Evaluation of Outpatient Cardiac Stress Testing After Emergency Department Encounters for Suspected Acute Coronary Syndrome

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Study objective: Professional guidelines recommend 72-hour cardiac stress testing after an emergency department (ED) evaluation for possible acute coronary syndrome. There are limited data on actual compliance rates and effect on patient outcomes. Our aim is to describe rates of completion of noninvasive cardiac stress testing and associated 30-day major adverse cardiac events.

Methods: We conducted a retrospective analysis of ED encounters from June 2015 to June 2017 across 13 community EDs within an integrated health system in Southern California. The study population included all adults with a chest pain diagnosis, troponin value, and discharge with an order for an outpatient cardiac stress test. The primary outcome was the proportion of patients who completed an outpatient stress test within the recommended 3 days, 4 to 30 days, or not at all. Secondary analysis described the 30-day incidence of major adverse cardiac events.

Results: During the study period, 24,459 patients presented with a chest pain evaluation requiring troponin analysis and stress test ordering from the ED. Of these, we studied the 7,988 patients who were discharged home to complete diagnostic testing, having been deemed appropriate by the treating clinicians for an outpatient stress test. The stress test completion rate was 31.3% within 3 days and 58.7% between 4 and 30 days, and 10.0% of patients did not complete the ordered test. The 30-day rates of major adverse cardiac events were low (death 0.0%, acute myocardial infarction 0.7%, and revascularization 0.3%). Rapid receipt of stress testing was not associated with improved 30-day major adverse cardiac events (odds ratio 0.92; 95% confidence interval 0.55 to 1.54).

Conclusion: Less than one third of patients completed outpatient stress testing within the guideline-recommended 3 days after initial evaluation. More important, the low adverse event rates suggest that selective outpatient stress testing is safe. In this cohort of patients selected for outpatient cardiac stress testing in a well-integrated health system, there does not appear to be any associated benefit of stress testing within 3 days, nor within 30 days, compared with those who never received testing at all. The lack of benefit of obtaining timely testing, in combination with low rates of objective adverse events, may warrant reassessment of the current guidelines. [Ann Emerg Med. 2019;74:216-223.]

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INTRODUCTION

Background

Responsible for greater than 7 million annual visits to the emergency department (ED), chest pain remains the second most common reason for ED presentation of adults in the United States.[1] A minority of these patients have acute coronary syndrome and most do not even have heart disease. However, stratifying this cohort is challenging, and the inappropriate discharge of patients with high risk for acute coronary syndrome is associated with high morbidity.[2]

The American College of Cardiology/American Heart Association recommends noninvasive cardiac stress testing within 72 hours after an acute myocardial infarction has been excluded by serial ECG and cardiac biomarker testing (class IIA recommendation).[3] However, little is known of the actual completion rates of guideline-recommended early outpatient stress testing and of the association of such testing on patient outcomes. Three studies have examined early outpatient stress test completion in the United States.[4-6] All were single-center studies with limited sample

Editor's Capsule Summary

What is already known on this topic

Based on limited data, professional guidelines recommend 72-hour cardiac stress testing after emergency department (ED) evaluations for suspected acute coronary syndrome.

What question this study addressed

The study uses existing data sets to determine compliance with urgent outpatient stress testing and 30-day incidence of major adverse cardiac events.

What this study adds to our knowledge

In a highly selected cohort of 7,922 patients (one third of ED encounters were included) treated in a well-integrated health care system, only 31% had stress testing within 72 hours. There were no deaths; 0.9% had a 30-day major adverse cardiac event that was not associated with the timing of stress testing.

How this is relevant to clinical practice

This study suggests that urgent outpatient stress testing does not benefit low-risk patients with negative ED evaluation results for acute coronary syndrome.

sizes, restricted inclusion to low-risk patients, and involved targeted efforts (such as follow-up telephone calls) to maximize completion rates. Two of these studies assessed associated major adverse cardiac events. One evaluated them at 6 months according to stress test completion status within that interval,[4] whereas the other assessed adverse cardiac events in 30 days or death in 12 months according to stress test completion status within that 12-month interval.[5] Given that clinicians are most sensitive to the immediate outcomes after ED evaluation, these long-term major adverse cardiac events timeframes may provide only limited insight to inform ED clinical decisionmaking and disposition planning.

In 2016, Kaiser Permanente Southern California EDs adopted a standard recommendation of using a History, ECG, Age, Risk Factors, and Troponin (HEART) pathway for patients evaluated for suspected acute coronary syndrome.[7,8] Our objective was to describe rates of completion of early noninvasive cardiac stress testing and associated 30-day major adverse cardiac events. Our study aimed to specifically address several of these knowledge gaps by examining all outpatient stress testing from the ED in a large-volume, multicenter, community setting.

MATERIALS AND METHODS

Study Design and Setting

We conducted a retrospective study of eligible encounters occurring from June 2015 through June 2017 at 13 EDs of Kaiser Permanente Southern California, which is an integrated health system providing health care for greater than 4 million members. Kaiser Permanente Southern California hospitals deliver care for greater than 1 million ED visits annually, with volumes of the study sites ranging from 25,000 to 95,000 ED visits per year. Of these ED visits, approximately 80% are from health plan members. One center has an emergency medicine residency program. All sites use the same troponin laboratory assay (Beckman Coulter Access AccuTnI+3; Beckman Coulter, Brea, CA), and emergency physicians have the ability to order noninvasive cardiac testing as part of the discharge and follow-up plan.

Selection of Participants

ED encounters were included for adult Kaiser Permanente health plan members (≥18 years) who were discharged from the ED after an evaluation for chest pain, and who had a troponin laboratory test and an ED order for outpatient cardiac stress test. We excluded patients who had a do-not-resuscitate or hospice status, had an ED acute myocardial infarction diagnosis or troponin level of greater than 0.5 ng/mL, died in the ED, transferred from another hospital, or completed a stress test before discharge. Chest pain diagnosis was defined with *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes (and *ICD-10* codes), and noninvasive cardiac tests were identified by current procedural terminology codes (Appendix E1, available online at http://www.annemergmed.com).

Outcome Measures

The primary outcome was the proportion of patients who completed an early outpatient stress test within 72 hours from ED discharge. Included in the primary outcome was the proportion of patients who completed a stress test within 4 to 30 days or not at all. We also measured 30-day incidence of major adverse cardiac events (all-cause death, acute myocardial infarction, and revascularization by percutaneous coronary intervention or coronary artery bypass grafting) as a secondary outcome to assess its relationship with early completion (Appendix E1, available online at http://www.annemergmed.com). Midway through the study period in May 2016, all study sites implemented decision support to capture HEART scores and to incorporate this tool into routine ED care.[7,8] We report the completion rates of stress testing stratified by

this subgroup of encounters with documented low- (0 to 3), moderate- (4 to 6), or high-risk (7 to 10) HEART scores. Mortality data were obtained from Kaiser Permanente Southern California administrative records, which were supplemented with data from the State of California and Social Security Administration.

Relevant demographic, clinical, comorbidity, and physician data were also obtained, using structured data from electronic health and administrative records. Patient age, sex, and race or ethnicity were obtained from administrative records, and patient socioeconomic status was measured with the census block-level median income based on patients' home zip codes. Cardiac risk factors measured were cardiac-related comorbidities as defined by using codes for the modified Elixhauser index[9] (eg, hypertension, diabetes), body mass index measured from either ED initial assessment or the most recently available from a previous encounter, and electronic medical record-recorded self-reported smoking history ("active," "secondhand," "quit," and "never"). Southern California Permanente Medical Group physicians were distinguished from per-diem and other employee types through administrative records.

Additionally, we considered that nonclinical, system-level factors could be key drivers of 72-hour completion. For this reason, we also recorded the Kaiser Permanente Southern California medical center at which ED encounters occurred, as well as day of the week and hour of the day of discharge.

Primary Data Analysis

Patient, visit, physician, and facility characteristics were summarized with means and SDs for continuous variables, and frequencies and percentages for categoric variables. Because of low levels of missingness in our continuous variables, we excluded patients missing body mass index (n=60) or socioeconomic status (n=7) from multivariable analyses. For missing categoric outcomes (smoking history, n=146), we included an "unknown" category.

The outcome of interest was completion of an ED-ordered stress test within 72 hours from ED discharge. We calculated this at the patient level, as well as medical center level, to assess variability between facilities. For the former, we used logistic regression to estimate the multivariable-adjusted associations between early stress test completion and the patient, visit, physician, and facility characteristics listed above. We also included an interaction term between medical center and day of the week to assess whether discharges occurring at the end of the week (Thursday to Friday) had different completion rates by medical center. We examined separate and composite 30-day major adverse cardiac events rates for patients completing noninvasive testing within 72 hours compared with those who did not. We summarized all model results with odds ratios and 95% confidence intervals. All analyses were conducted with SAS (version 9.3; SAS Institute, Inc., Cary, NC). This study was approved by the Kaiser Permanente Southern California institutional review board.

RESULTS

In the study period, there were a total of 24,459 ED encounters for chest pain evaluation prompting troponin analysis and noninvasive stress test ordering. Of these, 7,988 patients were discharged to complete cardiac stress testing as outpatients (Figure 1). Of this cohort, 2,497 patients (31.3%) completed a stress test within 72 hours of ED discharge, whereas 4,695 (58.7%) did so within 4 to 30 days and 796 (10.0%) did not complete testing within 30 days (Table 1). Among the tests ordered, 6,746 (84.5%) were exercise or pharmacologic stress ECG, 1,118 (14.0%) were exercise or pharmacologic stress echocardiogram, and 124 (1.5%) were myocardial perfusion imaging.

In comparing the early completion group with all others who did not receive a stress test within 72 hours of discharge, patient characteristics were similar in age, sex, race, and cardiac-specific comorbidities, with the exception of hypertension (Table 1, Table E1 [available online at http://www.annemergmed.com]). In the multivariable-adjusted model, no patient demographic, clinical, or comorbidity characteristics, or emergency physician

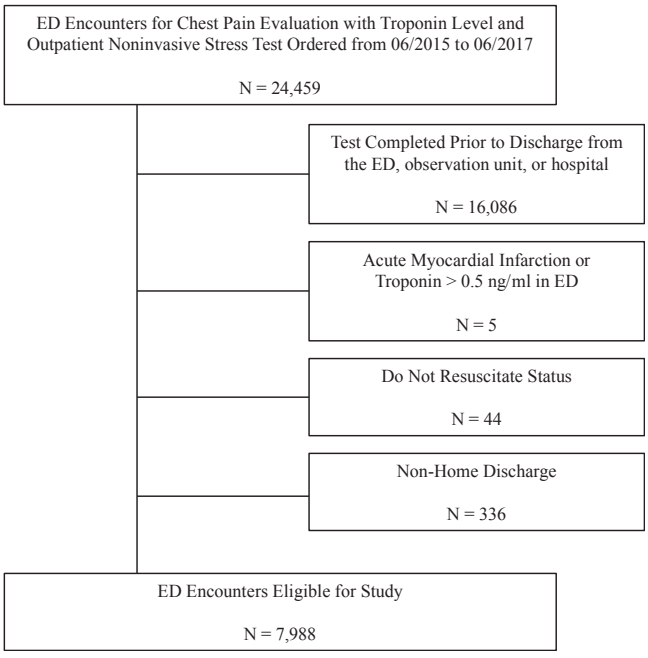

Figure 1. Flow diagram of the study cohort used for analysis.

Table 1. ED patient characteristics for adults assessed for possible acute coronary syndrome and discharged with an outpatient noninvasive cardiac stress test order.*

Patient Variables	Noninvasive Test Completion Timeframe			Total (N=7,988)
	Within 3 Days (N=2,497)	4 to 30 Days (N=4,695)	None Within 30 Days (N=796)	
Age, mean (SD), y	55.0 (11.50)	55.4 (11.82)	55.6 (11.68)	55.3 (11.71)
Women, No. (%)	1,351 (54.1)	2,606 (55.5)	479 (60.2)	4,436 (55.5)
Race, No. (%)				
White	1,179 (47.2)	2,257 (48.1)	413 (51.9)	3,849 (48.2)
Black	407 (16.3)	672 (14.3)	110 (13.8)	1,189 (14.9)
Asian	303 (12.1)	552 (11.8)	91 (11.4)	946 (11.8)
Alaska Native/Pacific Islander	42 (1.7)	94 (2.0)	18 (2.3)	154 (1.9)
Other	566 (22.7)	1,120 (23.9)	164 (20.6)	1,850 (23.2)
Elixhauser score, mean (SD)	2.4 (2.07)	2.5 (2.14)	2.5 (2.24)	2.5 (2.13)
Cardiac risk factors, No. (%)				
Coronary artery disease	114 (4.6)	239 (5.1)	44 (5.5)	397 (5.0)
Congestive heart failure	26 (1.0)	51 (1.1)	13 (1.6)	90 (1.1)
Diabetes	472 (18.9)	922 (19.6)	146 (18.3)	1,540 (19.3)
Hypertension	1,015 (40.6)	2,081 (44.3)	348 (43.7)	3,444 (43.1)
Liver disease	210 (8.4)	395 (8.4)	63 (7.9)	668 (8.4)
Peripheral vascular disorders	279 (11.2)	589 (12.5)	105 (13.2)	973 (12.2)
Body mass index				
Normal	509 (20.5)	922 (19.8)	165 (20.9)	1,596 (20.1)
Overweight	905 (36.5)	1,678 (36.0)	284 (35.9)	2,867 (36.2)
Obese	1,067 (43.0)	2,057 (44.2)	341 (43.2)	3,465 (43.7)
Missing	16	38	6	60
Smoking behavior, No. (%)				
Never	1,685 (67.5)	3,080 (65.6)	514 (64.6)	5,279 (66.1)
Quit	595 (23.8)	1,207 (25.7)	205 (25.8)	2,007 (25.1)
Passive	11 (0.4)	30 (0.6)	5 (0.6)	46 (0.6)
Active	158 (6.3)	297 (6.3)	55 (6.9)	510 (6.4)
Missing	48 (1.9)	81 (1.7)	17 (2.1)	146 (1.8)
ED encounter day of the week				
Saturday–Wednesday	2,105 (84.3)	2,963 (63.1)	532 (66.8)	5,600 (70.1)
Thursday–Friday	392 (15.7)	1,732 (36.9)	264 (33.2)	2,388 (29.9)

*Study sample is stratified by timing of test completion.

characteristics, were significantly associated with 72-hour test completion (Table 2).

In contrast, system or nonclinical factors had stronger associations with receipt of 72-hour stress testing than clinical characteristics. Specifically, the day of the week had a large effect, with Thursday to Friday discharges having much lower rates of 72-hour completion than those occurring Saturday to Wednesday (15.7% versus 84.3%) (Table 1). Compared with Thursday to Friday discharges, those occurring Saturday to Wednesday were 3.6 times as likely to result in early stress test completion (95% confidence interval 3.17 to 4.15) (Table 2). There was also a large amount of variability by medical center, ranging from less than 10% to nearly 70% for early completion (Figure 2). Medical center 13 was used as comparator because it had the highest completion rate, and patients discharged from other medical centers were anywhere from 30% to 98% less likely to have early completion of stress tests (Table 2). These two statistically significant associations remained after adjustment for the relevant patient, visit, physician, and facility

Table 2. Adjusted odds ratio estimates and confidence intervals for 72-hour noninvasive cardiac stress test completion among ED patients evaluated for possible acute coronary syndrome.

Effect	Estimate	95% Confidence Interval
Age, y		
≥65 vs 18–47	0.91	0.76–1.08
55–65 vs 18–47	0.94	0.81–1.10
47–55 vs 18–47	1.03	0.88–1.21
Women vs men	0.93	0.83–1.04
Race		
Alaska Native/Pacific Islander vs white	0.83	0.55–1.26
Asian vs white	0.91	0.76–1.09
Black vs white	0.84	0.71–0.99
Others vs white	0.92	0.80–1.07
Household median income (per $10,000)	0.99	0.97–1.01
Coronary artery disease: no vs yes	1.08	0.83–1.40
Elixhauser score		
1–2 vs 0	1.00	0.85–1.17
3–4 vs 0	0.97	0.81–1.16
≥5 vs 0	0.92	0.75–1.14
Body mass index		
Overweight vs normal	1.01	0.87–1.19
Obese vs normal	1.01	0.86–1.19
Physician affiliation: per diem vs full-time KPSC	1.09	0.97–1.23
ED visit day of week: Saturday–Wednesday vs Thursday–Friday	3.63	3.17–4.15
ED visit year: 2015 vs 2017	0.97	0.83–1.13
ED visit year: 2016 vs 2017	0.92	0.81–1.05
Medical center		
1 vs 13	0.23	0.17–0.30
2 vs 13	0.02	0.01–0.04
3 vs 13	0.04	0.03–0.06
4 vs 13	0.16	0.13–0.21
5 vs 13	0.30	0.22–0.40
6 vs 13	0.71	0.54–0.93
7 vs 13	0.09	0.07–0.12
8 vs 13	0.46	0.36–0.59
9 vs 13	0.09	0.06–0.13
10 vs 13	0.17	0.13–0.21
11 vs 13	0.04	0.03–0.05
12 vs 13	0.02	0.01–0.03

KPSC, Kaiser Permanente Southern California.

characteristics. There was also a statistically significant interaction between medical center and discharge day of the week, in which the odds ratios of early completion for Saturday to Wednesday compared with Thursday to Friday ranged from 1.6 to 8.2 across the 13 medical centers (Table E2, available online at http://www.annemergmed.com).

There were no all-cause deaths within 30 days. The rates of other types of 30-day major adverse cardiac events were low, with acute myocardial infarction at 0.7% and revascularization by percutaneous coronary intervention or coronary artery bypass grafting at 0.3%. Furthermore, rapid receipt of stress testing was not associated with improved adverse outcomes (Table 3) because patients completing stress testing within 72 hours were as likely to experience 30-day major adverse cardiac events as those who did not (odds ratio 0.92; 95% confidence interval 0.55 to 1.54). Subgroup analysis of 2,151 encounters with documented HEART scores (1,560 low risk, 584 moderate risk, and 7 high risk) showed that different risk pools did not affect the timing of follow-up stress testing (Table E1, available online at http://www.annemergmed.com).

LIMITATIONS

Limitations of our study include the retrospective analysis and restriction to a cohort of patients who presented with chest pain, as opposed to other atypical presentations that were evaluated for possible acute coronary syndrome. Additionally, our study excluded patients who were kept in the ED or observed in the hospital to receive a stress test. Our study results are related only to patients who an emergency physician stratified by risk and considered safe for discharge and outpatient stress testing. Another limitation is that our study population may not be representative of different types of US health systems. Other regional health care systems may not be as well integrated, and patients may have limited access to primary care and follow-up. Finally, our study design and analyses of major adverse cardiac events rates cannot demonstrate causal inference. This work will inform future analyses (eg, propensity score, instrumental variables) to assess the causal relationship between early noninvasive testing and 30-day major adverse cardiac events rates.

DISCUSSION

Our study of 7,988 ED encounters resulting in outpatient noninvasive cardiac testing found a 72-hour completion rate of 31.3%, with 90.0% completing within 30 days of the ED visit. Adverse outcome rates at 30 days were very low, with 0 deaths, 54 acute myocardial infarctions (0.7%), 4 percutaneous coronary intervention procedures (0.1%), and 13 coronary artery bypass grafting procedures (0.2%). Our results further suggest that early outpatient

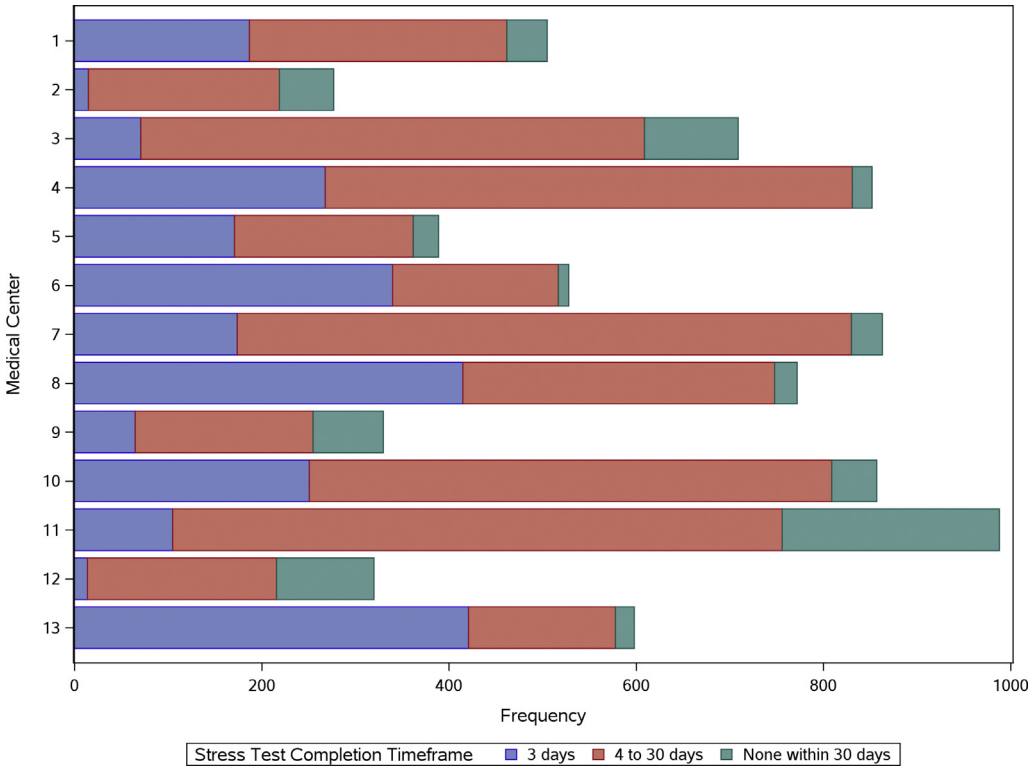

Figure 2. Distribution of noninvasive cardiac stress test completion timing stratified by each of 13 ED medical centers.

stress testing is not associated with lower major adverse cardiac events rates and may bring into question whether this population benefits from noninvasive testing at all.

Outpatient test completion rates previously reported in the literature have been the result of single-site performance improvement efforts. Two of these studies were at academic centers and found 72-hour completion rates of 6% (27 of 448 patients)[5] and 62% (170 of 275 patients).[6] A third study, performed more than a decade ago at a Kaiser Permanente community ED, found a 96-hour completion rate of 68% (613 of 979 patients).[4] In these previous studies, targeted adherence to test completion was the primary objective of an accelerated chest pain protocol or discharge from a designated ED chest pain unit. In contrast, our study investigated follow-up outcomes based on current practice among a large network of community EDs where an outpatient noninvasive test order was placed from the ED.

Table 3. Thirty-day major adverse cardiac outcomes stratified by timing of noninvasive cardiac stress test completion after an ED visit for suspected acute coronary syndrome.

	Noninvasive Test Completion Timeframe			
Outcome	Within 3 Days (N=2,497)	4 to 30 Days (N=4,695)	None Within 30 Days (N=796)	Total (N=7,988)
Death, N	0	0	0	0
AMI, No. (%)	19 (0.8)	30 (0.6)	5 (0.6)	54 (0.7)
PCI, No. (%)	2 (0.1)	2 (<0.1)	0	4 (0.1)
CABG, No. (%)	6 (0.2)	7 (0.1)	0	13 (0.2)
Unstable angina, No. (%)	18 (0.7)	24 (0.5)	1 (0.1)	43 (0.5)
MACE, No. (%)	27 (1.1)	39 (0.8)	5 (0.6)	71 (0.9)

AMI, Acute myocardial infarction; *PCI*, percutaneous coronary intervention; *CABG*, coronary artery bypass grafting; *MACE*, major adverse cardiac events (includes death, AMI, PCI, and CABG).

Our study shows that despite the advantages of an integrated health system with the availability of ED-based referral for stress testing, the 72-hour guideline concordance rate is low. For patients without the benefit of a similar health system mechanism to facilitate outpatient referral, the ability to complete testing within 72 hours may be even more limited.

Even with low guideline concordance, 30-day major adverse cardiac events rates were nevertheless very low for all categories. Meyer et al[4] similarly found infrequent adverse events among eligible patients who completed stress testing within any timeframe (1-month acute myocardial infarction rate of 0.1% and 6-month death, acute myocardial infarction, percutaneous coronary intervention, and coronary artery bypass grafting rates of 0%, 0.2%, 0.7%, and

0%, respectively). Milano et al[5] reported 12-month adverse events, finding a major adverse cardiac events rate of 0% among patients who received stress testing at any point, and 5 all-cause deaths (1.1%) and no acute myocardial infarction, percutaneous coronary intervention, or coronary artery bypass grafting among those who did not receive testing. With such a low event rate, our study was not powered to detect differences in major adverse cardiac events across all stress test completion timeframes. However, the few adverse events suggest appropriate assessment of safe discharges from the ED and no identifiable benefit of early outpatient noninvasive stress testing for this population.

This study adds to the recent literature that challenges routine stress testing.[10-13] Observational reports suggest that current use of early noninvasive tests leads to overtreatment without objective benefit. In a retrospective cohort of 421,774 privately insured patients, stress ECG, stress myocardial perfusion, and coronary computed tomography (CT) angiography were associated with increased rates of invasive coronary angiograms and revascularization without reduction in acute myocardial infarction risk when compared with no testing.[11] Similarly, in another retrospective cohort of 926,633 privately insured patients, noninvasive testing or coronary angiography within 30 days of ED presentation was associated with increased rates of invasive coronary angiograms and revascularization without reduction in acute myocardial infarction admissions.[12] At 224 hospitals, higher rates of noninvasive testing were correlated with increasing odds of admission, invasive angiograms, and revascularization, without reducing acute myocardial infarction risk.[13] Accordingly, the American College of Emergency Physicians (ACEP) recently recommended against routine diagnostic testing (coronary CT angiography, stress testing, and myocardial perfusion imaging) before discharge for low-risk patients in whom acute myocardial infarction has been ruled out (level B recommendation).[14]

Despite the lack of evidence of benefit, patients are often admitted (eg, to inpatient or observation status) to facilitate early noninvasive testing, as recommended by current guidelines. Because low- and medium-risk chest pain patients are so common, the current recommendations contribute to crowding of EDs, chest pain units, and clinical decision units, as well as treadmill laboratories, not to mention much patient inconvenience and stress, with little to no apparent benefit. Our results suggest that there may be no benefit to early stress testing and resources could be used more efficiently. The difficulty of obtaining guideline-concordant 72-hour stress testing on an outpatient basis, even under ideal health system conditions, and the unclear benefit of hospital-based evaluation, in combination with these low rates of objective adverse events, may warrant reassessment of the American College of Cardiology/American Heart Association guidelines.

Furthermore, our results demonstrate that patient-level factors did not contribute to 72-hour guideline concordance. Even within an integrated system of insured patients, it is the structural factors of day of week and medical center variability that dictate whether a patient is able to receive the test within the guideline-recommended timeframe. This variation by day of week and medical center presents an opportunity for future causal studies using instrumental variable analysis.[12]

In summary, patients who are discharged from the ED after an evaluation for possible acute coronary syndrome face a significant challenge in obtaining American College of Cardiology/American Heart Association guideline-recommended noninvasive cardiac testing within 72 hours. However, in exploratory analyses of this cohort of patients deemed safe for discharge in a well-integrated health care system, there does not appear to be any associated benefit of stress testing within 3 days, nor within 30 days, compared with never receiving testing at all. The lack of benefit of obtaining timely testing, in combination with low rates of objective adverse events, may warrant reassessment of the current guidelines.

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Author contributions: SN, BCS, and ALS conceived the study. BCS and ALS obtained research funding and managed the data, including quality control. ES and Y-LW provided statistical advice

on study design and analyzed the data. ALS chaired the data oversights committee. SN drafted the article, and all authors contributed substantially to its revision. ALS takes responsibility for the paper as a whole.

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