Comparative Effectiveness of Exercise Testing and Continuous Monitoring for Detecting Arrhythmias in Patients with Previous Myocardial Infarction

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SUMMARY

To detect unsuspected arrhythmias, 60 patients with previous myocardial infarction were studied by both submaximal treadmill exercise testing and 10 hours of continuous ECG monitoring (Holter technique) during normal activity. Significant arrhythmias were detected in 28 of 60 patients (47%). Eight patients (13%) had one or more premature ventricular contractions on their resting ECG and all had significant arrhythmias detected by exercise and/or Holter monitoring. Eighteen patients (30%) had frequent ectopic beats during or within 15 minutes after treadmill exercise and 22 patients (37%) had significant arrhythmias during continuous ECG monitoring. In 10 patients (17%) continuous ECG monitoring detected significant arrhythmias when exercise did not, while in six instances (10%) frequent premature ventricular beats were present with exercise but not during Holter monitoring. In four of 12 patients in whom both tests were positive, continuous ECG monitoring detected ventricular tachycardia when exercise showed only isolated ventricular beats. Fourteen patients (23%) had major arrhythmias detected by ECG monitoring; only six of the 14 were also detected by exercise testing. We conclude that both treadmill exercise and continuous ECG monitoring are useful for arrhythmia detection in post myocardial infarction patients but that continuous ECG monitoring often discloses different and more serious arrhythmias than treadmill exercise.

Additional Indexing Words:
Continuous ECG monitoring
Electrocardiogram
Submaximal treadmill exercise

VENTRICULAR ARRHYTHMIAS detected with the resting electrocardiogram or by continuous electrocardiographic monitoring (Holter technique) have been shown to be an independent risk factor for mortality in prospective studies of patients with previous myocardial infarction.1 2 Recently, submaximal treadmill exercise testing has been used to rapidly elicit ventricular arrhythmias in unselected patients and has been reported to be more sensitive than outpatient electrocardiographic monitoring.3 Accordingly, we compared the incidence of various arrhythmias detected by exercise testing and with continuous outpatient electrocardiographic (ECG) monitoring in post myocardial infarction patients.

Methods

Sixty outpatients, three to 44 months (mean 17 months) following myocardial infarction, were included in this study. The diagnosis of myocardial infarction was made in the Myocardial Infarction Research Unit on the basis of: 1) a history of typical prolonged chest pain; 2) electrocardiographic changes indicative of acute myocardial injury with subsequent evolution of a typical infarction pattern; and 3) characteristic elevations of serum enzymes (CPK, SGOT and/or LDH).

There were 53 males and 7 females ranging in age from 36 to 79 years (average age 57 years). Each patient was assigned a New York Heart Association (NYHA) functional class on the basis of a history and physical examination. Thirteen were in NYHA Class I, 41 were in Class II and 6 were in Class III. No patient had unstable angina pectoris and none had experienced a recent deterioration in his exercise ability. Patients were excluded if they were known to have arrhythmias and were receiving antiarrhythmic drugs, or if they were unable to complete the diagnostic studies described below.

A routine 12 lead resting electrocardiogram was performed on all patients, which contained 8 to 60 cardiac cycles, depending on the heart rate and whether or not a 3 channel recording machine was used. Immediately follow-
ing the resting electrocardiogram a submaximal treadmill exercise test was performed on all patients utilizing a modified Bruce protocol. An ischemic response was defined as at least 0.1 mV of J point depression when the slope of the first 80 msec of the ST segment toward baseline was less than 1 mV/sec. The test was discontinued by the monitoring physician if an ischemic response occurred, if typical angina pectoris occurred, if 90% of the maximum predicted heart rate was achieved, or if dyspnea or fatigue precluded further exercise. The electrocardiogram was continuously recorded during exercise and for 15 minutes after the termination of exercise. The tracings were then inspected for arrhythmias.

All patients had electrocardiographic tape recordings made during 10-12 continuous hours of routine daily activity, using the Holter-Avionics Electrocardiorecorder Model 350F. Approximately 80% of this recording was obtained while the patient was awake. Each tape was scanned for arrhythmias using the Avionics Composite Electrocardioscanner Model 650. Any arrhythmias detected were printed out and analyzed. In 41 of the 60 patients, recordings were also analyzed for ST segment changes after calibration with the Avionics Millivolt Calibrator Model 356A. An ischemic response was defined using the same criteria as above with treadmill exercise.

A positive test for the detection of significant arrhythmias was based on the following criteria: 1) one or more ventricular ectopic beats on the resting electrocardiogram; 2) greater than two ventricular premature beats per minute during and within 15 minutes after treadmill exercise, except during the last minute of exercise and the first 30 seconds of recovery; 3) one or more ventricular premature beats per 500 cardiac cycles during continuous ECG monitoring. Ventricular or atrial tachyarrhythmias and multifocal ventricular premature beats eight seconds or less apart were considered major arrhythmias.

Each patient had a supine posterior-anterior chest roentgenogram exposed at end-diastole with a standard inspiratory volume of one liter above functional residual capacity. The left heart dimension was measured from anterior midline markers to the apex of the left ventricle and was corrected for X-ray magnification and normalized per square meter of body surface area. A left heart dimension greater than 52 mm/m² BSA has been shown to be enlarged in our previous studies.

Results

Comparison of ECG, Treadmill and Monitoring

Twenty-eight of 60 patients (47%) had significant arrhythmias detected by one or more of the three methods. Figure 1 shows the percentage detected by each of the methods.

The resting electrocardiogram displayed ventricular premature beats in eight of 60 patients (13%) (fig. 1). All eight patients also had significant arrhythmias detected by treadmill exercise and/or outpatient continuous monitoring; one had a positive treadmill test, two had positive monitoring studies, and five had both tests positive.

Eighteen of 60 patients (30%) had a treadmill exercise test that was positive for arrhythmias (fig. 1). All but one of these 18 patients had frequent ventricular premature beats; the other developed rapid atrial fibrillation during exercise that persisted until three minutes after exercise. Four patients also had multifocal ventricular ectopic beats and one had ventricular tachycardia in addition to frequent single ventricular premature beats. Six of these 18 patients had frequent ventricular premature beats during treadmill exercise but not during continuous monitoring (fig. 2).

Twenty-two of 60 patients (37%) had a positive continuous ECG monitoring study (fig. 1). Eight patients had positive studies because of the frequency of ventricular premature beats alone and five of these eight had negative treadmill studies. Fourteen of the 22 positive outpatient monitoring studies revealed episodes of major arrhythmias (table 1), and five of these patients had negative treadmill tests. Thus, of 22 patients with significant arrhythmias detected by continuous ECG monitoring, 10 had negative treadmill studies (fig. 2).

Over-all, 12 patients had significant arrhythmias detected by both treadmill exercise and continuous ECG monitoring (fig. 2). The latter detected ven-

![Figure 1](http://circ.ahajournals.org/) The incidence of arrhythmias detected in 60 patients with previous myocardial infarction.

![Figure 2](http://circ.ahajournals.org/) Comparison of Holter monitoring and treadmill exercise for arrhythmia detection in 60 post myocardial infarction patients.
The Incidence of Major Arrhythmias Detected by the Three Techniques

<table>
<thead>
<tr>
<th></th>
<th>SUPRATVENTRICULAR TACHYARRHYTHMIAS ONLY</th>
<th>MULTIFOCAL VPBs ONLY</th>
<th>VENTRICULAR TACHYCARDIA*</th>
<th>TOTAL</th>
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<td>0</td>
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<tr>
<td>TREADMILL EXERCISE</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>6*</td>
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<tr>
<td>HOLTER MONITOR</td>
<td>1</td>
<td>5</td>
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* In addition, five of these patients had multifocal VPBs and two had supraventricular tachyarrhythmias.

† Also detected with Holter monitoring.

Arrhythmia detection in four of these patients when treadmill exercise showed only isolated ventricular premature beats.

Relationship of Arrhythmias to the Left Heart Dimension

The radiographic left heart dimension ranged from 33.6 to 67.8 (mean 47.4) mm/m² BSA in the 60 patients. The mean value of a large group of normal subjects was previously found to be 44.0 ± 4 mm (SD)/m². The left heart dimension (LHD) was enlarged (> 52 mm/m²) in 17 of 60 patients (28%). The mean LHD in patients with and without arrhythmias was almost identical, 47.5 and 47.4 mm/m², respectively. Eight of the 17 patients (47%) with an enlarged LHD had arrhythmias and 20 of 43 patients (47%) with a normal LHD had arrhythmias. Thus, an enlarged LHD did not appear to portend an increased risk of arrhythmias.

Relationship of Arrhythmias to Other Parameters

Few clinical parameters in the 60 post myocardial infarction patients correlated with the presence of arrhythmias, although all six patients in NYHA Class III had arrhythmias detected. The incidence in Class I and II patients was also high, 38 and 41% respectively. Four of five patients with symptomatic chronic obstructive lung disease and both patients with a history of cerebrovascular accident had arrhythmias detected, but their numbers were too small to make valid assumptions about the incidence of arrhythmias in such patients. Infarct location by electrocardiogram did not correlate with arrhythmia detection. Forty-nine percent of those with inferior infarctions and 40% of those with anterior infarctions had arrhythmias detected.

Arrhythmia detection also was not related to the response to exercise testing. The mean duration of exercise was somewhat longer in those without arrhythmias [370 ± 142 vs 398 ± 140 sec (SD)] but the difference was not statistically significant (P > 0.1). The mean heart rate response to exercise was identical in those with and without arrhythmias (145 ± 20). In addition, only 50% of patients with ST depression induced by exercise testing or recorded by continuous outpatient monitoring had arrhythmias detected, whereas 44% of those without ischemic ECG changes had significant arrhythmias.

Discussion

The primary purpose of identifying arrhythmias in patients with previous myocardial infarction is to select those patients who are at highest risk of sudden coronary death, so that prophylactic drug therapy can be instituted. A single ventricular premature beat on an electrocardiogram has been associated with an increased risk of sudden death in prospective studies of post myocardial infarction patients and in large, randomly selected populations. However, in a study of 101 post myocardial infarction patients, the presence of ventricular premature beats on the resting electrocardiogram did not correlate with an adverse prognosis during the first 5 years of follow-up. Accordingly, the reliability and sensitivity of the standard electrocardiogram for detecting significant arrhythmias have been questioned and other detection methods have been employed.

Kotler and associates employed continuous ECG monitoring in a study of 160 patients with previous myocardial infarction. Those with greater than one ventricular premature beat per 500 cycles, multiform ventricular ectopic beats and/or ventricular tachyarhythmias had an approximately sixfold increase in sudden death as compared to those without these arrhythmias. Thus, continuous ECG monitoring seems to be a sensitive method for reliably detecting those at risk for sudden death.

Exercise testing has been advocated as a quick, convenient way to induce arrhythmia in susceptible individuals, but the definition of a significant arrhythmia during exercise testing remains unclear. Kosowsky and associates considered any ventricular premature beat as abnormal. However, exercise testing in 561 clinically normal men revealed an incidence of ventricular premature beats from 31 to 49% depending upon age. Most of these arrhythmias occurred during the last 30 seconds of exercise and the first minute of recovery, usually when the heart rate was greater than 150 beats/min. By contrast, in 89 men with clinically apparent cardiovascular disease, ventricular premature beats occurred at slower heart rates. A long term, prospective, follow-up study of post myocardial infarction patients evaluated with exercise testing has not been done. Thus, the prognostic significance of arrhythmias detected by exercise is unknown.

To evaluate the results of our study, any ventricular premature beat on the standard electrocardiogram...
was considered significant (this being the only ventricular arrhythmia detected by this method), and all patients with this finding had an exercise study and/or a Holter monitor that was considered positive for arrhythmias. The criteria of Kotler and associates\(^4\) were used to designate significant arrhythmias during continuous ECG monitoring. We selected greater than two ventricular ectopic beats per minute during the exercise study because it identified patients who also had arrhythmias detected by other methods, and because of the high incidence of single premature beats in healthy subjects.\(^6\) If one or more ventricular ectopic beats with exercise had been used as the criteria, 39 of 60 (65%) would have had a positive treadmill study.

The selection of different frequency criteria for the significance of single ventricular ectopic beats clearly will alter the relative sensitivity of exercise testing and continuous ECG monitoring, but it is also evident that continuous monitoring detected major arrhythmias more often than did exercise testing. Only six instances of major arrhythmias were detected by exercise testing, whereas 14 instances of major arrhythmias were found with continuous monitoring, including the six patients detected by exercise (table 1). Our results vary from those of Kosowsky and associates,\(^3\) who detected twice the number of major ventricular arrhythmias with exercise testing as they did with continuous monitoring in 81 patients. However, their population was not limited to post myocardial infarction patients and included patients being evaluated for known arrhythmias. Moreover, Holter monitoring obviously involves a much greater period of observation than exercise testing, which undoubtedly enhances its sensitivity for detecting arrhythmias.

Theoretically, exercise testing might have limited sensitivity for detecting ventricular irritability, because the increased heart rate that accompanies exercise could diminish the propensity for ventricular premature beats. On the other hand, the ischemia which may accompany exercise in patients with coronary artery disease could lead to arrhythmias. Interestingly, however, there was no correlation in this study between ischemic ST segment changes with exercise testing and the frequency of arrhythmias. We also noted some patient reluctance to perform exercise testing because of a fear that vigorous exercise might damage the heart. This reluctance could have diminished performance and therefore the number of positive results.

Since the various clinical parameters evaluated in the present study were not very helpful in predicting which patients were likely to have arrhythmias, an objective evaluation for arrhythmias would seem necessary for all post myocardial infarction patients. The resting electrocardiogram detected only 29% of the arrhythmias demonstrable by the combined use of exercise testing and continuous ECG monitoring. Thus, patients should be evaluated by both techniques for the highest yield in arrhythmia detection. However, continuous ECG monitoring appears to be superior to exercise testing for several reasons. First, it is better accepted by patients with previous myocardial infarction. Second, it has detected more serious arrhythmias than exercise testing. Third, the prognostic significance of arrhythmias detected by continuous monitoring is well documented in post myocardial infarction patients,\(^4\) whereas comparable studies using exercise testing are not yet available.

It is remarkable that 47% of our post myocardial infarction patients who were not known to have arrhythmias and were not on antiarrhythmic drugs had presumably significant arrhythmias detected. Unfortunately, the efficacy of prophylactic antiarrhythmic therapy has not been established in a prospective study of post myocardial infarction patients with documented ventricular arrhythmias. Mass prophylaxis of all patients with a previous myocardial infarction with procaine amide has been attempted, but the large number of untoward reactions makes such indiscriminate use impractical.\(^1\) Quinidine sulfate may be more effective than procaine amide\(^13\) and may result in fewer side effects; however, careful studies using blood levels to insure the adequacy of therapy must be done before it can be ascertained that therapy with quinidine sulfate will reduce sudden death in post myocardial infarction patients with documented arrhythmias.

We conclude that unsuspected arrhythmias of presumed prognostic significance are common in patients with previous myocardial infarction. The resting ECG is not a sensitive method of detection but all patients with ventricular ectopic beats on their ECG had significant arrhythmias detected by treadmill exercise and/or continuous outpatient ECG monitoring. Treadmill exercise and continuous ECG monitoring are complimentary methods of arrhythmia detection, but in 60 post myocardial infarction patients continuous monitoring detected more major arrhythmias than treadmill exercise.

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