ORIGINAL INVESTIGATION

Outcomes of Patients Admitted for Observation of Chest Pain

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Background: Low-risk chest pain is a common cause of hospital admission; however, to our knowledge, there are no guidelines regarding the appropriate use of stress testing in such cases.

Methods: We performed a retrospective cohort study of patients 21 years and older who were admitted to our tertiary care center with chest pain in 2007 and 2008. Using electronic records and chart review, we sought (1) to identify differences in the use of stress testing based on patient demographics and comorbidities, pretest probability of coronary artery disease, and house staff coverage and (2) to describe the results of stress testing and patient outcomes, including revascularization procedures and 30-day readmissions for myocardial infarction.

Results: Of 2107 patients, 1474 (69.9%) underwent stress tests, and the results were abnormal in 184 patients (12.5%). Within 30 days, 22 patients (11.6%) with abnormal test results underwent cardiac catheterization, 9 (4.7%) underwent revascularization, and 2 (1.1%) were readmitted for myocardial infarction. In a multivariable model, stress test ordering was positively associated with age younger than 70 years (RR [relative risk], 1.12; 95% CI, 1.02-1.23), private insurance (vs Medicare/Medicaid: RR, 1.19; 95% CI, 1.11-1.27), and no house staff coverage (RR, 1.39; 95% CI, 1.28-1.50). Of patients with low (<10%) pretest probability, 68.0% underwent stress testing, but only 4.5% of these had abnormal test results.

Conclusions: Most patients who are admitted with low-risk chest pain undergo stress testing, regardless of pretest probability, but abnormal test results are uncommon and rarely acted on. Ordering stress tests based on pretest probability could improve efficiency without endangering patients.

Arch Intern Med. 2012;172(11):873-877.
Published online May 7, 2012.
doi:10.1001/archinternmed.2012.940

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Chest pain is a frequent cause of hospitalization, accounting for more than 600 000 hospital admissions annually in the United States and more than $ 3.7 billion in hospital costs.[1] Patients whose initial evaluation in the emergency department (ED) does not reveal an acute coronary syndrome are often admitted for additional observation to rule out myocardial infarction (MI) with the serial measurement of enzyme levels. If the levels do not demonstrate acute ischemia and the pain is nonanginal in nature, the patient is considered to be at low risk for acute coronary events in the short term.[2] Some patients undergo inpatient stress testing, often with added imaging modalities, even though evidence suggests that the diagnostic yield is low and that it is safe to further evaluate these patients in the outpatient setting.[2]

Guidelines for the management of acute MI and unstable angina have been created by the American College of Cardiology/American Heart Association (ACC/AHA), but there are no specific ACC/AHA guidelines for the treatment of patients who are hospitalized for low-risk chest pain. Much has been published about the management of chest pain in the ED, but little is known about how such cases are managed in the hospital. We reviewed all cases involving patients with chest pain who were admitted to our hospital for observation over a 2-year period to examine variation in care and outcomes. We sought to determine the rate of stress testing, the predictors of stress test ordering, the results of the stress tests, and the 30-day rates of revascularization and MI for this population.

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METHODS

We performed a retrospective cohort study of all patients with chest pain who were admitted to observation status at Baystate Medical Center between January 1, 2007, and Decem-

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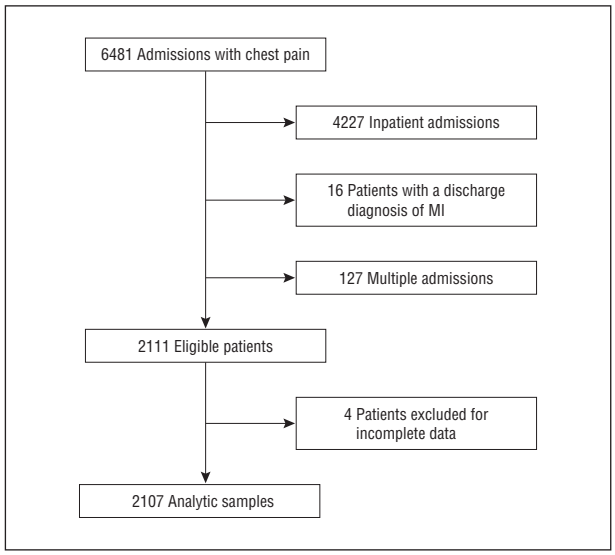

Figure 1. Enrollment flow diagram. MI indicates myocardial infarction.

Table 1. Baseline Characteristics

Baseline Characteristics	No. (%)
Age ≥70 y	415 (19.7)
Female	1107 (52.5)
Race	
White	1611 (76.5)
Black	215 (10.2)
Hispanic	171 (8.1)
Other	110 (5.2)
Private insurance	1620 (76.9)
Comorbidities	
Diabetes mellitus	78 (3.7)
Hypertension	947 (45.0)
Congestive heart failure	16 (0.8)
Peripheral artery disease	20 (1.0)
>1 Of the above comorbidities	121 (5.7)
Pretest probability of coronary disease	
Low, <10%	97 (26.7)
Intermediate, 10%-90%	252 (69.4)
High, >90%	14 (3.9)

ber 31, 2008. Baystate Medical Center, which is a 670-bed tertiary care center, serves as the Western Campus of Tufts University School of Medicine in Springfield, Massachusetts.

STUDY POPULATION

In our institution, patients who present with chest pain are admitted at the discretion of the ED physician. Patients who do not meet the InterQual definition for inpatient admission based on the results of electrocardiography (ECG) and initial cardiac biomarker testing are "admitted" to observation status for serial biomarker testing and further risk stratification.[2] Such patients are technically considered outpatients for insurance purposes but are cared for on inpatient wards by inpatient physicians and are otherwise indistinguishable from inpatients. Using the hospital billing database, we identified all patients 21 years and older who were admitted to observation status with chest pain during the study period. We excluded all patients who were diagnosed as having MI before stress testing. All other patients who were initially placed on observation and whose status was later upgraded to inpatient were included.

DATA COLLECTION

Patient demographics, comorbidities, stress test type, and house staff coverage were collected from administrative records for all patients. For patients who underwent stress testing, the reports were reviewed by one of us (S.C.P.), and the results were categorized as normal or abnormal. The test result was considered abnormal if (1) the ECG demonstrated ischemia; (2) nuclear imaging revealed any reversible, fixed, or mixed defect; or (3) stress echocardiography revealed a wall motion abnormality. All other findings, including equivocal results, were considered negative for ischemia. For all patients who had an abnormal stress test result, we performed a detailed review of the hospital discharge summary and recorded whether the patient underwent cardiac catheterization, revascularization, and/or relevant medication changes. To assess whether physicians documented patient risk and the relationship between risk and stress test ordering, we reviewed the inpatient records of a random sample of 17% of the study population and recorded the chest pain characteristics and documentation of pretest probability of coronary artery disease (CAD) by the admitting physician (if stated). Using age, sex, and chest pain characteristics, we estimated the probability of CAD for these same patients based on the work of Diamond and Forrester.[3] Pretest probability was then categorized as low (<10%), intermediate (10%-90%) or high (>90%). We considered stress testing to be appropriate only for patients at intermediate probability of CAD.[4] Finally, for all patients, we assessed whether they were readmitted within 30 days with an MI, using the universal definition.[5]

STATISTICAL ANALYSIS

Baseline comparisons of patient characteristics, pretest probabilities, house staff coverage, and stress testing were performed using χ^2tests (categorical) or 1-way analysis of variance (continuous). Poisson regression with robust standard errors was used to calculate relative risks, while controlling for covariates.[6,7] Model fit was confirmed using Pearson goodness of fit.[8] Tests of trend were conducted using methods described by Vittinghoff et al.[9] All analyses were conducted using Stata version 11.1 (StataCorp).

RESULTS

A total of 2107 admissions met inclusion criteria (**Figure 1**). The mean patient age was 57 years, 52.5% were female, and 76.4% were white (**Table 1**). Stress testing was performed in 1474 patients (69.9%). The most frequently ordered type was exercise nuclear stress (46.2%) followed by pharmacological nuclear stress (28.4%) and exercise stress (22.9%). Stress test results appear in **Figure 2**. Of 1474 stress tests performed, the results were abnormal in 184 (12.5%). Approximately half of the abnormal stress test results demonstrated ischemia by either ECG criteria or imaging; the remaining 52.2% showed only irreversible defects on imaging. After having an abnormal stress test result, 23 patients (12.5% with abnormal results) underwent further testing within 30 days: 22 cardiac catheterizations and 1 cardiac computed tomography. Six patients then underwent angioplasty and stenting, and 4 underwent coronary artery bypass graft surgery. Within 1 month of discharge, 7 patients (0.3%) were readmitted with an MI

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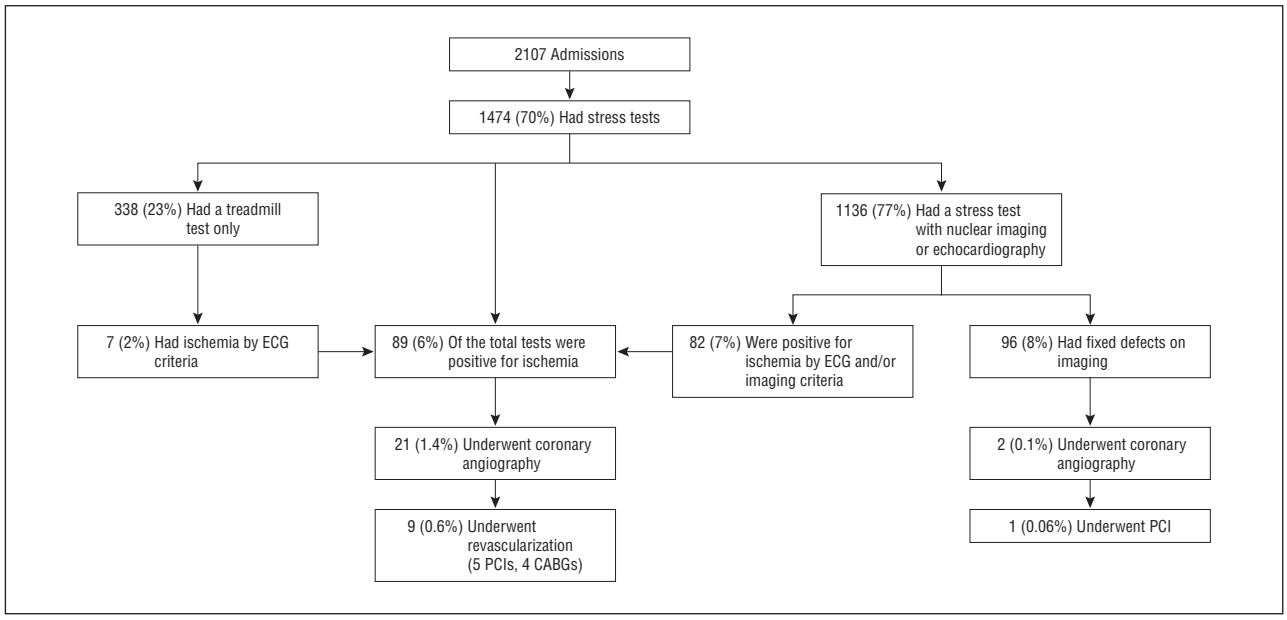

Figure 2. Stress tests and outcomes for patients with low-risk chest pain. CABG indicates coronary artery bypass graft; ECG, electrocardiogram; PCI, percutaneous coronary intervention.

Table 2. Outcomes by Stress Test Status

	No. (%)				
		Stress Test Results (n = 1474)			
Variable	Entire Cohort (N = 2107)	Normal (n = 1290)	Abnormal (n = 184)	No Stress Test (n = 633)	*P* Value[a]
Cardiac catheterization	65 (3)	3 (0.2)	23 (12.5)	39 (6.2)	<.001
PCI	18 (0.8)	1 (0.1)	6 (3.2)	11 (1.7)	.008
CABG	6 (0.3)	0	4 (2.0)	2 (0.3)	>.99
Readmission with MI in 30 d	7 (0.3)	1 (0.1)	2 (1.0)	4 (0.6)	.21

Abbreviations: CABG, coronary artery bypass graft; MI, myocardial infarction; PCI, percutaneous coronary intervention.
[a] Fisher exact test: stress test vs no stress test.

(**Table 2**). During the index admission, 3 of these 7 patients had undergone nuclear stress tests, 1 of which demonstrated no ischemia. Overall, the patients who underwent stress testing were less likely to have received a percutaneous coronary intervention than those who did not undergo stress testing (0.4% vs 1.7%, $P = .007$). There were no significant differences in any other outcomes.

Predictors of stress test receipt in the overall sample are shown in **Table 3**. In a multivariable Poisson model, independent predictors of stress testing included age younger than 70 years, documented hypertension or coagulopathy, private health insurance, and house staff coverage.

In a random sample of 363 patients, which was representative of the entire cohort, the physician documented a pretest probability for only 49 patients (13.5%). Based on the patients' age, sex, and chest pain characteristics described in the ED note and admitting history, 97 patients (26.7%) had low pretest probability, 252 (69.4%) had intermediate pretest probability, and 14 (3.8%) had high pretest probability. Most patients underwent stress testing regardless of pretest probability of CAD (68% with low pretest probability, 76% with intermediate pretest probability, and 86% with high pretest probability) (*P* for trend, .08). However, pretest probability of CAD was a strong predictor of an abnormal stress test result. Abnormal test results were found in 5% of patients with low pretest probability of CAD, 13% of patients with intermediate pretest probability of CAD, and 25% of patients with high pretest probability of CAD (*P* for trend, .02). In a multivariable model (n = 363) after patient age, comorbidities, insurance status, and house staff coverage were controlled for, intermediate (vs low) pretest probability was associated with stress test ordering (relative risk, 1.41; 95% CI, 1.09-1.83).

COMMENT

Low-risk chest pain presents an ongoing management challenge for hospital physicians. Currently, there are no consensus guidelines; consequently, the diagnostic approach varies widely among medical centers and individual physicians within centers.[10-13] In this retrospective cohort study from a single large academic center, we found that patients who were admitted for observation of chest pain were at very low risk for major cardiovas-

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Table 3. Predictors of Stress Test

Variable	RR (95% CI) Full Cohort (N = 2107)	RR (95% CI) Random Subsample With Pretest Probability (n = 363)
Age, y		
≥70	1 [Reference]	1 [Reference]
<70	1.12 (1.02-1.23)	1.28 (1.01-1.62)
Insurance		
Public[a]	1 [Reference]	1 [Reference]
Private	1.19 (1.11-1.27)	1.25 (1.07-1.46)
Other	1.27 (1.10-1.46)	1.43 (1.11-1.84)
Comorbidity		
Coagulopathy	1.39 (1.08-1.80)	1.77 (1.44-2.17)
Hypertension	1.08 (1.02-1.14)	0.94 (0.84-1.06)
House staff coverage		
Yes	1 [Reference]	1 [Reference]
No	1.39 (1.28-0.79)	1.38 (1.14-1.67)
Pretest probability		
Low, <10%	NA	1 [Reference]
Medium, 10%-90%	NA	1.17 (1.02-1.35)
High, >90%	NA	1.41 (1.09-1.83)

Abbreviations: NA, not applicable; RR, relative risk.
[a] Medicare/Medicaid.

cular events in the short term. Nevertheless, formal risk assessment by the admitting physician was rare, and most patients (about 70%) underwent some form of stress testing—most commonly a nuclear stress test—before discharge. The results of 1 in 8 tests were abnormal, but only 1 in 200 patients underwent a revascularization procedure, and 1 in 300 was readmitted with an MI within 1 month. Patient age and insurance status explained some of the variance in stress testing, and pretest probability of CAD played only a small role; interestingly, admission to a service covered by house staff was a strong, independent predictor of less stress test ordering.

The goal of observing patients with chest pain is presumably to avoid missing an MI. Studies from a decade ago found that approximately 2% of patients discharged from the ED had a diagnosis of missed MI on subsequent follow-up.[14] However, patients with negative troponin results on serial testing have very low mortality at 30 days.[15] A recent study demonstrated the safe use of a 2-hour accelerated diagnostic protocol to identify low-risk patients for early discharge. The rate of major cardiac events at 30 days was 0.9%.[16]

In contrast, the addition of stress testing to biomarkers has never been shown to influence mortality or to prevent MI. Nevertheless, stress testing is commonly used. Other studies have reported rates of 20% to 40%,[12-16] and in institutions with chest pain units, some of which advocate mandatory stress testing before discharge, the rates are 70% to 80%.[10,13,17] If physicians limited testing based on patient risk, then institutions or services with lower overall rates should have higher rates of positive test results. Despite the wide variation in overall rates of stress testing, however, the rate of abnormal test results is similar across studies, including ours (13%-14%).[17,18] One explanation for this finding is that positive test results are attributable to rates of underlying silent CAD, not unstable angina. This hypothesis is supported by the fact that very few of these positive test results prompted further diagnosis or treatment.

While studies from the early 1990s argued that mandatory stress testing in the ED was cost saving compared with hospital admission,[10,17] others have questioned the value of diagnostic testing beyond serial electrocardiograms and measurement of cardiac enzyme levels in low-risk patients.[19] The low rate of positive stress test results and the overall benign course that we observed in our cohort support the latter sentiment. It is paradoxical, then, that over the past decade not only have the rates of inpatient stress testing increased but also more expensive myocardial perfusion imaging studies are being used routinely, even among low-risk patients.

What might explain this increasingly conservative approach in the absence of evidence? One possibility is the fear of litigation.[20] For ED physicians, both fear of litigation and aversion to risk have been associated with admission decisions and test ordering for patients with chest pain.[21,22] Negative enzyme levels effectively rule out a current MI, but stress testing may be used by physicians to reassure themselves that the patient will not have an MI in the near future. This approach adds a degree of objectivity that may be perceived to have value in court, but, to our knowledge, there is no evidence to suggest that it influences patient outcomes. To the extent that consensus guidelines could relieve physician anxiety, they might reduce the use of this unproved strategy.

The finding that services covered by house staff had lower rates of stress testing runs counter to previous studies that have found that hospitalist services generally incur costs that are the same or lower than those on teaching services.[23,24] The reason is not entirely clear. It may be that the process of explaining why tests were ordered resulted in more targeted testing, or it may have been that having more time to consider the case or the opportunity to discuss it as a team gave the decision maker confidence not to order a test.

Our study has several limitations. First, it was performed at a single hospital, and results may not be generalizable to other institutions. Ours is a large independent academic medical center serving both a tertiary and a community role. Therefore, the population it serves would appear to be representative of the general population with chest pain. Second, follow-up was limited to patients who returned to our medical center. Patients who presented with acute MI to other institutions or who died in the community would have been missed. However, the proportion of such cases should be small, as Baystate Medical Center is the only angioplasty center in our region: most local patients would be treated there, even if they presented elsewhere. Finally, it is a retrospective cohort study potentially subject to confounding. Pretest probabilities were calculated based on documented symptoms, but undocumented factors may have also played a role in physician decision making.

With rising health care costs, it is important to find a safe and efficient way to treat patients with low-risk chest pain. The 2002 ACC/AHA guidelines on exercise testing recommend that stress testing be conducted only for patients with an intermediate (10%-90%) probability of having CAD based on age, sex, and the nature of the chest pain.[4] However, based on Diamond and Forrester's[3] classifica-

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tion, we found that 70% of patients in our study would be considered to have a probability that high. Because Diamond and Forrester's work was conducted more than 30 years ago using information from patients who underwent coronary angiography, it may not accurately predict CAD in our study population. Indeed, only 6% of the stress tests in our study were positive for ischemia, implying that, on average, our patients had a risk far below the 10% threshold recommended for testing.

How can the use of unnecessary stress tests be reduced? First, we need evidence-based guidelines that clarify when, if ever, stress testing should be used in the evaluation of patients with low-risk chest pain. Validated tools for risk stratification in the ED would be particularly useful. Until then, patients with chest pain could be routinely risk stratified using existing tools, such as that of Diamond and Forrester,[3] and stress tests could be reserved for those with at least an intermediate probability of disease. If the physicians in our study had limited their testing to patients at intermediate risk, the total number of stress tests could have been reduced by 30%. In hospitals in which physicians are hesitant to forgo stress testing, patients could be discharged with timely outpatient cardiology evaluation, followed by selective stress testing—a strategy we are currently evaluating in our institution. Ultimately, external pressures from insurers may drive change. Insurers have already reduced payments for evaluation of chest pain through observation status, which pays approximately 60% less than an inpatient admission, even if patients are cared for in an inpatient ward, usually with cardiac telemetry, as our patients were. Prompt discharge of most patients without stress testing would save money, but hospitals will need to confront physician culture and the fear, real or imagined, of litigation.

Accepted for Publication: January 14, 2012.
Published Online: May 7, 2012. doi:10.1001/archinternmed.2012.940
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Author Contributions: Dr Penumetsa had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Penumetsa, Mallidi, Hiser, and Rothberg. *Acquisition of data:* Penumetsa and Rothberg. *Analysis and interpretation of data:* Penumetsa, Mallidi, Friderici, and Rothberg. *Drafting of the manuscript:* Penumetsa, Mallidi, and Rothberg. *Critical revision of the manuscript for important intellectual content:* Penumetsa, Friderici, Hiser, and Rothberg. *Statistical analysis:* Penumetsa and Friderici. *Administrative, technical, and material support:* Penumetsa, Mallidi, and Hiser. *Study supervision:* Rothberg.
Financial Disclosure: None reported.
Additional Contributions: Reva Kleppel, our research assistant, helped with data collection.

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