

“False-Positive” Cardiac Catheterization Laboratory Activation Among Patients With Suspected ST-Segment Elevation Myocardial Infarction

David M. Larson, MD

Katie M. Menssen, BA

Scott W. Sharkey, MD

Sue Duval, PhD

Robert S. Schwartz, MD

James Harris, MD

Jeffrey T. Meland, MD

Barbara T. Unger, RN

Timothy D. Henry, MD

DESPITE ITS LIMITATIONS, THE standard 12-lead electrocardiogram (ECG) remains a key diagnostic tool directing the emergency management of patients with an acute myocardial infarction.¹ In 1980, DeWood et al² reported that patients presenting with acute chest pain, persistent ST-segment elevation progressing to Q waves, and elevations of cardiac biomarker levels were found to have a total thrombotic coronary occlusion in 87% of cases. A variety of other serious conditions aside from an acute myocardial infarction may also cause ST-segment elevation.³

Time to reperfusion is a major determinant of outcome in patients presenting with an ST-segment elevation myocardial infarction (STEMI).^{4,5} The American College of Cardiology/American Heart Association STEMI guidelines recommend that the emergency department physician make the

For editorial comment see p 2790.

Context Allowing the emergency department physician to activate the cardiac catheterization laboratory is a key strategy to reduce door-to-balloon times in patients with ST-segment elevation myocardial infarction (STEMI). There are limited data on the frequency of “false-positive” catheterization laboratory activation in patients undergoing percutaneous coronary intervention for suspected STEMI.

Objective To determine the prevalence, etiology, and outcomes of false-positive cardiac catheterization laboratory activation in patients with a suspected STEMI.

Design, Setting, and Patients Prospective registry from a regional system that includes transfer of patients with STEMI from 30 community and rural hospitals with pretransfer catheterization laboratory activation for percutaneous coronary intervention at a tertiary cardiovascular center in Minnesota. A total of 1345 patients were enrolled from March 2003 to November 2006.

Main Outcome Measure Prevalence of false-positive catheterization laboratory activation in patients with suspected STEMI by 3 criteria: no culprit coronary artery, no significant coronary artery disease, and negative cardiac biomarker results.

Results Of the 1335 patients with suspected STEMI who underwent angiography, 187 (14%; 95% confidence interval [CI], 12.2%-16.0%) had no culprit coronary artery and 127 (9.5%; 95% CI, 8.0%-11.2%) did not have significant coronary artery disease. Cardiac biomarker levels were negative in 11.2% (95% CI, 9.6%-13.0%) of patients. The combination of no culprit artery with negative cardiac biomarker results was present in 9.2% (95% CI, 7.7%-10.9%) of patients. Thirty-day mortality was 2.7% (95% CI, 0.4%-5.0%) without vs 4.6% (95% CI, 3.4%-5.8%) with a culprit coronary artery ($P=.33$).

Conclusions The frequency of false-positive cardiac catheterization laboratory activation for suspected STEMI is relatively common in community practice, depending on the definition of false-positive. Recent emphasis on rapid door-to-balloon times must also consider the consequences of false-positive catheterization laboratory activation.

JAMA. 2007;298(23):2754-2760

www.jama.com

decision regarding reperfusion therapy within 10 minutes of interpreting the initial diagnostic ECG,⁶ which may be challenging because clinical decisions are often made without a previous ECG result for comparison or time to observe evolutionary ST-segment changes or cardiac biomarker results. Upstream activation of the cardiac cath-

Author Affiliations: Minneapolis Heart Institute Foundation at Abbott Northwestern Hospital, Minneapolis, Minnesota (Drs Larson, Sharkey, Schwartz, and Henry and Mss Menssen and Unger); Department of Emergency Medicine, Ridgeview Medical Center, Waconia, Minnesota (Dr Larson); Riverwood Healthcare Center, Aitkin, Minnesota (Dr Harris); Northfield Hospital, Northfield, Minnesota (Dr Meland); and Division of Epidemiology and Community Health, University of Minnesota, Minneapolis (Dr Duval).

Corresponding Author: Timothy D. Henry, MD, Minneapolis Heart Institute Foundation, 920 E 28th St, Ste 40, Minneapolis, MN 55407 (henry003@umn.edu).

eterization laboratory by the emergency department physician has been recommended as a key strategy to reduce door-to-balloon times.⁷ Although rapid reperfusion is an important quality metric, the potential clinical and financial consequences associated with false alarms need to be considered.⁸

The objective of this study was to determine the prevalence, etiology, and outcomes of "false-positive" catheterization laboratory activation from a consecutive series of patients with suspected STEMI.

METHODS

The Minneapolis Heart Institute at Abbott Northwestern Hospital in Minneapolis, Minnesota, is a tertiary cardiovascular center with referral relationships with community hospitals throughout Minnesota and western Wisconsin. In 2002, a regional system for the management of STEMI, the Level 1 MI program, was initiated, with a standardized protocol for transfer of STEMI patients for primary or facilitated percutaneous coronary intervention from community hospitals up to 210 miles (338 km) from the percutaneous coronary intervention hospital. The detailed design and results of the Level 1 MI program have been previously reported.^{9,10} For patients presenting with symptoms for less than 24 hours with ST-segment elevation or new left bundle-branch block, the diagnosis and decision to activate the catheterization laboratory was made by the emergency department physician. With a single telephone call, the catheterization laboratory team was immediately called in by a group page and the interhospital transport service was summoned. All emergency department physicians were board certified in emergency medicine, family medicine, or internal medicine, depending on the size and staffing patterns at the community hospital. In cases of diagnostic uncertainty, at the discretion of the emergency department physician, the ECG may be faxed to the attend-

ing cardiologist for review before catheterization laboratory activation. Twenty-four-hour on-site cardiology consultation was available only at the percutaneous coronary intervention hospital. Patients who were transferred from a community hospital bypassed the emergency department at the percutaneous coronary intervention hospital (Abbott Northwestern) and were taken directly to the catheterization laboratory. The ECGs used in this analysis were those used to make the diagnosis of STEMI obtained at the transferring hospital.

Data obtained from all Level 1 MI patients were entered into a prospective registry that included clinical, laboratory, ECG, angiographic, and follow-up data. No patients were excluded from the transfer protocol unless the emergency department physician thought that reperfusion therapy was inappropriate because of underlying conditions such as advanced metastatic cancer or end-stage dementia. Patients with advanced age, cardiogenic shock, out-of-hospital cardiac arrest, nondiagnostic initial ECG results, and atypical presentations were included in the data registry. Institutional review board approval was obtained, including waiver of consent for in-hospital data collection, data analysis, and 30-day follow-up. Specific consent was then obtained from all patients for 5-year follow-up.

Angiographic data were obtained from the catheterization laboratory report and included the culprit coronary artery, number of vessels with coronary artery disease, type of intervention, flow according to Thrombolysis in Myocardial Infarction study guidelines before and after intervention, and ejection fraction using American College of Cardiology definitions. The culprit artery was determined by the interventional cardiologist to be the coronary artery responsible for the STEMI. If there was more than 1 potential coronary artery responsible, the culprit artery was listed as multiple potential culprit arteries. If there was no angiographic evidence of a coronary le-

sion responsible for an acute coronary syndrome, it was listed as none. Coronary angiograms, database forms, and discharge summaries were reviewed by an emergency department physician (D.M.L.) and cardiologist (T.D.H.) to confirm accuracy of the data and develop consensus. All index ECGs were reviewed retrospectively to determine whether criteria for ST-segment elevation or new left bundle-branch block were met. If not, the ECG was reported as nondiagnostic. In cases without a clear culprit artery, the presumed diagnosis from the discharge summary by the attending cardiologist, with supporting evidence, was reviewed by 2 of the authors (D.M.L. and T.D.H.).

Definitions

Considerable variability exists in the definition of a patient with a false-positive STEMI. Therefore, we considered 3 clinical scenarios separately: patients with ST-segment elevation but no clear culprit coronary artery, no significant coronary artery disease, and negative cardiac biomarker results.

ST-segment elevation was defined as J-point elevation in 2 or more contiguous leads, with a cutoff of greater than or equal to 0.2 mV in leads V1, V2, or V3 and greater than or equal to 0.1 mV in other leads.¹¹ Elevated cardiac marker levels were defined as a troponin T peak of greater than or equal to 0.1 or a creatine kinase MB fraction peak of greater than 7%. A culprit coronary artery was defined as the presence of an acute total or subtotal occlusion of a coronary artery or a coronary lesion with a visible thrombus responsible for the STEMI. For the purpose of this study, we considered culprit coronary artery synonymous with infarct-related artery.

Patients Without a Clear Culprit Artery. The following definitions were used for patients without a clear culprit artery by angiography. Pericarditis was defined by clinical findings of a pericardial friction rub,

typical chest pain worsened by position change or respirations with typical ECG findings (ST-segment elevation involving >1 vascular territory), and minimal coronary disease (<50% stenosis of any coronary vessels). Myocarditis was defined by typical ECG findings of pericarditis, elevations of cardiac troponin levels, a preceding infection, or characteristic findings on cardiac magnetic resonance imaging,¹² which was performed in 75% of cases.

Stress cardiomyopathy was defined by characteristic apical or midventricular ballooning noted on left ventriculography, reversible left ventricular systolic dysfunction without significant coronary stenosis,¹³ or cardiac magnetic resonance imaging demonstrating absent hyperenhancement, which was available in 70% of the cases. Previous myocardial infarction with persistent ST-segment elevation was defined by history of a Q-wave myocardial infarction with ST-segment elevation that was either demonstrated on a previous ECG or did not demonstrate ST-segment evolutionary changes. STEMI caused by emboli or spasm was presumed to be the etiology when there was no coronary lesion in a patient with positive cardiac biomarker results, and myocardial infarction was confirmed by cardiac magnetic resonance imaging (delayed enhancement) or a regional wall motion abnormality on left ventriculography or echocardiography in the expected vascular distribution. Pulmonary embolism was confirmed by computed tomographic pulmonary angiography.

Left ventricular hypertrophy was noted if identified by echocardiography or the ECG computer algorithm. Benign early repolarization or normal variant was identified in patients with negative cardiac biomarker results and at least 4 of the following criteria: concavity of the initial up-sloping portion of the ST-segment; notching or slurring of the J point; symmetric, concordant, predominant T waves; J-point elevation and widespread distribution of

the electrocardiographic abnormality; or temporal stability.¹⁴

No Significant Coronary Artery Disease. No significant coronary artery disease was defined as less than 50% stenosis in any coronary artery; moderate to severe disease was defined as 50% or greater stenosis in at least 1 coronary artery.

Patients With a Culprit Artery and Negative Cardiac Biomarker Results. Definitions for patients with a culprit artery but negative cardiac biomarker results included the following: aborted myocardial infarction was defined as diagnostic ST-segment elevation with a clear culprit artery with negative cardiac biomarker results. Unstable angina was defined as nondiagnostic ECG with a clear culprit artery and negative cardiac biomarker results.

Statistical Methods

Comparisons between patients with and without a clear culprit artery were performed with either *t* tests for continuous variables (age) or χ^2 tests for categorical variables. All subgroup comparisons were planned a priori, so no formal adjustment was made for multiple comparisons. Thirty-day mortality data were analyzed with Fisher exact test because of the small number of deaths. Hospitals were classified as having fewer than 10 000, 10 000 to 20 000, or more than 20 000 annual emergency department visits. To pool false-positive rates across hospitals within these 3 strata, fixed-effects meta-analytic methods with inverse-variance weighting were used. Tests of trend in false-positive rates across emergency department volume strata were obtained by including a term for emergency department volume in a meta-regression model. All analyses were performed with Stata, version 10 (StataCorp, College Station, Texas). *P* < .05 was considered statistically significant.

RESULTS

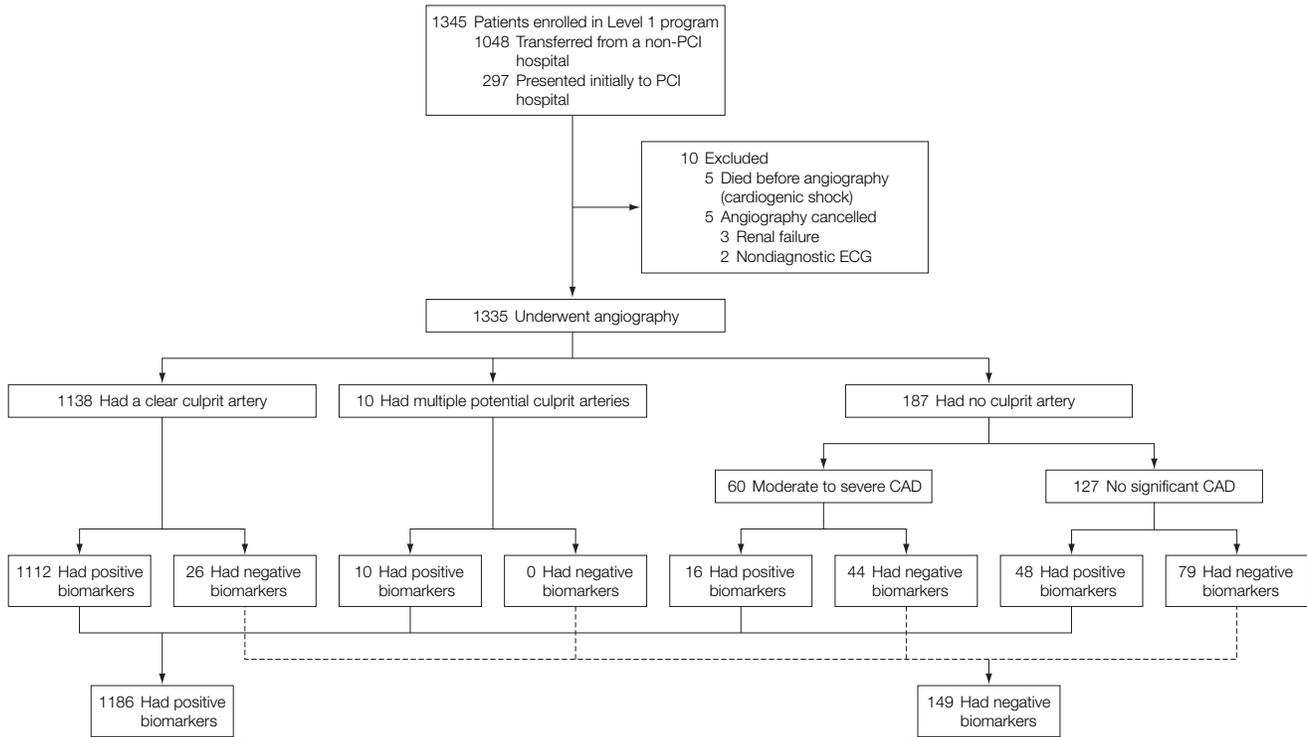
From March 2003 to November 2006, a total of 1345 patients with suspected STEMI were enrolled in the Level 1 MI program, including 1048 transferred

from 30 rural or community hospitals and 297 who presented to the percutaneous coronary intervention hospital directly. Five patients died before angiography, all of whom had diagnostic ST-segment elevation and were in cardiogenic shock at presentation. Angiography was canceled by the interventional cardiologist for 5 patients. Three of these were canceled because of an elevated creatinine level, and the other 2 had atypical symptoms, with an ECG considered nondiagnostic by the receiving interventional cardiologist (FIGURE).

No Clear Culprit Coronary Artery

Of the 1335 patients who underwent angiography, 187 (14%) did not have a clear culprit coronary artery, 10 patients (0.7%) had multiple potential culprit arteries (severe 3-vessel disease and positive cardiac biomarker results), and 1138 (85.3%) had a clear culprit artery. Patients with a culprit artery were treated with percutaneous coronary intervention (94%), coronary artery bypass surgery (4%), or medical management (2%). Retrospective review of the index ECG indicated that 24 patients (1.8%) did not have diagnostic ST-segment elevation but instead had ST-segment depression, T-wave inversion, or non-specific ST-T changes, including 3 patients with positive biomarker results (2 with non-STEMI and 1 with a drug overdose) and 21 with negative cardiac biomarker results. These patients were included in the no-culprit artery group.

The prevalence of false-positive catheterization laboratory activation with the no-culprit coronary artery criteria was 14% (95% confidence interval [CI], 12.2%-16.0%). A comparison of baseline characteristics and outcomes between patients with and without a culprit artery is shown in TABLE 1. For cardiac risk factors, there was a higher proportion of smokers (41.3% vs 32.1%; *P* = .02), men (72.8% vs 65.2%; *P* = .03), and advanced age (mean, 62.8 vs 57.4 years; *P* < .001) in individuals with a culprit artery. Patients with a clear cul-

Figure. Patients Enrolled in the Level 1 MI Program and Undergoing Angiography for Suspected ST-Segment Elevation Myocardial Infarction

No significant coronary artery disease (CAD) was defined as <50% stenosis in any coronary artery; moderate to severe CAD was defined as ≥50% stenosis in ≥1 coronary artery. PCI indicates percutaneous coronary intervention; ECG, electrocardiogram.

pruit artery were also more likely to have had a cardiac arrest (11.2% vs 3.7%; $P=.002$) or cardiogenic shock (12.8% vs 4.8%; $P=.002$). Patients without a culprit artery were more likely to have had a history of myocardial infarction (23.5% vs 16.4%; $P=.02$) or coronary artery bypass surgery (11.8% vs 6.2%; $P=.006$). The 30-day mortality was 2.7% (95% CI, 0.4%-5.0%) without vs 4.6% (95% CI, 3.4%-5.8%) with a culprit artery ($P=.33$).

Of the 14% of patients with no clear culprit artery, 64 (4.8%) had positive and 123 (9.2%; 95% CI, 7.7%-10.9%) had negative cardiac biomarker results. The etiologies are listed in TABLE 2. Approximately 75% of patients with no clear culprit artery and positive cardiac biomarker results had a cardiac magnetic resonance imaging result that confirmed the diagnosis of a myocardial infarction (presumably because of emboli or spasm), myocarditis, or stress (takotsubo) cardiomyopathy.

Table 1. Baseline Characteristics and Outcomes in Patients With and Without a Culprit Coronary Artery

	% (95% Confidence Interval)		<i>P</i> Value
	Clear Culprit Artery (n = 1138)	No Culprit Artery (n = 187)	
Baseline characteristics			
Age, mean (SD), y	62.8 (14.1)	57.4 (16.4)	<.001
Male sex	72.8 (70.3-75.4)	65.2 (58.4-72.1)	.03
Hypertension	55.0 (52.1-57.9)	49.2 (42.0-56.4)	.14
Diabetes	15.1 (13.0-17.2)	12.8 (8.0-17.6)	.42
Dyslipidemia	54.4 (51.5-57.3)	47.6 (40.4-54.8)	.08
Smoker	41.3 (38.4-44.1)	32.1 (25.4-38.8)	.02
Family history of coronary artery disease	46.4 (43.5-49.3)	40.1 (33.1-47.2)	.11
Previous myocardial infarction	16.4 (14.2-18.5)	23.5 (17.4-29.6)	.02
Previous percutaneous coronary intervention	17.8 (15.5-20.0)	22.5 (16.5-28.5)	.13
Previous coronary artery bypass graft	6.2 (4.8-7.7)	11.8 (7.1-16.4)	.006
Outcomes			
Hospital mortality	4.0 (2.8-5.1)	2.1 (0.1-4.2)	.22
30-Day mortality	4.6 (3.4-5.8)	2.7 (0.4-5.0)	.33
1-Year mortality	6.2 (4.8-7.7)	4.3 (1.4-7.2)	.40
Cardiac arrest	11.2 (9.4-13.1)	3.7 (1.0-6.5)	.002
Cardiogenic shock	12.8 (10.9-14.8)	4.8 (1.7-7.9)	.002
Positive biomarkers	97.7 (96.8-98.6)	34.2 (27.4-41.0)	<.001

Table 2. Etiologies of False-Positive Cardiac Catheterization Laboratory Activation in Patients Without a Culprit Artery (n = 187)

Etiologies by Biomarker Results	No.
Negative biomarker results (n = 123)	
Early repolarization	25
Nondiagnostic electrocardiogram	21
Pericarditis	20
Previous myocardial infarction	20
Left bundle-branch block	11
Left-sided ventricular hypertrophy	8
Vasospasm	4
Tachycardia related	3
Right bundle-branch block	3
Pacemaker	3
Brugada syndrome	1
Aortic dissection	1
Unknown	3
Positive biomarker results (n = 64)	
Stress cardiomyopathy	17
Myocarditis	15
Previous myocardial infarction	9
ST-elevation myocardial infarction—embolic/spasm	9
Left bundle-branch block	4
Non-ST-elevation myocardial infarction	2
Pulmonary embolus	2
Aortic neoplasm	1
Severe aortic stenosis	1
Drug overdose	1
Unknown	3

No Significant Coronary Artery Disease

Of the 1335 patients who had angiography and did not have a culprit artery, 127 (9.5%; 95% CI, 8.0%-11.2%) did not have significant coronary artery disease. However, 48 of these patients (38%) had positive cardiac biomarker results. The most common diagnosis in this subgroup was myocarditis, 15 (31%); stress cardiomyopathy, 15 (31%); or STEMI (confirmed by cardiac magnetic resonance imaging) without an angiographic lesion, 14 (29%). The 30-day mortality in individuals without significant coronary artery disease was 2.4% (95% CI, 0%-5.0%) vs 4.8% (95% CI, 3.6%-6.0%) in those with coronary artery disease ($P=.27$).

Negative Cardiac Biomarker Results

Of the 1335 patients who had angiography, cardiac biomarker results (troponin or creatine kinase MB fraction) were negative in 149 patients (11.2%; 95% CI, 9.6%-13.0%). Of this group, 26 patients (17.4%) had a clear culprit artery, including 14 with an aborted STEMI and 12 with unstable angina.

The 30-day mortality in those with negative cardiac biomarker results was 0.7% (95% CI, 0%-2.0%) vs 5.0% (95% CI, 3.7%-6.2%) with positive cardiac biomarker results ($P=.02$).

Sex Differences

There were 381 women (28.3%) enrolled in the Level 1 MI program. Women had a higher prevalence of no culprit artery, 17.1% (95% CI, 13.3%-20.8%) vs 12.7% (95% CI, 10.6%-14.8%), $P=.04$, as well as no significant coronary artery disease, 13.6% (95% CI, 10.2%-17.1%) vs 7.9% (95% CI, 6.2%-9.6%), $P=.001$. In contrast, there was no significant difference in negative cardiac biomarker results between women and men, 12.3% (95% CI, 9.0%-15.6%) vs 10.6% (95% CI, 8.6%-12.5%), $P=.36$.

Left Bundle-Branch Block

Of the 36 patients (2.6%) who presented with a new or presumably new left bundle-branch block, 16 (44%) did not have a culprit coronary artery, 10 (27%) had no significant coronary artery disease, and 13 (36%) had negative cardiac biomarker results. Thirty-day mortality for these patients was 8.3%.

The frequency of false-positive catheterization laboratory activation was compared among non-percutaneous coronary intervention hospitals stratified by annual emergency department volume to the percutaneous coronary intervention (Abbott Northwestern) center by using the definition of no clear culprit artery with negative cardiac biomarker results. The rates ranged from 6.7% at the percutaneous coronary intervention center to 9%, 9.6%, and 10.7% for hospitals with annual emergency department volumes of greater than 20 000 visits, 10 000 to 20 000 visits, and fewer than 10 000 visits, respectively, a difference that was not statistically significant ($P=.36$).

COMMENT

The prevalence of false-positive cardiac catheterization laboratory activation was 14% according to no-culprit

coronary artery, 9.5% according to no significant coronary artery disease, and 11.2% according to negative cardiac biomarker result. This consecutive series of 1345 patients presenting with suspected STEMI to 31 hospitals in a regional percutaneous coronary intervention network in Minnesota represents a wide range of hospital sizes and emergency department volume in an actual setting. In the current era of immediate coronary angiography, sensitive markers of myocardial necrosis, and cardiac magnetic resonance imaging, the definition of myocardial infarction and therefore false-positive catheterization laboratory activation is a complex issue, and there is no gold standard. The combination of no culprit artery and negative cardiac biomarker results was present in 9.2% of patients, which might be considered as the true measure of unnecessary catheterization laboratory activation.

The decision to provide reperfusion therapy to patients presenting with chest pain and ST-segment elevation is not always easy because conditions other than myocardial infarction may cause ST-segment elevation.³ For example, studies have shown that distinguishing benign early repolarization from acute myocardial infarction is challenging for emergency department physicians and cardiologists alike.^{15,16} Miller et al¹⁷ reported a 50% false-positive prevalence of STEMI in patients with a history of a myocardial infarction. Retrospective review of cases of presumed STEMI may identify ECGs that were "overcalled," especially in light of subsequent diagnostic data. However, physicians must make a rapid decision about whether to provide reperfusion therapy, which includes either fibrinolytic therapy or activation of the cardiac catheterization laboratory team for timely percutaneous coronary intervention. This critical decision process must balance the risk of a false alarm with the consequences of delaying myocardial reperfusion. Previous reports from single institutions using fibrinolytic therapy for STEMI have reported that 5.7% to 11% of pa-

tients treated for STEMI did not have a myocardial infarction.^{18,19} Adverse consequences have been reported in patients who receive inappropriate fibrinolysis and are subsequently found to have aortic dissections or pericarditis.^{20,21} This may be less important when primary percutaneous coronary intervention is the reperfusion strategy and an additional benefit of angiography includes immediate risk stratification in patients without a culprit artery. However, the issue of false-positive catheterization laboratory activation remains a significant concern because unnecessary emergency coronary angiography is not without risk to the patient and may impose a burden on limited human and physical catheterization laboratory resources.

The prevalence of false-positive ST-segment elevation in patients presenting with a suspected myocardial infarction and undergoing primary percutaneous coronary intervention has not been well described, even in clinical trials. For example, in the recently reported Assessment of the Safety and Efficacy of a New Treatment Strategy With Percutaneous Coronary Intervention Trial, only 88% of patients randomized to facilitated or primary percutaneous coronary intervention underwent intervention of a culprit lesion, and there was no discussion regarding the 12% of patients without an intervention.²² More important, randomized clinical trials may not reflect actual clinical practice.²³

Previous reports^{18,19} used only cardiac biomarker levels and the ECG result to define false-positive STEMI. The use of immediate angiography to characterize the coronary anatomy adds another component to the definition. For example, in our series nearly 20% of patients who had negative cardiac biomarker results also had a clear culprit artery and required an intervention. However, even with coronary angiography the etiology of the ST-segment elevation may not always be clear.²⁴ Cardiac magnetic resonance imaging also appears to be a useful diagnostic adjunct in patients without a culprit ar-

tery but with positive cardiac biomarker results.¹²

Achieving door-to-balloon times in less than 90 minutes is an important quality metric that is tied to pay for performance and has been the focus of recent quality improvement initiatives such as the American College of Cardiology's D2B Alliance and the American Heart Association's Mission: Lifeline. Upstream activation of the cardiac catheterization laboratory by the emergency department physician is one of the key strategies to reducing door-to-balloon times.⁷ A major challenge for the emergency department physician is the patient who presents with nonspecific symptoms or subtle ST-segment elevation or QRS repolarization abnormalities that obscure or mimic ST-segment elevation. In these cases, is it best to immediately activate the catheterization laboratory, considering the consequences of a false alarm, or take the time to obtain additional data, such as from serial ECGs, biomarkers, or an echocardiogram?

Our results indicate that a wide spectrum of etiologies may lead to false-positive catheterization laboratory activation. Many of these include high-risk patients who may benefit from early diagnosis and risk stratification. Several patient populations deserve special mention. Women had a higher prevalence of false-positive catheterization laboratory activation based on no culprit artery or no significant coronary artery disease, but there was no sex difference when negative cardiac biomarker results were used. Stress cardiomyopathy that occurs predominantly in women accounts for much of this discrepancy. Patients with new or presumably new left bundle-branch block had an inordinately high prevalence of false-positive catheterization laboratory activation (almost half did not have a culprit artery). Patients with a previous myocardial infarction or previous coronary bypass surgery had a significantly higher prevalence of no culprit artery, likely because of abnormal baseline ECG results.

Although a wide range of hospitals is included in the Level 1 MI program, all the hospitals receive initial training and immediate feedback and participate in ongoing quality improvement. Whether or not the prevalence of false-positive catheterization laboratory activation is similar in other centers is unclear. In this series, patients were categorized by the discharge diagnosis, which may have been presumed or suspected rather than based on strict diagnostic criteria. For example, a diagnosis of presumed pericarditis may have been non-cardiac-related chest pain with ECG changes because of early repolarization. Relying on cardiac markers to diagnose an acute myocardial infarction may underestimate the false-positive prevalence with this definition of negative cardiac marker results because cardiac troponin levels may be elevated by nonischemic cardiac causes, as well as noncardiac conditions such as renal insufficiency, pulmonary embolus, or sepsis.^{25,26} Because the patients enrolled in this study required activation of the Level 1 MI transfer protocol, we do not know how many patients with a STEMI were missed or undercalled by emergency department physicians.

CONCLUSION

In this series of 1345 patients with suspected STEMI, presenting to 30 hospitals in a regional STEMI network, the prevalence of false-positive cardiac catheterization laboratory activations was between 9.2% and 14%, depending on the definition based on coronary anatomy and cardiac biomarker levels. In the setting of increased emphasis on rapid door-to-balloon times, the consequences of false-positive catheterization laboratory activation need to be considered. False-positive catheterization laboratory activation may be another quality metric to monitor for a STEMI program.

Author Contributions: Dr Larson had full access to all of 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: Larson, Sharkey, Harris, Meland, Henry.

Acquisition of data: Larson, Menssen, Harris, Meland, Unger, Henry.

Analysis and interpretation of data: Larson, Menssen, Sharkey, Duval, Schwartz, Henry.

Drafting of the manuscript: Larson, Menssen, Sharkey, Henry.

Critical revision of the manuscript for important intellectual content: Larson, Sharkey, Duval, Schwartz, Harris, Meland, Unger, Henry.

Statistical analysis: Larson, Menssen, Duval, Henry.

Obtained funding: Larson, Henry.

Administrative, technical, or material support: Sharkey.

Study supervision: Larson, Sharkey, Schwartz, Unger, Henry.

Financial Disclosures: None reported.

Funding/Support: The study was supported by the Minneapolis Heart Institute Research Foundation.

Role of the Sponsor: The Minneapolis Heart Institute Research Foundation had no role in the design and conduct of the study; in the collection, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript.

Additional Contribution: We are grateful to Jennifer Krech, BA, of the Minneapolis Heart Institute Research Foundation for her assistance in preparation of the manuscript. Ms Krech received no compensation.

REFERENCES

- Zimetbaum PJ, Josephson ME. Use of the electrocardiogram in acute myocardial infarction. *N Engl J Med.* 2003;348(10):933-940.
- DeWood MA, Spores J, Notske R, et al. Prevalence of total coronary occlusion during the early hours of transmural myocardial infarction. *N Engl J Med.* 1980;303(16):897-902.
- Wang K, Asinger RW, Marriott HJL. ST-segment elevation in conditions other than acute myocardial infarction. *N Engl J Med.* 2003;349(22):2128-2135.
- Boersma E, Arthur M, Deckers J, Simoons M. Early thrombolytic treatment in acute myocardial infarction: reappraisal of the golden hour. *Lancet.* 1996;348(9030):771-775.
- Brodie BR, Hansen C, Stuckey TD, et al. Door-to-balloon time with primary percutaneous coronary intervention for acute myocardial infarction impacts late cardiac mortality in high-risk patients and patients presenting early after the onset of symptoms. *J Am Coll Cardiol.* 2006;47(2):289-295.
- Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction). *Circulation.* 2004;110(5):588-636.
- Bradley EH, Herrin J, Wang Y, et al. Strategies for reducing the door-to-balloon time in acute myocardial infarction. *N Engl J Med.* 2006;355(22):2308-2320.
- Barbagelata A, Ware DL. Denying reperfusion or falsely declaring emergency: the dilemma posed by ST-segment elevation. *J Electrocardiol.* 2006;39(4)(suppl):S73-S74.
- Henry TD, Unger BT, Sharkey SW, et al. Design of a standardized system for transfer of patients with ST-elevation myocardial infarction for percutaneous coronary intervention. *Am Heart J.* 2005;150(3):373-384.
- Henry TD, Sharkey SW, Burke MN, et al. A regional system to provide timely access to percutaneous coronary intervention for ST-elevation myocardial infarction. *Circulation.* 2007;116(7):721-728.
- Alpert JS, Thygesen K, Antman E, Bassand JP. Myocardial infarction redefined: a consensus document of the Joint European Society of Cardiology/American College of Cardiology Committee for the redefinition of myocardial infarction. *J Am Coll Cardiol.* 2000;36(3):959-969.
- Laissy JP, Hyafil F, Feldman LJ, et al. Differentiating acute myocardial infarction from myocarditis: diagnostic value of early- and delayed-perfusion cardiac MR imaging. *Radiology.* 2005;237(1):75-82.
- Sharkey SW, Lesser JR, Zenovich AG, et al. Acute and reversible cardiomyopathy provoked by stress in women from the United States. *Circulation.* 2005;111(4):472-479.
- Brady WJ. ST segment and T wave abnormalities not caused by acute coronary syndromes. *Emerg Med Clin North Am.* 2006;24(1):91-111.
- Turnipseed SD, Bair AE, Kirk JD, Diercks DB, Tabar P, Amsterdam EA. Electrocardiogram differentiation of benign early repolarization versus acute myocardial infarction by emergency physicians and cardiologists. *Acad Emerg Med.* 2006;13(9):961-966.
- Brady WJ, Perron AD, Chan T. Electrocardiographic ST-segment elevation: correct identification of acute myocardial infarction (AMI) and non-AMI syndromes by emergency physicians. *Acad Emerg Med.* 2001;8(4):349-360.
- Miller DH, Kligfield P, Schreiber TL, Borer J. Relationship of prior myocardial infarction to false-positive electrocardiographic diagnosis of acute injury in patients with chest pain. *Arch Intern Med.* 1987;147(2):257-261.
- Khoury NE, Borzak S, Gokli A, Havstad S, Smith ST, Jones M. "Inadvertent" thrombolytic administration in patients without myocardial infarction: clinical features and outcome. *Ann Emerg Med.* 1996;28(3):289-293.
- Sharkey SW, Berger C, Brunette D, Henry TD. Impact of the electrocardiogram on the delivery of thrombolytic therapy for acute myocardial infarction. *Am J Cardiol.* 1994;73(8):550-553.
- Kahn JK. Inadvertent thrombolytic therapy for cardiovascular diseases masquerading as acute coronary thrombosis. *Clin Cardiol.* 1993;16(1):67-71.
- Blankenship JC, Almqvist AK. Cardiovascular complications of thrombolytic therapy in patients with a mistaken diagnosis of acute myocardial infarction. *J Am Coll Cardiol.* 1989;14(6):1579-1582.
- Assessment of the Safety and Efficacy of a New Treatment Strategy with Percutaneous Coronary Intervention (ASSENT-4 PCI) Investigators. Primary versus tenecteplase-facilitated percutaneous coronary intervention in patients with ST-segment elevation acute myocardial infarction (ASSENT-4 PCI): randomised trial. *Lancet.* 2006;367(9510):569-578.
- Steg PG, Lopez-Sendon J, Lopez de Sa E, et al. External validity of clinical trials in acute myocardial infarction. *Arch Intern Med.* 2007;167(1):68-73.
- Topol EJ, Nissen SE. Our preoccupation with coronary luminology: the dissociation between clinical and angiographic findings in ischemic heart disease. *Circulation.* 1995;92(8):2333-2342.
- Mahajan N, Mehta Y, Rose M, Shani J, Lichstein E. Elevated troponin level is not synonymous with myocardial infarction. *Int J Cardiol.* 2006;111(3):442-449.
- Jaffe AS, Babuin L, Apple FS. Biomarkers in acute cardiac disease: the present and the future. *J Am Coll Cardiol.* 2006;48(1):1-11.