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Randomized Comparison of a Strategy of Predischarge Coronary Angiography Versus Exercise Testing in Low-Risk Patients in a Chest Pain Unit: In-Hospital and Long-Term Outcomes

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OBJECTIVES This randomized trial compared a strategy of predischarge coronary angiography (CA) with exercise treadmill testing (ETT) in low-risk patients in the chest pain unit (CPU) to reduce repeat emergency department (ED) visits and to identify additional coronary artery disease (CAD).

BACKGROUND Patients with chest pain and normal electrocardiograms (ECGs) have a low likelihood of CAD and a favorable prognosis, but they often seek repeat evaluations in EDs. Remaining uncertainty regarding their symptoms and diagnosis may cause much of this recidivism.

METHODS A total of 248 patients with no ischemic ECG changes triaged to a CPU were randomized to CA (n = 123) or ETT (n = 125). All patients had a probability of myocardial infarction ≤7% according to the Goldman algorithm, no biochemical evidence of infarction, the ability to exercise and no previous documented CAD. Patients were followed up for ≥1 year and surveyed regarding their chest pain self-perception and utility of the index evaluation.

RESULTS Coronary angiography showed disease (≥50% stenosis) in 19% and ETT was positive in 7% of the patients ($p = 0.01$). During follow-up (374 ± 61 days), patients with a negative CA had fewer returns to the ED (10% vs. 30%, $p = 0.0008$) and hospital admissions (3% vs. 16%, $p = 0.003$), compared with patients with a negative/nondiagnostic ETT. The latter group was more likely to consider their pain as cardiac-related (15% vs. 7%), to be unsure about its etiology (38% vs. 26%) and to judge their evaluation as not useful (39% vs. 15%) ($p < 0.01$ for all comparisons).

CONCLUSIONS In low-risk patients in the CPU, a strategy of CA detects more CAD than ETT, reduces long-term ED and hospital utilization and yields better patient satisfaction and understanding of their condition. (J Am Coll Cardiol 2001;37:2042–9) © 2001 by the American College of Cardiology

Recent reports in the media portray a decline in the public's perception of the capability of emergency departments (EDs) to provide rapid and effective care, as a result of an overburdened system (1). Chest pain symptoms alone account for more than five million patient visits annually to EDs (2). However, objective electrocardiographic (ECG) evidence of myocardial ischemia is present in only slightly more than one fourth of these patients, and a final diagnosis of an acute coronary syndrome is made in less than one fifth (3,4). Therefore, in recent years, the concept of chest pain units (CPUs) has been popularized as a rapid, efficacious and cost-effective alternative to in-patient hospital admissions for those patients without ischemic ECG changes and a low probability of myocardial infarction (MI) (5,6). Although rapid evaluation of these patients, utilizing sensitive biochemical markers of myocardial injury and predischarge exercise treadmill testing (ETT), is now common practice, it remains uncertain whether such protocols adequately test for the presence of underlying coronary artery disease (CAD) (7–9). This uncertainty is reflected by the fact that as many as 21% of ED chest pain evaluations are for repeat visits within six months of the initial presentation (10,11).

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The present study addresses two important issues related to this current practice. First, what are the prevalence and angiographic features of CAD in low-risk patients with chest pain? Second, will a negative invasive diagnostic strategy reduce the uncertainty among patients and physicians and result in fewer returns to the ED and hospital admissions? A prospective, randomized design was used to compare in-hospital and one-year outcomes using predis-

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Abbreviations and Acronyms

CA = coronary angiography or angiogram
CAD = coronary artery disease
CPU = chest pain unit
ECG = electrocardiogram or electrocardiographic
ED = emergency department
ETT = exercise treadmill test or testing
MI = myocardial infarction

charge CA versus ETT after ruling out MI in a CPU setting.

METHODS

Design and patient selection. This trial was conducted at the University of Texas Medical Branch at Galveston, a public teaching hospital. Patient screening and enrollment occurred, and informed consent was obtained in the hospital's CPU from November 1995 through February 1997. Inclusion criteria were age 20 to 65 years; low probability (≤7%) of acute MI, according to the Goldman algorithm (12); absence of new ST segment or T wave changes diagnostic or suggestive of ischemia; no evidence of ischemia or injury, as assessed by biochemical markers (creatine kinase, MB fraction mass <5 ng/ml and cardiac troponin T <0.2 ng/ml by qualitative testing) at ≥10 h from symptom onset; the ability to exercise; and no previous documented CAD. In addition, patients who had previous CA within the past four years, noninvasive testing for CAD within the past two years or ECG confounders for ETT interpretation (left bundle branch block, left ventricular hypertrophy with strain or ventricular paced rhythm) were also excluded.

Among 550 consecutive patients screened, 248 met the entry criteria and agreed to be randomized to either CA or ETT. Patients were considered for randomization when either test could be performed within 24 h of presentation. Therefore, patients presenting between Sunday evening and Friday were eligible for enrollment. The Institutional Review Board approved the project. Written, informed consent was obtained from each patient.

Intervention and management. Data on demographics, risk factors and the quality of chest pain were collected in a prospective, standardized manner before diagnostic testing. The details of medication use, including anti-ischemic drugs, gastric acid inhibitors and psychotropic medications, were also recorded.

After consent, patients were randomized to ETT or CA. The patients assigned to ETT were evaluated using a symptom-limited, standard or modified Bruce protocol. A cardiologist not involved in the study interpreted the tests. The ETT was considered positive if ≥0.1 mV of new horizontal or downsloping ST segment depression or ST segment elevation >60 ms beyond the J point occurred during exercise or recovery in two or more contiguous leads. A nondiagnostic test was defined as a negative ETT with a peak heart rate <85% of the age-predicted maximal heart rate. However, the results from patients who did not achieve the target heart rate, but who completed ≥10 metabolic equivalents, were also considered as negative because we anticipated that this low-risk chest pain population would include young, physically fit individuals. Patients with positive exercise results were referred to CA at the discretion of the attending physician. Patients with negative/nondiagnostic ETTs were discharged without further inpatient evaluation.

For patients randomized to CA, the procedure was performed using a standard femoral approach. In the presence of CAD, decisions regarding revascularization were made by the attending physician. Patients with normal angiograms were observed for ~6 h before discharge. All angiographic results of this study were obtained by quantitative off-line analysis. Coronary artery disease was defined as "moderate" when there was 50% to 69% lumen narrowing of a major epicardial artery or its branches, or as "severe" when there was ≥70% diameter stenosis. Angiographic lesion features, including length, calcification, thrombus and complexity, were analyzed by two independent observers, using previously reported definitions (8,13).

All patients were seen before discharge by one of the investigators. Patients with a normal CA or a negative ETT were told that they had no noteworthy CAD and that their prognosis was excellent. Patients with nondiagnostic ETTs were told that although they did not achieve their target heart rate, based on their exercise capacity and the absence of ECG findings, the probability of a cardiac ischemic etiology for their symptoms was very low and their discomfort did not necessitate worry or require any limitations of daily activities. For all patients, a letter summarizing the test results and discharge diagnosis was sent to the patients' regular physicians.

Follow-up. To facilitate subsequent medical care after discharge, all patients were offered referral to a primary care physician if they did not have regular medical follow-up. Patients were followed up by telephone interviews every three months for a minimum of one year. End points included death, MI, return to the ED with chest pain as the chief complaint and hospital admissions for chest pain. Medical records were reviewed to confirm the end points. In addition, patients were queried about recurrent chest pain, which was defined as frequent when there were four or more episodes per month, similar in quality to the initial presentation. At six months, using a standardized questionnaire, the patients were surveyed about their current perception of chest pain as cardiac or noncardiac and the utility of their index cardiovascular evaluation, to provide insight into the etiology of their symptoms.

Statistical analysis. Outcome analyses were based on the intention-to-treat principle. Analysis of variance and chi-square tests for multi-way contingency tables were used to compare group differences for continuous and categorical data, respectively. Freedom from ED returns between the

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Table 1. Prerandomization Characteristics in All Patients and Patients Grouped by Test Results

	All Patients Group (n = 248)	Positive CA Group (n = 23)	Positive ETT Group (n = 9)	Negative CA Group (n = 100)	N/N ETT Group (n = 116)
Demographic data					
Age (years)	49 ± 8	53 ± 8*	48 ± 8	48 ± 9	48 ± 9
Male gender	110 (44%)	12 (52%)	5 (56%)	39 (39%)	54 (47%)
Race					
White	148 (60%)	17 (74%)	3 (33%)	57 (56%)	71 (61%)
African American	66 (27%)	2 (9%)	5 (56%)	28 (28%)	31 (27%)
Hispanic	29 (12%)	4 (18%)	1 (11%)	12 (12%)	12 (10%)
Other	5 (2%)	0	0	3 (3%)	2 (2%)
Insured	179 (72%)	18 (78%)	7 (78%)	70 (70%)	84 (72%)
Cardiac risk factors					
Diabetes	53 (21%)	11 (48%)	1 (11%)	19 (19%)	22 (19%)
Hypertension	125 (50%)	12 (52%)	5 (56%)	51 (51%)	57 (49%)
Smoking	127 (51%)	16 (70%)	4 (44%)	45 (45%)	62 (53%)
Hypercholesterolemia	79 (32%)	7 (30%)	4 (44%)	33 (33%)	35 (30%)
≥2 Risk factors	124 (50%)	16 (70%)	4 (44%)	45 (45%)	59 (51%)
Chest pain features					
Pressure	127 (51%)	15 (65%)	5 (56%)	52 (52%)	55 (47%)
Substernal	184 (74%)	19 (82%)	6 (67%)	74 (74%)	85 (73%)
Exertional	62 (25%)	6 (26%)	5 (56%)	27 (27%)	24 (21%)
Relieved by nitrates or rest	100 (40%)	13 (57%)	3 (33%)	44 (44%)	40 (34%)
Radiated to left arm	124 (50%)	11 (48%)	5 (56%)	52 (52%)	56 (48%)
Associated with SOB/ diaphoresis	182 (73%)	17 (74%)	8 (89%)	79 (79%)	78 (67%)
Medications used					
Nitrates	33 (13%)	7 (32%)	1 (11%)	9 (9%)	16 (14%)
Calcium antagonists	27 (11%)	4 (17%)	2 (22%)	10 (10%)	11 (9%)
Beta-blockers	20 (8%)	2 (9%)	1 (11%)	7 (7%)	10 (9%)
H_2-blockers	31 (13%)	4 (17%)	3 (33%)	11 (11%)	13 (11%)
Psychotropics	21 (8%)	2 (9%)	1 (11%)	7 (7%)	11 (9%)

*$p < 0.05$ vs. every other group. Data are presented as the mean value ± SD or number (%) of patients.
CA = coronary angiography; ETT = exercise treadmill test; N/N = negative/nondiagnostic; SOB = shortness of breath.

groups was estimated by using the Kaplan-Meier survival technique and compared using the log-rank test.

For patients with negative tests, the association between demographic and clinical variables and the likelihood of ED return was assessed by Cox proportional hazard analysis. To avoid destabilizing the analyses when relatively few events occurred, separate models were built using a stagewise approach, with the following domains of variables: demographic characteristics, risk factors, chest pain features and medications used (Table 1). The incremental influence of the testing strategy on the risk of ED return visits was assessed by adding to each model a dichotomous variable (coded as 0 for ETT and 1 for CA) and computing the change in the models' chi-square value. To allow for variable mixing and to ascertain which determinants carried the strongest predictive power, we built a final model that included all predictors with $p \leq 0.10$ in the former analysis, and adjusted relative risks with 95% confidence intervals were calculated.

For all tests, a two-sided p value <0.05 was regarded as significant. Computations were performed using the Statistica, version 5.1 (StatSoft Inc., Tulsa, Oklahoma) software package.

RESULTS

In-hospital outcomes. Of the 248 patients enrolled, 123 were randomized to CA and 125 to ETT. All patients completed their assigned procedures. Figure 1 illustrates the in-hospital outcomes of the two groups.

The exercise protocol was completed with no complications in all patients. The test was negative in 82 patients (66%) and nondiagnostic in 34 (27%). Patients with nondiagnostic results attained a mean heart rate of 71 ± 9% (median 73%) of the age-predicted maximum (15 had a heart rate ≥75% of the age-predicted maximum); the exercise time was 5.9 ± 1.6 min (median 6.2) using a Bruce protocol, and a mean of 10 ± 3.4 min (median 10.7) using a modified Bruce protocol. Of the nine patients (7%) with positive test results, eight underwent CA and one declined. Six (75%) of these eight patients had CAD, and five underwent revascularization.

For patients undergoing CA, the procedure resulted in no death, MI or stroke. The presence of disease was detected in 23 patients (19%), including 5 with intermediate lesions and 18 with severe stenosis. The percentage of patients with disease on the CA was significantly greater than the percentage of patients with a positive ETT ($p = 0.012$). Of

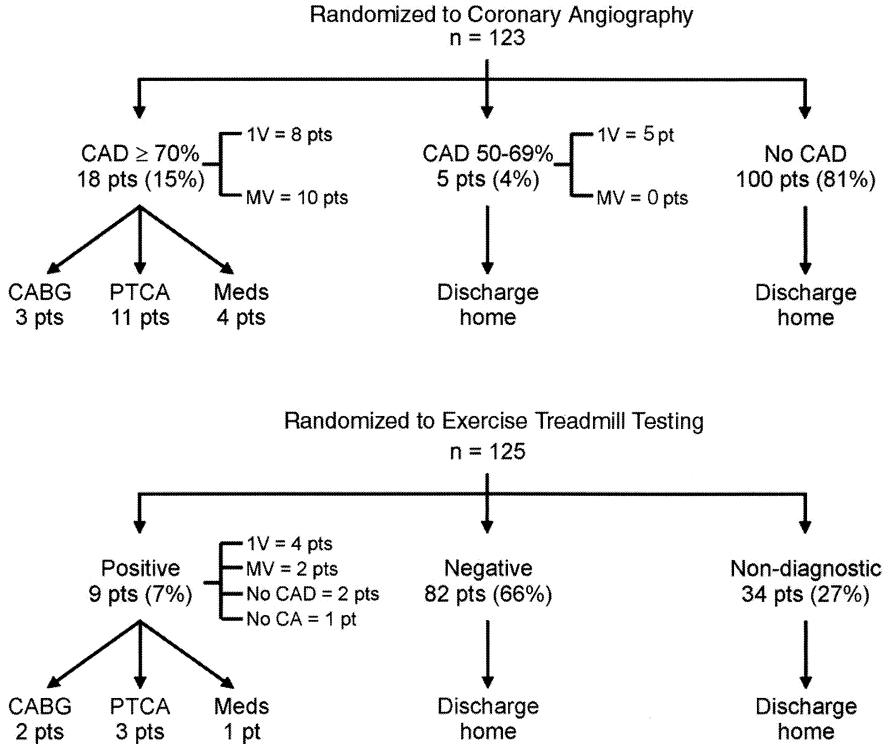

Figure 1. Flow diagram of in-hospital clinical outcomes of patients randomized to coronary angiography (CA) or exercise treadmill testing. 1V = single-vessel disease; CABG = coronary artery bypass grafting; CAD = coronary artery disease; Meds = medical therapy; MV = multivessel disease; PTCA = percutaneous transluminal coronary angioplasty.

the 18 patients with severe stenosis determined by CA, 14 underwent coronary revascularization.

Table 1 reports the demographic and clinical characteristics for all patients and patients grouped according to the results of CA and ETT. Other than a slightly older mean age in the positive-CA group, other variables were not significantly different.

The angiographic features of the lesions were not dissimilar in patients randomized to CA and ETT. Overall, the frequencies of left main coronary artery disease, intracoronary thrombus and complex lesion morphology were 6%, 4% and 45%, respectively. No significant intergroup differences in lesion location, degree of stenosis or plaque morphologic features were observed.

Long-term outcomes. Follow-up data were available for 238 patients (96%). After 374 ± 61 days (median 375), none of the patients died, and one patient (0.4%) with a positive CA had an acute MI.

The events for 208 of the 216 patients with negative or nondiagnostic tests who were followed up (96%) are reported in Table 2. Frequent episodes of chest pain were reported by 29% of these patients, with a higher frequency among patients who underwent ETT versus CA ($p = 0.04$). Among 43 patients who returned to the ED, none had ECG or enzymatic evidence of an acute coronary event. Patients with a negative CA had significantly fewer ED visits and re-admissions to the hospital, compared with patients with a negative/nondiagnostic ETT ($p = 0.0008$ and $p = 0.003$, respectively). In patients with a nondiagnostic ETT, there was no greater likelihood of ED representation (12 [35%] of 34) or re-admission (4 [12%] of 34) compared with patients with a negative ETT (ED returns:

Table 2. Follow-Up of Patients With Negative/Nondiagnostic Tests

	All Patients (n = 208)	Negative CA Group (n = 98)	N/N ETT Group (n = 110)	p Value
Death	0	0	0	—
Myocardial infarction	0	0	0	—
Frequent recurrent chest pain*	60 (29%)	21 (21%)	39 (35%)	0.04
Emergency department return for chest pain	43 (21%)	10 (10%)	33 (30%)	0.0008
Hospitalized for chest pain	21 (10%)	3 (3%)	18 (16%)	0.003

*Four or more episodes per month. Data are expressed as number (%) of patients.
Abbreviations as in Table 1.

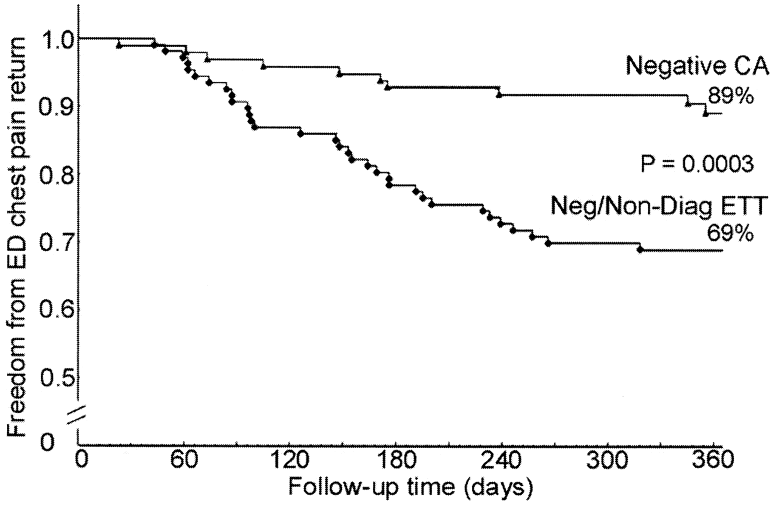

Figure 2. Twelve-month Kaplan-Meier plot depicting temporal distribution of emergency department (ED) returns for chest pain among 208 low-risk patients with chest pain with a negative coronary angiogram (CA) or a negative/nondiagnostic exercise treadmill test (ETT). **Circles** or **triangles** denote end point.

21 [28%] of 76, p = 0.55; re-admissions: 14 [18%] of 76, p = 0.55).

Of the 10 patients with a negative CA who returned to the ED during one year (2 with multiple visits; 13 total visits), only 3 were admitted to the hospital, and no further testing for CAD was done after observation. Of the 33 patients with a negative/nondiagnostic ETT who presented to the ED (12 with multiple visits, 48 total visits), 18 were admitted to the hospital. Ten patients had further noninvasive testing, and none were positive; but one patient with initial nondiagnostic results underwent CA and subsequent coronary artery bypass graft surgery. Three other patients also underwent CA directly after observation, and none had CAD.

The temporal distribution of first ED returns after the index observation for patients with negative/nondiagnostic tests is shown as Kaplan-Meier curves (Fig. 2). A difference in the curves became apparent by 60 days after the index observation and widened progressively throughout one year. By one year, patients with a negative CA had a significantly lower probability of returning to the ED, compared with patients with a negative/nondiagnostic ETT (p = 0.0003). Finally, when all study patients were considered (positive and negative results), the cumulative proportion free of ED returns at one year still remained significantly lower for patients randomized to ETT versus CA (69% vs. 83%; p = 0.041).

Multivariate analysis. To discern whether factors, other than choice of diagnostic test, may significantly influence the probability of a patient with a negative test result returning to the ED with chest pain, multivariate analysis was performed. The predictive ability of four clinical models tested, including demographic characteristics, cardiac risk factors, chest pain features and medications used, was significantly increased after adding the variable of randomization strategy, as expressed by the change in the models' chi-square value. In all these models, randomization strategy was an independent predictor ($p < 0.001$). Finally, when all variables with $p \leq 0.10$ in the former models were combined, the CA strategy was the only significant predictor associated with a reduced likelihood of ED returns (Fig. 3).

Follow-up questionnaire. Table 3 reports the results of the follow-up questionnaire for 229 patients who responded. The vast majority of patients with positive tests perceived their chest pain as cardiac and rated their index evaluation as useful for determining chest pain etiology. In contrast, patients with a negative/nondiagnostic ETT, versus those with a negative CA, were more than twice as likely to still consider their symptoms to be cardiac-related (15% vs. 7%) or were still uncertain of the etiology of their chest pain symptoms (38% vs. 26%) (overall $p < 0.01$). This is reflected in 39% of the patients with a negative/nondiagnostic ETT, not considering their index diagnostic procedure as useful, versus only 15% of the patients with a negative CA ($p < 0.01$).

Responses to the survey were not different according to whether the ETT was negative or nondiagnostic. In particular, the proportion of patients who found the index evaluation not helpful in identifying the cause of their chest pain was 41% (29 of 71) among patients with a negative ETT, and 35% (12 of 34) among those with a nondiagnostic ETT (p = 0.74).

DISCUSSION

To the best of our knowledge, this is the first randomized study to prospectively compare an immediate diagnostic strategy of CA with ETT for the assessment of low-risk patients with chest pain triaged to a short-term observation unit. Our major findings are: 1) the prevalence of CAD detected by CA was significantly higher than that antici-

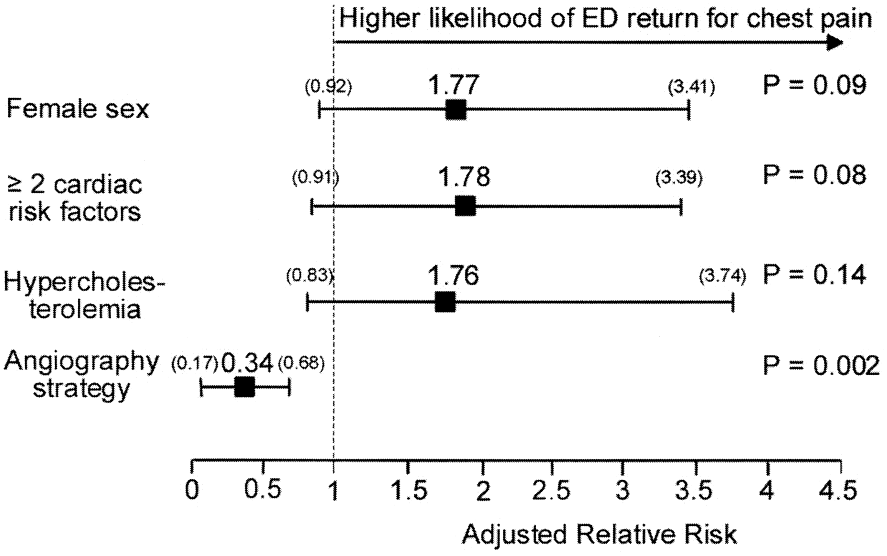

Figure 3. Adjusted relative risks for factors influencing the likelihood of emergency department (ED) return with chest pain in 208 low-risk patients with chest pain with a negative coronary angiogram or a negative/nondiagnostic exercise treadmill test. The **error bars** represent 95% confidence intervals, with relative risk minimal and maximal limits indicated by **numbers in parentheses**.

pated with ETT in this study, as well as previous studies (14–16); and 2) a normal CA resulted in a threefold lower incidence of ED returns and a fivefold reduction in readmissions for chest pain during a one-year period, compared with a negative/nondiagnostic ETT.

Detection of CAD. The 19% rate of angiographic CAD is particularly striking, as patients with a higher pretest likelihood of disease (age >65 years or previous documented CAD) were specifically excluded from our study. Furthermore, coronary lesions with complex morphology, which are frequently associated with acute coronary syndromes (13), were a common finding (45%) in this study. This suggests that in some patients, chest pain alone, with a clinical low-risk presentation, represents part of the continuum of acute coronary syndromes.

The rate of positive ETT (7%) was comparable to that reported in previous nonrandomized studies of low-risk patients (range 1% to 13%) (14–16). If one assumes a similar prevalence of CAD in the two randomization arms in the present study (given the equivalency of clinical characteristics), the sensitivity of ETT for detecting CAD is lower than anticipated. This may reflect an absence of referral bias regarding CA, due to our randomized study design, and is consistent with the reported sensitivity of ETT for detecting CAD in other studies that have eliminated referral bias to CA (7). In addition, the inclusion of patients with moderate disease (50% to 69% stenosis) may further lower the sensitivity of ETT to detect CAD. Although it is likely that some of these lesions may not be hemodynamically significant, they may ultimately predict patients at higher risk for future MI or death (17). Thus, an approach utilizing routine CA can offer an opportunity for early identification of a range of CAD severities, as well as the potential for initiation of prevention strategies to reduce long-term cardiac morbidity and mortality (18). This initial diagnosis may be missed by currently accepted rapid-evaluation algorithms that utilize ETT.

Chest pain and recidivism. Although this study and others have shown that meeting clinical criteria for a CPU places the patient in a low-risk group for subsequent death or MI during long-term follow-up (19), a major problem for low-risk patients with chest pain is the frequent recurrence

Table 3. Results of the Follow-Up Questionnaire for 229 Patients Who Responded

	Positive CA Group (n = 22)	Positive ETT Group (n = 7)		Negative CA Group (n = 95)	N/N ETT Group (n = 105)	
What do you think about the cause of your chest pain?						
Cardiac	17 (77%)	5 (71%)	p = NS	7 (7%)	16 (15%)	p < 0.01
Other	3 (14%)	1 (14%)		63 (66%)	49 (47%)	
Don't know	2 (9%)	1 (14%)		25 (26%)	40 (38%)	
Was your evaluation helpful for determining the cause of your chest pain?						
Yes	19 (86%)	6 (86%)	p = NS	81 (85%)	63 (60%)	p < 0.01
No	3 (14%)	1 (14%)		14 (15%)	41 (39%)	

Data are expressed as the number (%) of patients.
Abbreviations as in Table 1.

of symptoms, with repeat ED presentations and re-admissions (10,11). Recurrence of multiple chest pain episodes was a common finding in our study, even in patients with normal angiograms. Despite symptom persistence, however, there was a 14% net improvement in the proportion of patients free of ED returns (83% vs. 69%) in the routine CA arm. Particularly striking was that a negative CA, compared with a negative/nondiagnostic ETT, resulted in substantially fewer admissions over the year (3 vs. 18). As re-admission in our study was not driven by strong clinical or ECG reasons, one can surmise a lack of faith in noninvasive testing. Thus, for both the patients evaluated and the physicians who later provided care for these patients, the higher degree of certainty that CAD was not present altered subsequent utilization of hospital resources. Such a hypothesis is not without precedent, as several retrospective studies have documented significant reductions in ED visits, re-admissions and overall resource utilization after documentation of an absence of CAD by CA in patients with chronic chest pain syndromes (20,21). This interpretation is also supported by the results of our patient survey, which identified improved patient understanding of their condition (as either cardiac or noncardiac in origin) through the results of a test (i.e., CA).

Importantly, however, routine CA of our low-risk patients in the CPU led to a higher number of initial revascularization procedures (14 vs. 6), with no beneficial effect on "hard" end points. This is consistent with the findings of randomized studies of medical versus percutaneous coronary interventional management of low- to-moderate-risk stable patients with CAD (22,23).

Negative versus nondiagnostic ETT. For patients with a nondiagnostic ETT, the remaining uncertainty about their diagnosis could strongly influence their return rate. Although it is possible to risk stratify low-risk patients with chest pain by means of myocardial perfusion imaging with technetium-99m sestamibi or stress echocardiography, whether such tests should be performed for all low-risk patients in the CPU or only for those with a nondiagnostic ETT remains debatable (24). Our study confirms the safety of discharging such patients without further work-up (15), as there were no deaths or MIs in this group, and only one patient was subsequently found to have CAD requiring revascularization.

In our patients, exercise tolerance was generally good, and the percentage of nondiagnostic results was consistent with other studies of low-risk patients in the CPU (15,16). The lack of difference between the nondiagnostic and negative ETT in terms of the risk of repeat ED presentation, re-admission or perception of the usefulness of their index evaluation, suggests that nondiagnostic results do not specifically identify patients who would routinely benefit more from further diagnostic testing for CAD.

Study limitations. For patients randomized to CA, evidence of severe disease frequently led to a revascularization procedure, even in the absence of objective documentation of myocardial ischemia. The compulsion to intervene once stenosis is identified is widely recognized (25), and the use of interventions is particularly prevalent in our region of the U.S. (i.e., southwestern) (26). Therefore, it is uncertain whether some of these patients may have done as well or better with a trial of medical therapy or an ischemia-guided approach to revascularization.

For patients with normal angiograms, we often made an assumption that symptoms were of noncardiac etiology. However, a minority may have had ischemia in the absence of angiographically significant lesions (27). Although such patients could more frequently have recurrent symptoms, the implications of this finding are uncertain because the prognosis for this group of patients is excellent and no definitive treatment exists.

For low-risk patients, CA may not be practical at many institutions, because it is not widely available on an immediate basis for nonemergent use. The invasive nature of the procedure will also limit its acceptance for this indication. Current guidelines recommend symptom-limited ETT during the initial CPU assessment and consideration of CA in "repeat presenters" with previous negative cardiac evaluations and with no other identifiable sources of symptoms (28,29). Although we did not test this specific strategy, our data at least provide support for such an intermediate tactic. In the future, alternative noninvasive coronary imaging techniques may be used to accurately exclude CAD (30), making our findings applicable for most centers.

Demographics and selection criteria may change the prevalence of CAD in a low-risk group of patients selected for an accelerated diagnostic protocol. Our patient selection was protocol-driven and based on a well-established CPU algorithm (12). Considering the results of our multivariate analysis, the decreased repeat ED presentation rate for patients with a negative CA should hold across a variety of populations and demographic characteristics. However, several factors, including different physicians' opinions, both on patients' symptoms and the value of diagnostic tests performed, and possible differences in postdischarge ambulatory care, may have influenced returns to the ED and re-admissions. Evaluating the weight of these factors was beyond the scope of the present study.

Finally, we chose to exclude patients >65 years old because of their higher pretest likelihood of CAD and potential concomitant noncardiac reasons for failing to obtain a target heart rate on ETT. Therefore, the excellent prognosis of our patient group may not be directly extrapolated to elderly patients in the CPU.

Clinical implications. When initially considered, use of CA in low-risk patients with chest pain is contrary to the current emphasis on reducing the utilization of in-patient health care resources. The fact that immediate CA in the current study detected significantly more CAD than expected, and a normal angiogram heralded reduced ED returns and re-admissions, raises important questions as to whether current diagnostic strategies for low-risk patients

without biochemical evidence of MI are optimal for immediate diagnosis, long-term resource utilization and patient satisfaction. Further studies may be warranted to determine whether there is potential long-term cost-effectiveness of a strategy of CA early in the evaluation of low-risk patients with chest pain observed in a CPU setting.

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