Immediate Exercise Testing to Evaluate Low-Risk Patients Presenting to the Emergency Department With Chest Pain

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OBJECTIVES Our purpose was to determine the safety and accuracy of immediate exercise testing in low-risk patients presenting to the emergency department (ED) with chest pain suggestive of a cardiac etiology.

BACKGROUND Safe, efficient management of low-risk patients presenting to the ED with chest pain is a continuing challenge. We have employed immediate exercise testing to evaluate a large, heterogeneous group of low-risk patients presenting with chest pain.

METHODS Patients presenting to the ED with chest pain compatible with a cardiac origin and clinical evidence of low risk on initial assessment underwent immediate exercise treadmill testing in our chest pain evaluation unit. Indicators of low clinical risk included no evidence of hemodynamic instability, arrhythmias or electrocardiographic signs of ischemia. Serial measurements of cardiac injury markers were not obtained.

RESULTS Exercise testing was performed to a sign- or symptom-limited end point in 1,000 patients (520 men, 480 women; age range 31 to 82 years) and was positive for ischemia in 13%, negative in 64% and nondiagnostic in 23% of patients. There were no adverse effects of exercise testing, and all patients with a negative exercise test were discharged directly from the ED. At 30-day follow-up there was no mortality in any of the three groups. Cardiac events in the three groups included: negative group, 1 non–Q-wave myocardial infarction (MI); positive group, 4 non–Q-wave MIs and 12 myocardial revascularizations; nondiagnostic group, 7 myocardial revascularizations.

CONCLUSIONS Immediate exercise testing of patients presenting to the ED with chest pain and evidence of low clinical risk is safe and accurate for determining those who require admission and those who can be discharged to further outpatient evaluation. (J Am Coll Cardiol 2002;40:251–6) © 2002 by the American College of Cardiology Foundation
have included limited numbers of patients. This investigation extends our previous findings on the safety and efficacy of immediate exercise testing to a much larger group of low-risk patients. Some patients in this study were included in a previous report (11).

MATERIALS AND METHODS

Patients. The study group comprised consecutive patients who underwent immediate exercise testing if they presented to the ED with nontraumatic chest pain of suspected cardiac etiology but were considered to be at low clinical risk. Chest pain varied from typical to atypical for myocardial ischemia. Persistent chest pain did not preclude exercise testing, and patients with previously documented coronary artery disease (CAD) were not excluded. Prior evidence of CAD was based on coronary angiography or electrocardiographic (ECG) and/or serum marker criteria of MI. Criteria of low risk included hemodynamic stability, no arrhythmia and no evidence of an acute cardiopulmonary process on physical examination (ECG) or chest roentgenogram. Each patient’s coronary risk factors were assessed by history and medical record. At the discretion of the attending physician in the ED or in the Chest Pain Evaluation Unit, a single cardiac serum marker (creatinine kinase-MB or troponin I) was measured in selected patients prior to the exercise test, which was performed if the marker was negative. Inclusion criteria were a resting ECG that was normal, had only minor ST-T changes (<0.5 mm ST depression and/or flat but not inverted T waves) or, if abnormal, was unchanged from a prior ECG. The presence of pathologic Q waves, if documented to be old, did not preclude exercise testing. If the patient presented with an abnormal ECG and no prior ECG was available for comparison, the patient was excluded from immediate testing. Patients whose ECGs demonstrated changes of ischemia or infarction were excluded, as were patients with repolarization changes on the baseline ECG that precluded accurate interpretation of the exercise ECG.

The evaluation and risk stratification of patients presenting to the ED with chest pain, which includes immediate exercise testing in low-risk patients, is considered standard of care at our institution. Approval by the University of California-Davis, Human Subjects Review Committee was obtained before the beginning of data collection on immediate exercise testing, and a statement of exemption for this study was subsequently granted by the Review Committee. All data are part of our continuous quality-improvement process.

Exercise test. All exercise tests were performed by internists who serve as attending physicians in our Chest Pain Evaluation Unit. These physicians are not trained in emergency medicine but have special training in the evaluation of patients with chest pain and in performing and interpreting exercise treadmill tests. We have previously reported the comparability of these physicians to cardiologists in the performance and interpretation of exercise tests in the ED setting (13). Exercise testing was provided between 8:00 AM and 8:00 PM daily. Therefore, the study group includes patients seen during this interval who fulfilled the inclusion criteria. The exercise test procedure has been previously reported (10–12). Briefly, immediately after the aforementioned screening evaluation, patients were transported to the exercise testing laboratory where a modified Bruce protocol was employed. Exercise end points included significant symptoms, ECG evidence of myocardial ischemia (1.0 mm horizontal ST–segment shift at 80 ms after the J point), 10 mm Hg decrease in systolic blood pressure, coupled ventricular extrasystoles or a sustained supraventricular tachyarrhythmia. The criteria for a positive test for ischemia were the previously noted exercise-induced ST–segment alterations. A nondiagnostic test was defined by absence of ECG evidence of ischemia at a heart rate <85% of age-predicted maximum.

Further evaluation. Evaluation subsequent to immediate treadmill testing consisted of further cardiac studies and/or clinical follow-up, which was attempted in each patient to determine clinical status at 30 days after the immediate treadmill test.

The predictive value of a positive exercise test was determined by further studies in the subgroup of patients with a positive test. These studies included coronary angiography, in which a significant stenosis was defined as >50% reduction in lumen diameter of a major coronary artery; myocardial stress (exercise or pharmacologic) scintigraphy by single-photon emission computed tomography in which a positive test was a stress-induced myocardial perfusion defect; or stress (exercise or dobutamine) echocardiography, in which a positive test was a stress-induced ventricular wall motion abnormality.

Patients with negative immediate exercise tests were discharged from the ED with a referral for outpatient follow-up. Patients with positive tests were admitted for further evaluation. Depending on the individual exercise test findings, patients with nondiagnostic tests were either discharged from the ED or admitted to the Chest Pain Evaluation Unit for further assessment.

Follow-up was attempted in all patients to determine clinical status at 30 days after exercise testing by: 1) review of the patient’s medical record; 2) telephone interviews of the patients; 3) mailed questionnaires; 4) review of coroners’ records in Sacramento and its five surrounding counties; and 5) the Social Security Death Index.
1.69 [95% CI 0.69 to 1.00], p = 0.05. Negative tests were more frequent in men than in women (69% vs. 57%, OR 1.3 to 2.2, p < 0.001) and men had fewer nondiagnostic tests (20% vs. 28%, OR 0.63 [95% CI 0.47 to 0.85], p = 0.003). There was no difference in the ages of the patients in the three exercise test groups. Median number of coronary risk factors was one in the positive and negative groups and two in the nondiagnostic patients.

**Follow-up.** Based on data from the Social Security Death Index, there was no mortality in any of the groups. Clinical follow-up at 30 days after exercise testing was obtained in 85% of patients, including 89% with negative tests, 78% of the nondiagnostic group and 77% with positive tests. The group of 149 patients (15%) in whom clinical follow-up was not obtainable did not differ from the patients with follow-up data within their respective subgroups (negative, positive, nondiagnostic exercise tests) with respect to age, gender, median number of coronary risk factors, proportion with known CAD and percent of maximum predicted heart rate attained during exercise testing.

The group (15%) in whom clinical follow-up at 30 days was not obtainable included 68 patients (11%) with negative immediate exercise tests, 10 of whom underwent additional diagnostic testing within the 30-day interval. Of the 29 patients (23%) with positive tests in whom 30-day clinical follow-up data were unavailable, 18 had further testing. In the 52 patients (22%) with nondiagnostic tests in whom 30-day follow-up data were unavailable, 9 had additional testing. Therefore, clinical follow-up and/or further cardiac testing was available within 30 days in a total of 888 patients (89%), including 91% in the negative immediate exercise test group, 91% in the positive group and 82% in the nondiagnostic group (Table 2).

**Negative exercise tests.** The 640 patients in this group included 363 men (57%) and 277 women (43%). Heart rate achieved during the exercise test for the entire group was 92% of age-predicted maximum and was slightly but significantly higher in men than in women (92% vs. 90%, p < 0.01). All patients with negative tests were discharged directly from the ED. Of the 582 patients (91%) with clinical follow-up or further diagnostic evaluation within 30 days, the only cardiac events were non-Q-wave MI in 1 patient and a diagnosis of CAD in another based on myocardial stress scintigraphy (Table 2).

**Positive exercise tests.** Of the 125 patients with positive tests (55 men [44%], 70 women [56%]), 102 (82%) had further diagnostic testing, which yielded positive results in 33 (coronary angiography, 28/48; myocardial stress scintigraphy, 4/29; stress echocardiography 1/25) (Table 2). Based on these findings, the positive predictive value of the initial exercise test was 33% and was higher in men than in women (36% vs. 19%, p = 0.025). Heart rate attained during the exercise test was 85% of predicted maximum for the total group. This value was lower in patients with true positive tests (80%) than with false positive tests (87%, p < 0.001).

Median age was greater in patients with a true positive than a false positive exercise test (58 ± 11 years vs. 50 ± 11 years, p < 0.001). Of the 96 patients with clinical follow-up at 30 days,
cardiac events occurred in 16 (17%): non-Q-wave MI, 4 patients; myocardial revascularization, 12 patients (Table 2). The four non-Q-wave MIs were detected by cardiac serum injury markers in blood obtained before the exercise test and reported after hospital admission. Evolution of the injury markers in each of these four patients revealed a descending pattern consistent with onset of infarction prior to the exercise test, which did not appear to alter the pattern of evolution. All infarctions were uncomplicated, and all four patients underwent elective coronary angioplasty during the hospitalization. Of the 29 patients who did not have clinical follow-up for 30 days, 18 underwent further testing within this interval, and it was positive in 2 (coronary angiography 1/4, stress scintigraphy 1/7, stress echocardiography 0/7).

**Nondiagnostic exercise tests.** This group of 235 patients included 102 men (43%) and 133 women (57%). Further diagnostic evaluation, performed in 79 patients (34%), was positive for CAD or ischemia in 25 (coronary angiography 9/16, stress scintigraphy 14/44, stress echocardiography 2/19) (Table 2). Clinical follow-up for 30 days in 183 patients (78%) demonstrated no MIs during this interval. Seven of the patients underwent elective coronary revascularization (coronary angioplasty, 3; coronary artery bypass graft surgery, 4) (Table 2).

Group mean heart rate attained during the initial exercise test was 73% of age-predicted maximum, and this did not differ in either men or women. Of the patients in this group, 58 (25%) reached a heart rate 80% to 84% of age-predicted maximum, and further evaluation was positive for CAD by coronary angiography in three patients (5%), one of whom underwent coronary angioplasty. No MIs occurred during the 30-day follow-up interval in this subgroup.

**Comparative predictive value of immediate exercise test results.** In those patients with 30-day clinical follow-up or a confirmatory diagnostic test during this interval, the predictive value of the three immediate exercise test results (positive, negative, nondiagnostic) was compared for the total number of coronary events (mortality, MI or revascularization) or diagnosis of CAD (by coronary angiography or cardiac stress imaging). The rate of an event and/or diagnosis of coronary disease was 29% (33/114) in the positive group, 13% (25/192) in the nondiagnostic patients and 0.3% (2/582) in those with negative tests. Compared to a negative exercise test, the relative risk of a nondiagnostic test for the aforementioned end points was 38 (95% CI = 9 to 161, p < 0.0001) and that of a positive test was 114 (95% CI = 27 to 484, p < 0.0001).

**DISCUSSION**

The results of this study not only confirm our earlier reports on the safety and utility of immediate exercise testing but also extend them to a much larger group of low-risk patients presenting to the ED with chest pain (10–13). The study population was diverse and included men and women of a wide age range extending to over 80 years. In addition, more than 7% of patients had previously documented CAD. Of primary importance, there were no adverse effects of exercise testing. The major clinical advantage of this strategy has been facilitation of appropriate discharge directly from the ED in a majority of these patients by safe, efficient documentation of absence of exercise-induced myocardial ischemia. The utility of this method is further demonstrated by the high relative risk of CAD or a coronary event in patients with a positive immediate exercise test compared to those with a negative or nondiagnostic result.

The majority of patients presenting to the ED with chest pain are at relatively low risk for a coronary event, and this group can be identified by clinical assessment at the time of presentation (1,5–7). Clinical recognition of low risk has provided a rationale for innovative management strategies for these patients, thus obviating the need for traditional hospital admission to “rule out MI.” However, because at least 2% of patients with a coronary event are inadvertently discharged from the ED (3,4), further assessment for an ACS is mandatory. To this end, accelerated diagnostic protocols are now increasingly implemented in chest-pain observation units by a 6–12-h period of ECG monitoring and serial cardiac serum markers (1,7–9). Negative results are commonly followed by stress testing either before patients are discharged or in the early postdischarge period.

Evaluation of low-risk patients at the time of presentation to the ED has also been performed by myocardial scintigraphy in which negative results have accurately identified those who do not require hospital admission (14). In this

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*Within 30-day follow-up period. †Some patients had both a “clinical event” and a “positive test for CAD.” ‡Number with clinical follow-up and/or further diagnostic evaluation of total number in group.

CAD = coronary artery disease; IET = immediate exercise test; MI = myocardial infarction.
regard, a comparative study of low-risk patients presenting with chest pain revealed that early treadmill exercise testing was as informative as, and more cost-effective than, scintigraphy in identifying patients who did not require hospitalization (15). It is our experience, as well as that advocated in the foregoing study (15), that exercise testing is suitable for evaluation of the majority of low-risk patients presenting with chest pain and that scintigraphy should be reserved for the minority in whom exercise testing is not feasible (16).

In our application of immediate exercise testing, clinical indicators of low risk have reliably identified patients who are appropriate candidates for this approach. As reported in our earlier studies, only a small proportion of patients had a positive exercise test (10–12), of which slightly more than one-third were true positives based on further evaluation. The high rate of false positive results is typical of a low-risk population (17). As expected, men had a higher rate of true positive tests than women (36% vs. 19%), and patients with a true positive result were older than those with false positive results (58 vs. 50 years). Despite the low frequency of true positive tests, there was a considerable gradient of risk between the groups with the three immediate exercise test results. The total rate of coronary events and diagnosis of coronary disease in the negative group was only 1.0% that of patients in the positive group and 2.3% that of patients with nondiagnostic results.

The occurrence of only one coronary event at 30 days in the patients with negative results confirmed the reliability of the exercise test in predicting low short-term risk, thereby complementing the clinical impression and permitting direct discharge of these patients from the ED. It is noteworthy that one-fourth of patients with nondiagnostic initial exercise tests reached a heart rate 80% to 84% of predicted maximum, and there were no MIs or deaths in this subgroup. This finding suggests that absence of exercise-induced ischemia at heart rates 80% or more of predicted maximum may be adequate for identifying low short-term risk in patients with clinical evidence of only modest risk on presentation. This concept requires further investigation.

Although clinical assessment is basically reliable in identifying low-risk patients with chest pain, it is imperfect and can result in inadvertent failure to admit a small proportion of patients with unrecognized ACS (3,4). This problem is reflected by the inclusion of four patients with occult non–Q-wave MIs in those we selected for immediate exercise testing. All of these patients had positive exercise tests, serum enzyme evidence of infarction, an uncomplicated course and successful myocardial revascularization. To minimize this hazard, we now obtain one set of cardiac injury markers prior to exercise testing. Our overall record of safety is based upon the application of rigorous selection criteria for exercise testing and indications for terminating the test. In our system, internists trained in exercise testing staff the Chest Pain Evaluation Unit and perform all exercise tests (13). In this regard, our method differs from that of Senaratne et al. (15), who emphasize the direct involvement of cardiologists in the exercise test.

**Study limitations.** Our study has several limitations. Although mortality data were available for all patients, clinical follow-up is incomplete. However, in this large study population, 30-day data were obtained in 85% of patients. Further, nearly 90% of the total group had either clinical follow-up or further diagnostic studies within 30 days. Additionally, no differences were observed in important clinical characteristics between the patients with and without 30-day clinical follow-up. Because patients with negative and nondiagnostic exercise tests who were directly discharged from the ED did not have serial ECGs and cardiac serum marker testing, an ACS may not have been recognized in some. However, the absence of mortality and major morbidity during the follow-up period reduces this possibility. Although the follow-up interval was only 30 days, it was our purpose to assess the utility of immediate exercise testing in the assessment of short-term risk. This strategy is predicated on timely patient follow-up and further outpatient evaluation. Finally, our approach entails the possibility of performing exercise testing in patients with an unrecognized ACS. Although there have been no complications in these patients, continued caution is a critical element of this process.

Innovative approaches have been developed to promote cost-effective, accurate evaluation of low-risk patients presenting with acute chest pain. Application of our strategy in a large, heterogeneous patient population has proven safe and accurate for risk stratification, identifying those patients who require hospital admission and those who can be safely discharged and managed as outpatients.

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**REFERENCES**


