time of the study.

**Rest left ventricular function.** The heart rate at rest was 68 ± 12 beats/min (range 45 to 97). The blood pressure at rest was 124 ± 19 mm Hg (range 90 to 170). Left ventricular ejection fraction at rest was 51 ± 12% (range 18 to 73). Neither heart rate nor blood pressure at rest showed a significant correlation with ejection fraction at rest. The correlation between rest ejection fraction and coronary artery score was weak (r = -0.35, p < 0.01) (Fig. 1). The end-diastolic volume at rest ranged from 109 to 332 ml, and the end-systolic volume at rest ranged from 37 to 273 ml. The rest ejection fraction, end-diastolic volume and end-systolic volume for the three subgroups of patients are shown in Table 1.

**Exercise Left Ventricular Function**

Of the 65 patients who underwent exercise radionuclide angiography, exercise was terminated in 27 (42%) because of a positive exercise electrocardiogram, in 5 (7.5%) because of attainment of at least 85% of predicted maximal heart rate without chest pain or electrocardiographic changes, in 28 (43%) because of fatigue, and in 5 (7.5%) because of chest pain without electrocardiographic changes.

**Ejection fraction.** Correlation with exercise duration. The duration of exercise was 7.4 ± 3.1 minutes (range 2 to 14.5) for the entire group of patients. There was poor correlation between rest left ventricular ejection fraction and exercise duration (r = 0.22, p = not significant [NS]). The exercise ejection fraction showed a weak correlation with exercise duration (r = 0.41, p < 0.001). A weak inverse correlation was also observed between the coronary artery score and exercise duration (r = -0.37, p < 0.01). There was no correlation between the change in ejection fraction (the change in left ventricular ejection fraction from rest to exercise) and exercise duration. Because the work load was increased every 1-1/2 minutes, the peak work load attained was proportional to the duration of exercise.

**The heart rate** for the 65 patients at peak exercise was 123 ± 22 beats/min (range 74 to 180). The blood pressure was 165 ± 31 mm Hg (range 90 to 260), and blood pressure-heart rate product was 21 ± 7 × 10³ (range 7.5 to 33.8). Twenty-eight patients (42%) achieved an exercise heart rate of 130 beats/min or greater.

**Correlation with coronary angiographic findings.** The left ventricular ejection fraction at peak exercise ranged from 18 to 86%. There was a weak correlation between the change in ejection fraction and the ejection fraction at rest (r = -0.34, p < 0.01) and during exercise (r = 0.46, p < 0.001). The ejection fraction for patients with no coronary disease increased from 56 ± 7% at rest to 66 ± 10% with exercise (p < 0.001) for patients with single vessel disease it was 52 ± 11% at rest and 52 ± 9% with exercise (p = NS), and for patients with multivessel disease it decreased from 46 ± 15% at rest to 42 ± 11% during exercise (p = NS) (Fig. 2, Table 1). The exercise ejection fraction was higher in patients with no coronary disease than in patients with one vessel disease or multivessel disease (p < 0.001) (Fig. 3). An abnormal ejection fraction response to exercise (< 5% increase) was present in 17 (65%) of the 26 patients.

### Table 1. Rest and Exercise Left Ventricular Function in the Three Subgroups

<table>
<thead>
<tr>
<th>CAD Score</th>
<th>No CAD† (n = 18)</th>
<th>1VD (n = 26)</th>
<th>MVD (n = 21)</th>
<th>Total (n = 65)</th>
</tr>
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<tbody>
<tr>
<td>CAD score</td>
<td>4.2 ± 7.4 14.8 ± 3.9</td>
<td>30.4 ± 8.1</td>
<td>16.7 ± 12.3</td>
<td></td>
</tr>
<tr>
<td>Rest LVEF (%)</td>
<td>56 ± 7 52 ± 11</td>
<td>46 ± 15</td>
<td>51 ± 13</td>
<td></td>
</tr>
<tr>
<td>Ex LVEF (%)</td>
<td>66 ± 10 52 ± 9</td>
<td>42 ± 11</td>
<td>52 ± 14</td>
<td></td>
</tr>
<tr>
<td>Rest EDV* (ml)</td>
<td>160 ± 26 156 ± 56</td>
<td>212 ± 53</td>
<td>169 ± 57</td>
<td></td>
</tr>
<tr>
<td>Ex EDV* (ml)</td>
<td>163 ± 19 206 ± 50</td>
<td>230 ± 49</td>
<td>201 ± 50</td>
<td></td>
</tr>
<tr>
<td>Rest ESV* (ml)</td>
<td>69 ± 16 76 ± 41</td>
<td>118 ± 68</td>
<td>89 ± 51</td>
<td></td>
</tr>
<tr>
<td>Ex ESV* (ml)</td>
<td>61 ± 15 113 ± 77</td>
<td>155 ± 72</td>
<td>100 ± 53</td>
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</table>

*Volumes available for 47 of 65 patients. †Normal coronary arteries or coronary stenosis not exceeding 70% of the diameter of a major coronary artery.

CAD = coronary artery disease; EDV = end-diastolic volume; ESV = end-systolic volume; Ex = exercise; LVEF = left ventricular ejection fraction; MVD = multivessel disease, n = number, 1VD = one vessel disease

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**Figure 1.** Correlation between rest left ventricular ejection fraction and coronary artery disease (CAD) score. No propranolol = patients not on propranolol therapy; propranolol = patients on propranolol therapy.
with one vessel disease and in 16 (76%) of the 21 patients with multivessel disease (p = NS).

Five of the 18 patients with normal arteries or mild coronary artery disease had an increase in left ventricular ejection fraction of less than 5% with exercise. In a separate group of 20 subjects with low probability of coronary disease who did not undergo cardiac catheterization, all 20 had a normal rest ejection fraction (64 ± 7%) and 17 (85%) of the 20 subjects had a 5% or greater increase in ejection fraction during exercise. The remaining three subjects who failed to have an increase of 5% or greater in ejection fraction during exercise had a hyperkinetic left ventricle at rest with a rest ejection fraction of 70% or greater. The exercise ejection fraction for the 20 subjects (75 ± 4%) was significantly higher than the rest ejection fraction (p < 0.001).

Correlation with probability of coronary heart disease. On the basis of clinical evaluation and rest electrocardiograms, the probability of coronary heart disease was considered high in 32 of the 47 patients with angiographically documented coronary artery disease and was considered intermediate in the remaining 15 patients. An abnormal rest ejection fraction or abnormal ejection fraction response to exercise, or both, was present in 30 patients (94%) with high probability and in 11 patients (73%) with intermediate probability of coronary artery disease. All 18 patients with normal coronary angiograms or insignificant coronary artery disease were thought to have a low probability of coronary disease, but 5 (28%) of the 18 patients had an abnormal ejection fraction at rest or abnormal response to exercise. The rest ejection fraction was normal (≥ 50%) in 25 of the 47 patients with coronary artery disease; of these patients, 19 had abnormal ejection fraction response to exercise (11 with one vessel and 8 with multivessel disease). The remaining six patients (five with one vessel and one with multivessel disease) had a normal response to exercise. The ejection fraction at rest was depressed (< 50%) in 22 of the 47 patients with coronary artery disease; of these, 14 had abnormal response to exercise (6 with one vessel and 8 with multivessel disease) and 8 had a normal response (4 with one vessel and 4 with multivessel disease).

Exercise-induced regional wall motion abnormality or an increase of less than 5% in left ventricular ejection fraction during exercise was seen in 20 patients (77%) with one vessel disease, although 20 patients (95%) with multivessel disease had abnormal rest ejection fraction, abnormal ejection fraction response to exercise, abnormal wall motion at rest or during exercise or a combination of these findings.

Correlation with coronary artery disease score. The change in ejection fraction showed a weak correlation with coronary artery disease score (r = -0.42, p < 0.001) (Fig. 4). When only the 28 patients with an exercise heart rate of 130 beats/min or greater were considered, the correlation was improved (r = -0.59, p < 0.001).

The exercise left ventricular ejection fraction showed a strong correlation with coronary artery disease score in the 65 patients (r = -0.70; p < 0.001) (Fig. 5A). The correlation was good even in patients on propranolol therapy (r = -0.66; p < 0.001). Of the 28 patients with a normal exercise ejection fraction (≥ 55%), only 1 had a coronary artery disease score of more than 24 points. If exercise...
ejection fraction was less than 40%, 11 (92%) of 12 patients were found to have extensive coronary artery disease. Of the 28 patients with exercise heart rate of 130 beats/min or greater, a slightly better correlation was found between exercise ejection fraction and coronary artery disease score (r = -0.73; p < 0.001). The correlation was also strong if the exercise duration was longer than 8 minutes (n = 24, r = -0.78, p < 0.001). In patients under the age of 60 years, the correlation between coronary score and exercise ejection fraction was slightly better (n = 45, r = -0.74, p < 0.001) (Fig. 5B). Patients younger than 50 years of age showed even better correlation between exercise left ventricular ejection fraction and coronary artery disease score (n = 27, r = -0.82, p < 0.001) (Fig. 5C).

Proximal versus distal coronary stenosis. In patients with one vessel disease, the coronary stenosis was proximal in 20 patients and distal in 6 patients. In patients with proximal stenosis, the ejection fraction was 53 ± 13% at rest and 51 ± 9% during exercise. In patients with distal stenosis, the ejection fraction was 51 ± 6% at rest and 57 ± 7% during exercise. The change in ejection fraction from rest to exercise was significantly different in the two groups of patients (-2 ± 10% versus 6 ± 4%, p < 0.05). Similarly, the exercise ejection fraction was significantly lower in the 12 patients with multivessel disease in whom the disease was proximal in all vessels than in 5 patients in whom the disease was distal in all vessels (36 ± 7% versus 48 ± 11%, p < 0.02).

Ventricular volume changes. The end-diastolic volume for all patients in this study increased with exercise from 174 ± 49 ml at rest to 200 ± 50 ml during exercise (p < 0.001). In patients with no coronary disease, end-diastolic volume increased from 160 ± 26 ml at rest to 163 ± 19 ml during exercise (p < 0.05). In patients with single vessel disease, the end-diastolic volume increased from 156 ± 56 ml at rest to 206 ± 50 ml during exercise (p < 0.01); in patients with multivessel disease, the volume increased from 212 ± 53 ml at rest to 230 ± 50 ml during exercise (0.10 > p > 0.05).

An increase in end-systolic volume during exercise was seen in 18 (86%) of 21 patients with one vessel disease and in 12 (86%) of 14 patients with multivessel disease. Three patients with one vessel disease and two patients with multivessel disease who had a normal ejection fraction response to exercise had an increase in end-systolic volume during exercise. However, minimal increase in end-systolic volume during exercise was also seen in four subjects with no significant coronary artery disease. There was no correlation between change in end-diastolic volume (change from rest to exercise) and coronary artery disease score (r = 0.005; p = NS).

The end-systolic volume for all patients in the study increased from 87 ± 50 ml at rest to 100 ± 51 ml during exercise (p < 0.001). There was no correlation between the
Figure 5. Correlation between exercise left ventricular ejection fraction and coronary artery disease (CAD) score. A, results in 65 patients; B, results in patients under 60 years of age; and C, results in patients under 50 years of age.

Positive versus inconclusive electrocardiographic stress tests. Twenty-seven patients had a positive electrocardiographic stress test and 33 had an inconclusive test (because of submaximal heart rate). The remaining five patients had a normal exercise electrocardiographic test. There were no significant differences between the two groups in regard to rest ejection fraction, exercise ejection fraction and coronary artery disease score (Table 2). However, the group with a positive stress test had a blood pressure-heart rate product at peak exercise of $22.8 \pm 5.1 \times 10^3$ versus $17.9 \pm 5.8$
and a change in ejection fraction from rest to exercise of $-4 \pm 12\%$ versus $5 \pm 8\%$, respectively (p < 0.001).

**Discussion**

The results of our study are consistent with the hypothesis that it is not the magnitude of change in global left ventricular function during exercise but the absolute level of global function at exercise that correlates best with the extent of coronary artery disease. The exercise left ventricular ejection fraction represents a combination of the muscle mass in jeopardy during ischemia along with the degree of fibrosis. The former is affected by many factors such as age, exercise heart rate, medications, exercise duration and extent of coronary disease.

Variations in individual hemodynamic change during exercise have been observed in patients grouped by similar anatomic extent of disease, thus confirming this heterogeneous response (6). However, previous reports on exercise radionuclide angiography have dealt with a conventional method of analysis of presence and extent of coronary artery disease (no coronary disease or single, double and triple vessel disease) (18). Significant disease has been variably defined as stenosis greater than 50 or 70% of the luminal diameter of the vessel. Although convenient, this evaluation of coronary disease is simplistic because it does not take into account the location and degree of stenosis and the number of stenoses.

**Ejection fraction and coronary artery disease score.** The coronary artery disease scoring system employed in our present study is not ideal. However, it determines the extent of disease much more closely than the conventional method because it provides a better estimate of the extent of myocardium at jeopardy during exercise. As seen in Table 1 and Figure 3, the mean values for exercise ejection fraction were significantly higher among patients with no significant coronary disease than among patients with single or multivessel disease; the overlap, however, was considerable. For example, the exercise ejection fraction in patients with no significant disease ranged from 53 to 86%. On the other hand, the coronary artery disease scores in these patients varied from 0 to 18 points. One patient with single vessel left anterior descending disease had a coronary artery disease score of 9. This patient had a normal exercise ejection fraction of 58%; in another patient with proximal left anterior descending disease and a coronary artery disease score of 21, the exercise ejection fraction was 27%. Likewise, patients with multivessel disease showed a wide scatter of exercise ejection fractions and coronary artery disease scores. We found that if the exercise left ventricular ejection fraction was 55% or greater, most (27 of 28 patients, or 96%) patients will have a low coronary artery disease score (< 24). Likewise, if the exercise ejection fraction is less than 40%, more than 90% of patients will have extensive coronary artery disease shown at catheterization.

**Effect of age.** Age has been shown to affect the exercise but not the rest ejection fraction in patients without coronary artery disease (9). However, there is no reason to doubt the exercise response in patients with coronary artery disease is also affected by age. In the present study, the correlation between extent of disease and exercise ejection fraction was greater in the younger patients, with the best correlation seen in patients under 50 years of age.

**Effect of propranolol.** The effect of propranolol on exercise left ventricular ejection fraction in patients with coronary artery disease shows individual variation (19). Battler et al. (20) showed an improvement in exercise ejection fraction with propranolol administration. Rainwater et al. (21) reached similar conclusions in patients with coronary artery disease without prior infarction. We found that in our patients, the extent of coronary disease correlated well with exercise ejection fraction whether or not the patients were on propranolol therapy. These differences are not difficult to reconcile because of the individual differences mentioned earlier; thus, even in patients on propranolol therapy, we found an excellent correlation between exercise ejection fraction and extent of angiographic coronary artery disease.

**Effect of exercise heart rate and blood pressure.** We also found that the exercise left ventricular ejection fraction correlated better with coronary artery disease score if an exercise heart rate of 130 beats/min or greater was obtained. The correlation was not improved if heart rate and blood pressure product was used. Both heart rate and blood pressure have been shown to be good predictors of myocardial oxygen demand during exercise in normotensive patients with ischemic heart disease (22). However, it seems that the exercise heart rate alone may be used to assess adequate myocardial stress.

### Table 2. Comparison Between Patients With Positive and Those With Inconclusive Exercise Electrocardiograms

<table>
<thead>
<tr>
<th></th>
<th>Positive Ex ECG (n = 27)</th>
<th>Inconclusive Ex ECG (n = 33)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP x HR (mm Hg x beats/min)</td>
<td>$22.8 \pm 5.1 \times 10^3$</td>
<td>$17.9 \pm 5.8 \times 10^3$</td>
<td>&lt; 0.001</td>
</tr>
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</table>

The results represent the number of patients and percent in each group or mean ± standard deviation. Five patients achieved at least 85% of the maximal predicted heart rate and had normal exercise electrocardiograms. These patients were excluded from the above analysis.

BP x HR = blood pressure x heart rate (mm Hg x beats/min), CAD = coronary artery disease; ECG = electrocardiogram; Δ EF = change in ejection fraction from rest to exercise, EF = ejection fraction; Ex = exercise, n = number, NS = not significant.
Correlation with extent of coronary artery disease. Despite the different levels of exercise end points as usually encountered in practice, we found the exercise ejection fraction to be the best exercise variable to correlate with extent of coronary artery disease. Although there has been a tendency to rely on the change in ejection fraction from rest to exercise (change in left ventricular ejection fraction) as a predictor of coronary artery disease, we found a weak correlation between this variable and extent of coronary disease. Also because the changes in left ventricular volumes and absolute exercise volumes showed considerable overlap in relation to the number of diseased vessels and extent of coronary disease, they were not useful in predicting the extent of coronary disease. Patients with a positive stress electrocardiogram did not differ in extent of coronary disease, rest or exercise ejection fraction from patients with an inconclusive exercise electrocardiogram (Table 2), but the change in ejection fraction differed in the two groups. This fact could be due to the higher exercise blood pressure and heart rate achieved in the patients with a positive stress test.

Correlation with exercise electrocardiogram. Exercise electrocardiographic results have been used as indicators of presence and severity of coronary disease. Specifically, ischemic changes appearing in the first 3 minutes of exercise and persisting for 8 minutes or longer in the recovery period have been correlated with extensive coronary disease (23). The exercise electrocardiographic results have also been useful prognosticators, thus, a higher incidence of ischemic events has been found in patients with early onset of ischemia (24). However, the diagnostic usefulness of exercise electrocardiography is limited (25). We found a weak correlation between exercise duration, extent of coronary artery disease and exercise ejection fraction.

Clinical implications. The changes in ejection fraction from rest to exercise and exercise-induced wall motion abnormalities are useful in the detection of coronary heart disease. The exercise ejection fraction is strongly correlated with the extent of coronary artery disease as determined by a scoring system. The younger the patient and the higher the exercise heart rate, the better the correlation. Precatheterization testing showing a normal exercise ejection fraction may reduce the number of catheterizations performed in patients with minimal or no symptoms in the search for extensive operable coronary disease. Further study is necessary to evaluate the prognostic value of the exercise ejection fraction in patients with coronary artery disease who are being treated medically.

References


