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ORIGINAL ARTICLE

Risk stratification of patients in an emergency department chest pain unit: prognostic value of exercise treadmill testing using the Duke score

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Abstract
Background Exercise treadmill testing (ETT) has been standard for evaluating outpatients at risk for cardiovascular events. Few studies have demonstrated its prognostic usefulness in emergency department chest pain units or have used the Duke score [(exercise duration in minutes) − (5 × ST-segment deviation in millimeters) − (4 × treadmill angina index)] to grade its performance.
Aims Our objective was to assess the usefulness of this score in a chest pain unit to predict cardiovascular events.
Methods From November 2000 to October 2001, we retrospectively studied consecutive patients in the chest pain unit. Those undergoing ETT were stratified into "low" (Duke score ≥5) and "moderate/high" risk groups (<5). Cardiovascular events defined as death, myocardial infarction >24 h after presentation, revascularization, acute congestive heart failure, stroke or arrhythmia were identified within 1 year after presentation. Differences in risk of having a cardiovascular event among low-risk and moderate/high-risk groups are presented.
Results During the study period, 1,048 patients entered the chest pain unit; 800 met inclusion criteria. Of these, 599 received ETT and 201 had contraindications or a positive finding in the chest pain unit protocol before ETT. Cardiovascular event rates were 0.7% (3/454), 15.2% (22/145) and 14.9% (30/201) after 1 month of follow-up for low-risk, moderate/high-risk and no-ETT groups, respectively.
Conclusions According to the Duke score, the low-risk group developed minimal cardiovascular events compared with the moderate/high-risk group. The Duke score appears effective for risk stratification of chest pain patients in chest pain units.

Keywords Cardiovascular · Prognosis · Retrospective study · Risk stratification

Abbreviations

AHCPR	Agency for Health Care Policy and Research
CABG	coronary artery bypass grafting
CHF	congestive heart failure
CI	confidence interval
ECG	electrocardiography
ED	emergency department
ETT	exercise treadmill testing
MI	myocardial infarction
PTCA	percutaneous transluminal coronary angioplasty

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Introduction

Background

Chest pain is the second most common chief complaint of patients presenting to an emergency department (ED). In the year 2000, it constituted approximately 5.8 million or 5.4% of visits to EDs at a cost of US $6 billion [1]. In this vast population presenting with chest pain, the emergency medicine physician must identify those with acute coronary syndrome or acute myocardial infarction (MI).

Chest pain units have been in use since 1981 to better balance the emergency physician's need to establish a cause of chest pain and the increasing emphasis on cost containment.

Importance

Numerous modalities of functional cardiac stress testing have been used to evaluate chest pain patients, including exercise treadmill testing (ETT) [2], echocardiography [3], nuclear scans [4] and electron-beam computed tomographic scanning [5]. Currently, there are no standardized clinical decision-making rules for selecting the best functional cardiac or stress testing modality for patients in a chest pain unit.

Goals of this investigation

ETT is a staple for evaluating outpatients at risk for acute coronary syndrome or acute MI [6]. Many studies of chest pain units have included ETT after a negative work-up in the chest pain unit [2]. Although these studies have shown that ETT is being used in chest pain units, information about its prognostic use in this setting is limited. Few studies have used the Duke score [7–9] to grade a patient's ETT performance for risk stratification. This score is from a simple formula easy for emergency physicians to apply in clinical decision making. The score uses three prognostic variables from the treadmill test: the amount of net exercise-induced ST-segment deviation, in any lead except aVR, the presence and severity of exercise-induced angina and the duration of exercise on the standard Bruce protocol. These variables are combined into the following equation: [(exercise duration in minutes) − (5 × ST-segment deviation in millimeters) − (4 × treadmill angina index)] [8, 9]. The treadmill angina index is equal to 0 for no exercise angina, 1 for exercise angina and 2 for exercise-limiting angina (Table 1). The aim of our study was to assess the prognostic value of ETT in a chest pain unit by using this formula.

Table 1 Duke prognostic exercise treadmill score and annual cardiac mortality[a] [8, 9]

Risk group	Treadmill score	Average annual cardiac mortality, %
Low	≥5	0.25-0.50
Moderate	−10 to <5	1.25-2.0
High	≤−11	5.0-7.0

[a] Duke formula: treadmill score = (exercise duration in minutes) – (5 × ST-segment deviation in millimeters) – (4 × treadmill angina index), where the treadmill angina index = 0 for no exercise angina, 1 for exercise angina and 2 for exercise-limiting angina

Methods

Study design

This retrospective study included consecutive patients admitted to our chest pain unit from 1 November 2000 to 31 October 2001 with chest pain of indeterminate cause. Initial screening for patients admitted to the ED with chest pain consisted of a physical examination, determination of serum levels of cardiac enzymes and 12-lead electrocardiography (ECG). To be eligible for admission to the chest pain unit, patients had to be ≥18 years old, have no ongoing chest pain, low to intermediate risk by Agency for Health Care Policy and Research (AHCPR) guidelines, without an obvious noncardiac cause of chest pain and without coexisting conditions requiring inpatient care.

Selection of participants

Patients in the chest pain unit were eligible for the study if they were residents of our center's county or one of the surrounding nine counties and granted research authorization in compliance with Minnesota Statute 144.335. The study was approved by the Mayo Foundation Institutional Review Board.

Setting

The study was conducted in a 1,200-bed teaching hospital and tertiary referral center.

Chest pain unit protocol

After enrollment in the approximately 9 h chest pain observation protocol, the serum level of troponin T was determined at presentation and 90 min before a functional cardiac test. Cardiac monitoring and 12-lead ECG were performed before functional cardiac testing and during any recurrence of chest pain. If a patient had recurrent chest pain, ST-segment instability or abnormal serum levels of

markers any time during the protocol, the patient was admitted to a cardiology service. If a patient did not experience any of the above, ETT was performed. An alternative functional cardiac test was performed if a patient had an abnormal resting ECG, was unable to walk at least 2.5 mph or was currently taking digoxin.

ETT, following the standard Bruce protocol, was performed by specialized ETT laboratory personnel. Data from the test were used to calculate the Duke score. On the basis of this score, patients were risk stratified into low-risk (≥5) and moderate/high-risk (<5) groups. Patients in the moderate/high-risk group were admitted, and those in the low-risk group were discharged, with follow-up by their primary care physician.

Study outcome measures

All patients entered into the chest pain unit protocol were retrospectively followed for cardiovascular events for 1 year. Cardiovascular events were defined as cardiac-related death, MI >24 h after presentation, acute congestive heart failure (CHF), stroke, arrhythmia (including ventricular fibrillation or ventricular tachycardia), arrest or cardiac revascularization [including coronary artery bypass grafting (CABG) or percutaneous transluminal coronary angioplasty (PTCA)]. Inter-rater reliability for cardiovascular events was calculated, and outcome assessors were blinded to the results of functional cardiac testing.

ED course, cardiovascular events and follow-up information were obtained from review of a standardized chest pain unit form and our institution's electronic medical record and entered into a database.

Primary data analysis and methods of measurement

The incidence of cardiovascular events at 1 month and 1 year after evaluation in the chest pain unit were summarized with percentages and exact 95% confidence intervals (CIs). Differences in demographic features and cardiac risk factors between patients with low- and either moderate- or high-risk Duke scores were evaluated using the Wilcoxon rank sum and χ^2 tests. All tests were two-sided and $P<.05$ was considered statistically significant. Statistical analyses were performed with the SAS software package (SAS Institute, Cary, NC, USA).

Results

During the study period, 4,448 patients presented to the ED with chest pain. Of these patients, 1,048 entered the chest pain unit, 800 of whom met the study criteria. Of the 248 patients who did not meet inclusion criteria, 195 did not meet the geographic restrictions and 53 did not grant research authorization. Of the 800 patients who met the study criteria, 599 (74.9%) underwent ETT and 201 (25.1%) did not. Among the 599 patients who had ETT, 454 (75.8%) had low-risk Duke scores, 142 (23.7%) had moderate-risk scores, and 3 (0.5%) had high-risk scores. The mean Duke score was 6.5 (median: 7.2, range: −17 to 15.5). Among the 201 patients who did not have ETT, 88 (43.8%) had an alternative stress test and 113 (56.2%) did not have any stress test. Fifty-three patients (6.6%) did not return after the initial ED visit, and 747 (93.4%) were seen at least once during the 1 year of follow-up.

Of the 800 study patients, 55 (6.9%, 95% CI: 5.2–8.9) had a cardiovascular event within 1 month after evaluation in the chest pain unit. Three patients (0.7%, CI: 0.1–1.9) with a low-risk Duke score and 22 (15.2%, CI: 9.8–22.1) with a moderate/high-risk score had a cardiovascular event. All three patients with a high-risk score had an event. Of the 201 patients who did not undergo ETT, 30 (14.9%, CI: 10.3–20.6) had a cardiovascular event, including 8 (9.1%) of the 88 patients who had an alternative stress test and 22 (19.5%) of the 113 who did not have any stress test (Table 2).

Within 1 year after evaluation in the chest pain unit, 68 (8.5%, CI: 6.6–10.7) of the 800 study patients had a cardiovascular event. These events occurred in 7 patients (1.5%, CI: 0.6–3.2) with a low-risk Duke score and 25 patients (17.2%, CI: 11.5–24.4) with a moderate/high-risk score. Of the 201 patients who did not have ETT, 36 (17.9%, CI: 12.9–23.9) had a cardiovascular event, including 11 (12.5%) of the 88 patients who had an alternative stress test and 25 (22.1%) of the 113 who did not have any stress test (Table 2).

Comparison of cardiovascular risk factors between the groups is summarized in Table 3.

Inter-rater reliability showed full agreement on 29 of 32 charts, yielding a κ statistic of 0.52.

Limitations

This study is limited by its retrospective design. Other limitations include the 6.6% of patients for whom we do not have follow-up data. Furthermore, this study was conducted at a large academic medical center, which may introduce selection bias. To decrease this possibility, only patients who resided in a local ten-county area were included in the study. Our institution serves a suburban and rural population. Future studies should attempt to duplicate these results in urban populations.

Table 2 Patient group distribution and cardiovascular events after 1 month and 1 year

Group	Patients, no. (%)	Events, no. of patients (%)	
		1 month	1 year
ETT	599	25 (4.2)	32 (5.3)
Low risk	454 (75.8)	3 (0.7)	7 (1.5)
Moderate risk	142 (23.7)	19 (13.4)	22 (15.5)
High risk	3 (0.5)	3 (100)	3 (100)
Moderate/high risk	145 (24.2)	22 (15.2)	25 (17.2)
No-ETT	201	30 (14.9)	36 (17.9)
Alternative test	88	8 (9.1)	11 (12.5)
Dobutamine echo	58 (65.9)	7 (12.1)	9 (15.5)
Sestamibi imaging	26 (29.5)	1 (3.9)	2 (7.7)
Atrial pacing	4 (4.6)	0	0
No test—reason	113	22 (19.5)	25 (22.1)
Recurrent chest pain	28 (24.8)	5 (17.9)	5 (17.9)
ECG change	16 (14.2)	3 (18.8)	5 (31.3)
Increased enzyme levels	11 (9.7)	8 (72.7)	8 (72.7)
Admitted to hospital	32 (28.3)	5 (15.6)	6 (18.8)
Discharged	26 (23.0)	1 (3.8)	1 (3.8)
Total	800	55 (6.9)	68 (8.5)

ECG electrocardiographic, *echo* echocardiography, *ETT* exercise treadmill test

Discussion

The goal of the chest pain unit is to safely and efficiently risk stratify patients into those who can be appropriately discharged and those who need to be admitted for further evaluation. This retrospective study demonstrated that the Duke score is useful for risk stratification and prognostic evaluation of patients in a chest pain unit. Because of the small number of events in the discharged group and the much higher risk of cardiovascular events in the admitted groups, we believe that the Duke score is safe and effective.

A majority of the cardiovascular events occurred in the first month after evaluation. The risk of having a cardiovascular event was almost twice as high during the first

Table 3 Comparison of cardiovascular risk factors among patient groups[a]

Risk factor	All study groups	Duke score group		Exercise treadmill test		Alternative stress test	
		Low risk (n=454)	Moderate/high risk (n=145)	No (n=201)	Yes (n=599)	No (n=113)	Yes (n=88)
Age at evaluation, years							
Mean	56.5	52	60	64.4	53.9	62.1	67.4
Median (range)	55 (19-94)	51 (21-89)	60 (20-87)	67.0 (19-94)	53.0 (20-89)	65.0 (19-93)	71.5 (30-94)
Sex, no. of patients (%)							
Female	361 (45.1)	186 (41.0)	78 (53.8)	97 (48.3)	264 (44.1)[b]	50 (44.2)	47 (53.4)[b]
Male	439 (54.9)	268 (59.0)	67 (46.2)	104 (51.7)	335 (55.9)[b]	63 (55.8)	41 (46.6)[b]
Family history of cardiovascular disease, no. of patients (%)	92 (11.5)	51 (11.2)	23 (15.9)[b]	18 (9.0)	74 (12.4)[b]	13 (11.5)	5 (5.7)[b]
History of, no. of patients (%)							
Smoking	170 (21.3)	93 (20.5)	34 (23.4)[b]	43 (21.4)	127 (21.2)[b]	28 (24.8)	15 (17.0)[b]
Hypertension	318 (39.8)	141 (31.1)	68 (46.9)	109 (54.2)	209 (34.9)	59 (52.2)	50 (56.8)[b]
Diabetes mellitus	88 (11.0)	29 (6.4)	20 (13.8)	39 (19.4)	49 (8.2)	20 (17.7)	19 (21.6)[b]
Hypercholesterolaemia	340 (42.5)	160 (35.2)	77 (53.1)	103 (51.2)	237 (39.6)	62 (54.9)	41 (46.6)[b]
Previous myocardial infarction, no. of patients (%)	69 (8.6)	23 (5.1)	12 (8.3)[b]	34 (16.9)	35 (5.8)	22 (19.5)	12 (13.6)[b]

[a] On the basis of univariate analyses of patients undergoing exercise treadmill testing, those with the following characteristics were significantly more likely to have moderate or high Duke score: older age, female, hypertension, diabetes mellitus or hypercholesterolaemia

[b] Difference is not statistically significant (P>.05)

month than during 1 year for both the moderate/high and no-ETT groups. This is likely explained by the cohort of admitted patients having a cardiovascular event >24 h after being admitted from the chest pain unit. The data demonstrate that patients who are at risk for a cardiovascular event according to the Duke score and are unable to undergo ETT need to be observed closely after discharge.

In the original studies that defined the Duke score, patients were risk stratified into low-, moderate- and high-risk groups. It was found that the annual cardiac mortality rates for outpatients in these groups were 0.25%, 1.25% and 5.0%, and for inpatients 0.5%, 2.0% and 7.0%, respectively [9]. Our study identified only one death in the low-risk group (Duke score, 5.8) and no deaths in the moderate/high-risk group over the 1 year of follow-up. Furthermore, there were two deaths in the alternative stress test group and one in the no-ETT group. For our low-risk patients who were discharged, the annual cardiac mortality rate was 0.22%, lower than that of both the outpatient and inpatient groups in the original Duke score study. This demonstrates that we did not discharge patients from the chest pain unit who were at high risk for cardiovascular death, suggesting that using the Duke score as a measure of ETT performance is safe in this setting.

After the initial chest pain work-up, 6.6% of patients did not return for follow-up. Participation in the study was limited by a residency requirement, and it was assumed that if a patient experienced chest pain, the patient would return to the institution of the initial chest pain work-up. This assumption would not hold if a patient's residency changed or if a cardiovascular event occurred while the patient was outside the ten-county area. The patients not seen after the initial work-up could be assumed to be lost to follow-up or not to have any important health issues that would bring them to our medical centre. In retrospect, a prospective study cohort or obtaining permission to contact the patients would have strengthened our study design.

Recently, it has been questioned whether stress testing in a chest pain unit is warranted or if a standard protocol without stress testing would be adequate [10]. If stress testing had not been required in our protocol, we would have discharged all 599 ETT patients from the chest pain unit. This group had 32 (5.3%) cardiovascular events, including 1 cardiac death during the 1 year of follow-up. The use of a protocol without stress testing would deny these patients early intervention and potentially place them at risk for a more serious out-of-hospital event.

In summary, the Duke score provides a straightforward and clinically meaningful tool to aid in risk stratification of patients undergoing ETT in an ED-based observation unit.

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