Evaluation of Chest Pain in Low-Risk Patients Presenting to the Emergency Department: The Role of Immediate Exercise Testing

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Study objectives: To determine the safety and utility of immediate exercise testing in the evaluation of low-risk patients presenting to the emergency department with chest pain and its applicability to a heterogeneous population of men and women.

Methods: We conducted a prospective study of the safety and utility of immediate exercise testing in low-risk patients, as indicated by clinical and ECG criteria. The study group was large, heterogeneous, and included patients with a history of coronary artery disease. The patients were treated at a large, university medical center. Exercise testing (immediate exercise treadmill testing) was performed by internists, and cardiac serum enzyme levels were not measured before the exercise test.

Results: A total of 212 patients (121 men, 91 women) underwent exercise testing with no adverse effects. Twenty-eight (13%) patients had positive results on exercise ECGs. Twenty-three of the latter had further evaluation that revealed evidence of coronary artery disease in 13 (57%). Fifty-nine percent (125/212) of patients had negative exercise test results and 28% (59/212) had nondiagnostic tests. All patients with negative test results and 93% with nondiagnostic test results were discharged directly from the ED. Thirty-day follow-up was achieved in 201 (95%) patients and revealed no mortality in any of the patients in the three groups. One patient with a positive exercise test result returned to the ED within 30 days with mild congestive heart failure.

Conclusion: Our results in this patient population support the safety and utility of immediate exercise testing of low-risk patients who present to the ED.

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INTRODUCTION

More than 5 million patients present annually to emergency departments with chest pain suggestive of myocardial ischemia.[1] Of the 2 million individuals in this group who are hospitalized for suspected myocardial infarction (MI), a coronary event is diagnosed in fewer than 30%.[2] More efficient management of low-risk patients with chest pain could reduce unnecessary hospitalizations, lower costs, and improve utilization of monitored beds, all of which are essential to cost-effective care. Studies during the past two decades have revealed that low-risk patients with chest pain can be identified by clinical evaluation at the time of presentation.[2-7] Brush et al[4] demonstrated that the initial ECG results alone can discriminate between high and low risk in these patients. They reported that a normal or near-normal ECG was associated with a .6% occurrence of serious complications during hospitalization compared with a 14% incidence in patients with abnormal ECGs. In a recent study of more than 10,000 patients who presented to EDs with acute chest pain, a group with less than 1% probability of major complications could be distinguished by the initial clinical assessment.[5] Furthermore, among patients hospitalized for suspected MI, a subgroup with a coronary event rate less than 5% could be identified on the basis of history, symptoms, and ECG.[6] The ability to recognize low-risk patients presenting with chest pain has led to alternatives to conventional coronary care for this group, including reduced time in coronary care units,[7,8] direct admission to a step-down unit,[9,10] and management in short-stay observation units.[11,12]

Although there has been concern regarding the potential hazards of stress testing in patients with a possible coronary event, the aforementioned data support the utility of clinical assessment in recognizing chest pain patients at low risk for a coronary event and its complications. Thus we have used immediate exercise treadmill testing in selected patients to identify those requiring admission and those who can undergo further evaluation as outpatients. Our preliminary report in a limited number of patients with no history of coronary artery disease (CAD) suggested that this strategy, as implemented by cardiologists, was practical and safe with the potential for major cost savings.[13] The current study extends this approach in several important respects: (1) the study group is larger and more heterogeneous, (2) patients with known CAD are not excluded, (3) exercise testing is performed by internists serving as attending physicians on the Chest Pain Emergency Department Service rather than cardiologists, who now serve as consultants as needed, and (4) cardiac enzyme levels are no longer measured before exercise testing.

MATERIALS AND METHODS

Patient Selection

All patients considered for hospital admission because of chest pain of suspected cardiac origin were eligible for this study. Patients' descriptions of chest pain varied from typical to atypical for cardiac ischemia. Low-risk patients were selected from this group on the basis of initial ECG interpretation by the chest pain ED attending physician; these initial ECGs were categorized as those that were either normal or had only minor nonspecific repolarization abnormalities. Patients with ECGs diagnostic for acute MI or ischemia were excluded as were those with repolarization abnormalities, such as associated with left ventricular hypertrophy or bundle branch block. Patients with clinically evident left ventricular dysfunction and those unable to perform a treadmill test were also excluded. Evaluation in the ED before treadmill testing included complete history, cardiac risk factor profile, physical examination with bilateral upper extremity blood pressure measurements, and chest radiograph to help exclude patients with clinical evidence of pulmonary embolism, aortic dissection, and other intrathoracic or intraabdominal processes. The study patients met our previous criteria for admission to rule out MI.[12] The presence of persistent chest pain did not preclude immediate exercise testing. Cardiac serum enzyme levels were not measured before exercise testing. However, blood samples were obtained before the test and held for subsequent measurement of enzyme levels in patients with a positive exercise test result. MI was diagnosed if the creatine kinase–MB fraction was elevated and subsequently declined to normal.

Clinical Protocol

Study patients were referred by emergency physicians to the attending physician on our chest pain ED service. This service comprises a specialized unit staffed by a physician from the Division of Emergency Medicine who provides subsequent care to patients with chest pain suspicious of an acute coronary syndrome, whose ECGs are not diagnostic for ischemia. Treadmill testing was available between 8 AM and 10 PM daily. Therefore the study design included consecutive patients seen in the ED during this interval who fulfilled the inclusion criteria. After the treadmill test, decisions regarding patient disposition and further evaluation

were made by the chest pain ED attending physician. Consultation with an attending cardiologist was obtained in selected patients. This protocol was previously approved by the Human Subjects Committee of the University of California–Davis, and consent for treadmill testing was obtained from the patients.

Exercise Test

Exercise treadmill testing was performed according to a modified Bruce protocol, as previously described.[12] The exercise test was performed immediately after an initial, negative screening examination, described above, in patients fulfilling study criteria. Endpoints for the exercise test were 1 mm or greater horizontal or downsloping ST-segment depression or elevation 80 ms after the J point, decrease in systolic blood pressure of 10 mm Hg or more, coupled ventricular ectopic beats, sustained supraventricular dysrhythmia, or significant symptoms. Criteria for a positive (ischemic) test result were the aforementioned ST-segment changes. A nondiagnostic test result was defined as one resulting in an exercise ECG without ischemic changes at a peak heart rate less than 85% of age-predicted maximum.

Further Diagnostic Studies

The frequency of true- and false-positive exercise test results was based on the subgroup of patients who underwent clinically indicated further evaluation by coronary angiography (positive= >50% reduction in coronary artery lumen diameter), myocardial stress (exercise or pharmacologic) scintigraphy by single photon emission computed tomography (positive=stress-induced perfusion defect), or stress (dobutamine or exercise) echocardiography (positive= stress-induced segmental wall motion abnormality).

Follow-Up Procedure

We attempted to determine the clinical status of all patients 30 days after the exercise test by the following measures: (1) review of each patient's medical record for evidence of return visits or hospitalization, (2) telephone interviews of patients, (3) return mail questionnaires, and (4) review of coroners' records in Sacramento and its five surrounding counties.

Statistical Analysis

Continuous data are presented as mean (median)±SD and were analyzed with Student's *t* test if there were more than 30 patients per group and Wilcoxon rank sum test if there were less than 30 per group. In addition, the Wilcoxon rank sum test was applied to ordinal variables. Dichotomous categorical variables were analyzed with Fisher's exact test. Ninety-five percent confidence intervals (CI) were given for differences in mean values for continuous data and for odds ratios (ORs) for dichotomous categoric variables. Differences were considered significant for *P* values less than .05.

RESULTS

Study Group

Of 424 consecutive patients referred to our chest pain ED service between October 1993 and October 1994, 223 patients met the study criteria for immediate treadmill testing. In 11 of the latter group, the test was deferred by individual decision of the chest pain ED attending physician. Therefore the study group comprised 212 patients (121 men, 91 women). As indicated in the Table, more than 90% of patients had no prior evidence of CAD. The men were younger than the women (46.7 versus 51.4 years, difference=4.7, 95% CI=–7.6 to –1.7). There were no significant differences between men and women in median number of cardiac risk factors (1 versus 1) and prior history of CAD (7% versus 4%, OR=1.7, 95% CI=.55 to 5.5).

Exercise Test

A majority of patients had negative exercise test results, approximately one fourth had nondiagnostic test results, and fewer than 15% had positive test results (Figure 1). The results of the exercise test were similar in men and women, respectively: negative (64% versus 52%, OR=1.7, 95% CI=.98 to 3.0), nondiagnostic (25% versus 32%, OR= .70, 95% CI=.39 to 1.3), positive (11% versus 16%, OR=.61, 95% CI=.28 to 1.3). The rate of positive exercise tests in patients with previously diagnosed CAD (23% [3/13]) did

Table.
Clinical characteristics of patients.

ParameterPP	Total	Men	Women
No. of patients	212 (100%)	121 (57%)	91 (43%)
Age (yr)	49±11	47±12	51±10
Median no. cardiac risk factors	1	1	1
History of CAD	13 (6%)	9 (7%)	4 (4%)

CAD defined as myocardial infarction or positive coronary angiogram; cardiac risk factors include hypertension, diabetes mellitus, hyperlipidemia, cigarette smoking, and family history of CAD.

not differ from those without a history of CAD (13% [25/199], OR=2.1, 95% CI=.58 to 7.6).

Follow-Up

Follow-up data at 30 days were available in 201 (95%) of the 212 patients, including all 28 patients (100%) with a positive exercise test result, 118 (94%) of those with negative test results, and 55 (93%) of the nondiagnostic group. The 11 patients for whom data were not available at 30 days did not differ significantly from those with 30-day follow-up with respect to median age, percent of men and women, proportion with documented CAD, or percent of age-predicted maximum heart rate attained during the exercise test. None of these 11 patients was among fatalities recorded by the coroners' offices of Sacramento and its five surrounding counties during the 30-day follow-up interval.

Patients With Positive Exercise Test Results

Of the 28 patients with positive exercise test results, 23 underwent further diagnostic studies that yielded positive results in 13 (coronary angiography 9/12, myocardial stress scintigraphy 3/5, dobutamine echocardiography 1/6). On the basis of these findings, the positive predictive value of the immediate exercise test was 57% (13/23). Median age was significantly higher in men with a true-positive test result than in men without a true-positive test result (60 versus 44 years, *P*=.006), but there was no difference in median age between women with a true-positive test result and those without a true-positive test result (50 versus 50 years). The median age of all patients with true-positive test results was significantly higher than that of all other study patients (57 versus 47 years, *P*=.03). The predictive accuracy of a positive test did not differ in men (50% [5/10] and women 62% [8/13], OR=.63, 95% CI=.12 to 3.2). The median number of cardiac risk factors was higher in patients with positive exercise tests results than in those with negative test results (2 versus 1, *P*=.02) but did not differ in the group with true-positive test results compared with those with false-positive results (2 versus 2).

There were no adverse effects of immediate exercise testing. In the 28 patients with positive test results, serial cardiac serum enzyme studies on blood obtained before the exercise test and on subsequent samples revealed non–Q-wave MI in two patients and a previously unrecognized inferior Q-wave MI in one patient that most likely occurred 3 days before the exercise test. The serum enzyme patterns did not appear to be altered by the exercise test (Figure 2). The clinical course in each of these patients was uncomplicated. Diagnosis in the other 10 patients with true-positive test results was unstable angina based on history and further noninvasive or invasive testing, or both, as described above. Clinical course in these 10 patients was uncomplicated at 30 days.

Of the 13 patients with true-positive exercise test results, four underwent elective percutaneous transluminal coro-

Figure 1.
Percent of patients with negative, nondiagnostic, and positive immediate treadmill tests result. (n=Number of patients.)

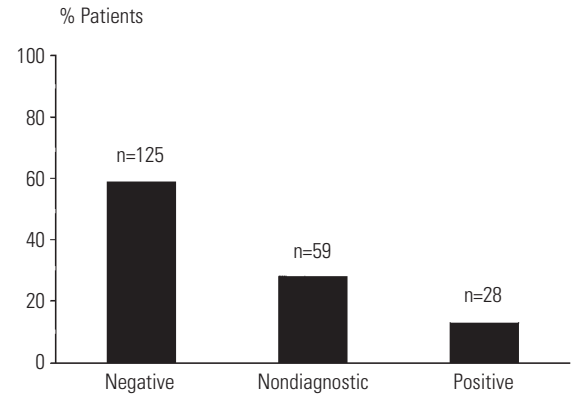
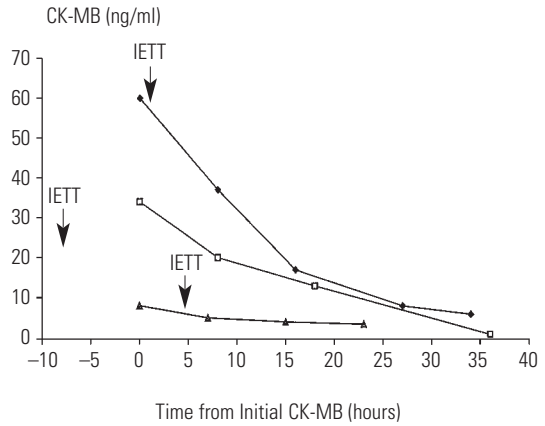


Figure 2.
Temporal relationship of serum creatine kinase–MB fraction (CK-MB) to immediate exercise treadmill test (IETT) in three patients with enzyme evidence of acute MI. The evolution of CK-MB concentration is consistent with elevation before exercise testing.



nary angioplasty, two had elective coronary artery bypass graft surgery, and seven were managed medically. The remaining 15 patients with positive exercise test results (those with false-positive results and those declining further diagnostic studies) were managed medically. Three of the latter group returned to the ED within 30 days, two with stable angina and one with mild congestive heart failure. There was no mortality at 30 days in the 28 patients in this group.

Patients With Negative Exercise Test Results

All 125 patients with negative exercise test results were discharged directly from the ED after completion of the test. There were no significant differences in mean age between patients with negative exercise test results and those with positive or nondiagnostic test results (49.7 versus 48.0 years). The median number of cardiac risk factors in patients with negative exercise test results was lower than in those patients with positive or nondiagnostic test results (1 versus 2, P=.008). Cardiac enzyme levels were not measured in any patients in this group. Two patients underwent further outpatient studies within 30 days. One had a second negative exercise test result, and the other underwent elective coronary angiography, which revealed no change from a previously abnormal angiogram. There was no morbidity or mortality at 30 days in the patients (94%) in whom follow-up was achieved.

Patients With Nondiagnostic Exercise Test Results

Fifty-five (93%) of the 59 patients in this group were discharged directly from the ED after completion of the exercise test and four were admitted for further evaluation, which demonstrated no cardiac events or complications. Although the mean percent of age-predicted maximal heart rate during the exercise test in the entire nondiagnostic group was 74%±10%, a majority (54%) attained a heart rate between 75% and 84% of the age-predicted maximum. There was no difference in percent of predicted maximum heart rate achieved in men and women (77% versus 74%). There were no significant differences between the 59 patients in this group and the rest of the study group, respectively, in age (48 versus 49 years) and median number of cardiac risk factors (1 versus 1).

Follow-up data obtained in 93% of this group revealed no morbidity or mortality at 30 days. Further evaluation in 11 patients within 30 days was positive in three (myocardial stress scintigraphy—3/6; dobutamine echocardiography—0/2; coronary angiography—0/3). There was no morbidity or mortality during the 30-day follow-up period in any of the 55 patients.

Excluded Patients

Of the 11 patients who met study criteria but were excluded from immediate exercise testing, no cardiac events were detected during hospitalization. Subsequent evaluation in nine patients was positive in two (exercise test—0/4; dobutamine echocardiography—0/2; myocardial stress scintigraphy—1/1; coronary angiography—1/2). There was no morbidity or mortality at 30 days in the 11 patients, one of whom underwent elective coronary artery bypass graft surgery.

DISCUSSION

This study demonstrates the safety and utility of immediate exercise testing in a large group of low-risk patients presenting to the ED with chest pain. Clinical indicators reliably identified low-risk patients who were candidates for exercise testing, which afforded stratification of these patients into a group that could be discharged and a group requiring admission. Only 13% of patients had positive exercise test results, of which slightly more than half were true positives. Not surprisingly, an increased number of coronary risk factors, including age, was associated with an increased rate of positive exercise test results. No complications resulted from exercise testing and follow-up at 30 days revealed no mortality. During this interval, only one patient required hospitalization because of mild congestive heart failure, in addition to the patients readmitted for elective procedures. Our results, therefore, demonstrate that nearly 90% of patients initially identified as low risk by clinical assessment[3-6,14,15] can be safely discharged from the ED based on the results of the exercise test.

These findings confirm those of our pilot study on immediate exercise testing in this patient population.[13] In addition, they extend our earlier results since, in the current investigation, cardiac serum enzyme levels were not measured before exercise testing, patients with documented CAD were included, and exercise testing was performed by internists with cardiologists serving as consultants in selected patients. Our findings with this expanded protocol continue to indicate a low rate of positive exercise test results in this patient population, and they confirm the utility and safety of this approach in enhancing cost-effective management. Moreover, our results demonstrate the broad applicability of this method, which was equally useful in men and women over a wide age range.

The rationale of our approach is based on clinical studies that have demonstrated that low-risk patients presenting to the ED with chest pain can be identified by clinical indi-

cators, have a very low coronary event rate, and neither require nor benefit from management in coronary care units.[3-15] Moreover, recently published guidelines on the management of unstable angina[16] suggest that low-risk patients (who are similar in clinical characteristics to the patients in this study) can, in many cases, be safely discharged from the ED and managed as outpatients. Therefore, based on algorithms for identifying low-risk patients with acute chest pain,[5,6] we predicted a 5% coronary event rate in our study group, which was similar to the 6% (13/212) recognized in our patients. Because 5 of the 28 patients with positive exercise tests were not admitted and declined further evaluation, the precise rate of coronary events in our patients is uncertain. However, if all 5 had a coronary event, the resultant rate of 8.5% would still approximate that predicted.

Our results suggest that immediate exercise testing in selected patients with acute chest pain is safe despite the possibility of testing patients with unrecognized MI or ischemia. All 13 patients with subsequent diagnoses of unstable angina or myocardial infarction had positive exercise test results with no associated complications. Cardiac enzyme data in the three patients with infarction were consistent with elevation of these serum markers before exercise testing; moreover, the pattern of enzyme evolution did not appear to be affected by the exercise test. Exercise testing proved safe in our small, select group of patients with known CAD, supporting further investigation of this patient population.

Although IETT was safely performed in 13 of our patients with an acute coronary syndrome (ACS), this experience is insufficient to confirm the safety of the procedure. However, support for this approach is provided by our earlier experience, which included 6 patients with an ACS,[13] our recent report of IETT in 70 patients with documented CAD without adverse effects,[17] and the safe performance of IETT in 900 patients since the conclusion of the study reported herein. To maximize the safety of this method, two components are mandatory: appropriate selection of low-risk patients, and high levels of skill and experience in performing and interpreting treadmill exercise testing.

The use of IETT in ED patients with chest pain has been met with considerable resistance. Exercise testing in the outpatient setting has proven to be very safe, with a reported complication rate of .8 per 10,000 tests.[18] Many patients undergoing such testing have had acute symptoms and are subsequently found to have severe CAD. Although data are insufficient to draw firm conclusions, the low risk of exercise testing in the latter group may be similar to that of IETT in our study group. Further investigation of this question is warranted.

Although we used conventional criteria to define a nondiagnostic exercise test (no ischemic ECG alterations at a peak heart rate <85% of age-predicted maximum), this definition may not be appropriate when the test is used to exclude ischemia, in contrast to its standard application for detecting CAD in patients in stable condition. More than half of our patients with nondiagnostic exercise test results reached heart rates in excess of 75% of predicted maximum. The lack of ECG evidence of ischemia at these heart rates is consistent with absence of an acute ischemic process in a group with a very low pretest probability of active myocardial ischemia. Therefore we believe that patients without ischemic ECG changes at exercise heart rates in excess of 75% of age-predicted maximum may frequently not require hospitalization.

Several limitations of this study require consideration. Because immediate exercise testing was available only 14 hours each day, all patients fulfilling study criteria could not be included. However, our study group is representative of low-risk patients frequently admitted to exclude MI.[2-14] The 11 patients who were excluded by individual physician decision did not differ from the entire study group in their clinical characteristics and outcomes. Because not all patients with negative and nondiagnostic test results underwent serial ECG and cardiac enzyme testing, unstable angina or MI may not have been recognized in some individuals. However, it is unlikely that a serious cardiac event was overlooked in these low-risk patients since there were no major morbid events during the follow-up period. Although our patient follow-up was incomplete, data were missing in only 5% and these individuals did not differ from the entire patient population in their clinical characteristics.

Innovative approaches to the management of low-risk patients with chest pain have been evolving for more than a decade.[3] Immediate exercise testing is a new concept that provides a safe and reliable method for risk stratification of these patients into those requiring admission and those who can be discharged and undergo further management as outpatients. This approach improves utilization of telemetry beds, affords vital cost savings, and maintains sound patient care.

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