# Prevalence and Factors Associated With False-Positive ST-Segment Elevation Myocardial Infarction Diagnoses at Primary Percutaneous Coronary Intervention–Capable Centers

## *A Report From the Activate-SF Registry*

*James M. McCabe, MD; Ehrin J. Armstrong, MD, MSc; Ameya Kulkarni, MD; Kurt S. Hoffmayer, PharmD, MD; Prashant D. Bhave, MD; Sonia Garg, MD; Ateet Patel, MD; John S. MacGregor, MD, PhD; Priscilla Hsue, MD; John C. Stein, MD; Scott Kinlay, MBBS, PhD; Peter Ganz, MD*

**Background:** Rapid activation of the cardiac catheterization laboratory for primary percutaneous coronary intervention (PCI) improves outcomes for ST-segment elevation myocardial infarction (STEMI), but selected emphasis on minimizing time to reperfusion may lead to a greater frequency of false-positive activations.

**Methods:** We analyzed consecutive patients referred for primary PCI for a possible STEMI at 2 centers from October 2008 to April 2011. "False-positive STEMI activation" was defined as lack of a culprit lesion by angiography or by assessment of clinical, electrocardiographic, and biomarker data in the absence of angiography. Clinical and electrocardiographic factors associated with false-positive activations were evaluated in a backward stepwise selection bootstrapped logistic regression model.

**Results:** Of 411 STEMI activations by emergency physicians, 146 (36%) were deemed to be false-positive activations. Structural heart disease and heart failure were the most common diagnoses among false-positive activations. Electrocardiographic left ventricular hypertrophy (adjusted odds ratio [AOR], 3.15; 95% CI, 1.55-6.40; $P=.001$), a history of coronary disease (AOR, 1.93; 95% CI, 1.04-3.59; $P=.04$), or prior illicit drug abuse (AOR, 2.67; 95% CI, 1.13-6.26; $P=.02$) independently increased the odds of false-positive STEMI activations. Increasing body mass index decreased the odds of a false-positive activation (AOR, 0.91; 95% CI, 0.86-0.97; $P=.004$), as did angina at presentation (AOR, 0.28; 95% CI, 0.14-0.57; $P<.001$).

**Conclusions:** More than a third of patients referred for primary PCI from the emergency department did not have a STEMI. Multiple patient-level characteristics were significantly associated with an increased odds of false-positive STEMI activation.

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**Author Affiliations** are listed at the end of this article.

Reperfusion therapy with percutaneous coronary intervention (PCI) is recommended for treatment of ST-segment elevation myocardial infarction (STEMI) when readily available.[1] One strategy that was found to facilitate a more rapid administration of PCI is autonomous STEMI team activation by emergency department (ED) physicians without routine cardiology consultation.[2-7]

Appropriate STEMI care and national health care quality metrics emphasize the timeliness of reperfusion therapy, but patient safety and health care costs demand thoughtful and judicious implementation of emergency coronary angiography. Nevertheless, inaccurate STEMI diagnoses with so-called false-positive activations of the cardiac catheterization team for emergent cardiac angiography are not only anticipated, they are readily accepted in an effort to preferentially emphasize diagnostic sensitivity. However, acceptable rates of false-positive activations are not established. Furthermore, current STEMI diagnosis accuracy remains uncertain owing to discrepancies in defining

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a false-positive STEMI diagnosis,[8,9] temporal trends in primary PCI availability at nontertiary care centers,[10,11] and potential reclassification bias within national angiographically based STEMI registries.

The objective of this study was to determine the prevalence of false-positive STEMI diagnoses among emergency physicians at primary PCI-capable centers. We also assessed the relationship between false-positive activations and clinical and electrocardiographic (ECG) factors available at the time of diagnosis.

## METHODS

### ACTIVATE-SF REGISTRY

The Activate-SF Registry consists of consecutive patients with a clinical diagnosis of STEMI admitted to the EDs of a tertiary care hospital (University of California, San Francisco) and an urban trauma center (San Francisco General Hospital) in San Francisco between October 2008 and April 2011. Details regarding the registry have been previously published.[12] Briefly, both institutions have primary PCI capacity, and the ED physicians autonomously activate their respective cardiac catheterization teams via centralized paging systems for any clinical diagnosis of a STEMI. The cardiology service was consulted prior to a STEMI activation only if the ED physician was unsure of the need for activation. All ED physician–initiated STEMI activations were recorded in the Activate-SF registry irrespective of subsequent outcome. Among the 434 total STEMI activations by the ED during our study period, all patients who were brought to the catheterization laboratory (n=352) were included in the present analysis. Among the 82 patients who did not undergo diagnostic angiography owing to contraindications, death, patient refusal, or a clinical decision by the interventional cardiologist that angiography was not warranted, 59 had sufficient data to be analyzed for true vs false status.

### DATA COLLECTION

All clinical data were collected from the ED physician and nursing notes. Incorrect or incompletely recorded patient-level data were not amended in order to reflect only the information on which ED decisions were formulated. The inciting STEMI ECGs (ie, the ECG that led to the decision to activate the catheterization laboratory) were deidentified and reread for key variables by 2 cardiologists (E.J.A. and K.S.H.) blinded to clinical outcomes. Laboratory values, angiographic and echocardiographic data were collected from the electronic medical records. A waiver of consent was obtained from the institutional review board at University of California, San Francisco. Study data were collected and managed using REDCap (Research Electronic Data Capture) tools hosted at the University of California.[13]

### DEFINITIONS

Angiography is considered the gold standard test for establishing a STEMI diagnosis and is therefore the gold standard test for defining a "false-positive" STEMI diagnosis. We defined a false-positive activation as any patient taken to the catheterization laboratory who lacked a thrombotic total or subtotal coronary artery occlusion and had Thrombosis in Myocardial Infarction (TIMI) grade III flow in all vessels. In the absence of angiography, multiple lines of evidence may support a STEMI diagnosis including the following (A) positive cardiac biomarkers, (B) ECG findings consistent with American College of Cardiology/American Heart Association guidelines for diagnosis of a STEMI,[14] and (C) an appropriate clinical scenario including the use of medical therapies for treatment of acute coronary syndrome beyond the confines of the ED, and/or a lack of an alternative primary diagnosis for the index hospitalization. Medical therapies for acute coronary syndrome were considered present if thienopyridines, glycoprotein IIb/IIIa inhibitors, heparin, or other therapeutic anticoagulants were initiated or escalated. For the purposes of this classification scheme, hospital mortality or transition to hospice care within the first hospital day for patients who did not receive angiography was considered clinically consistent with a STEMI diagnosis. In an effort to emphasize sensitivity over specificity, we chose to categorize the 59 patients who did not go to the catheterization laboratory as a false-positive STEMI activation if they lacked 2 of the 3 lines of evidence for a STEMI (eg, had negative biomarkers and an alternative diagnosis, lacked ECG criteria and had negative biomarkers, lacked ECG criteria and were not treated for acute coronary syndrome). All cases initially identified as false-positives were secondarily adjudicated by an additional cardiologist (A.K.), who reviewed the primary clinical and angiographic data to corroborate the false-positive label.

ST-segment elevation was defined as J-point elevation in 2 or more contiguous leads of 2 mm or more in leads $V_1$, $V_2$, or $V_3$ or 1 mm or more in other leads[14]; or 1 mm or more of ST depression in leads $V_1$ through $V_3$ consistent with a posterior STEMI.[15] Left bundle-branch block (LBBB) was recorded separately. An arrhythmia was recorded as present if any rhythm other than sinus was identified or for third-degree heart block. Electrocardiographic left ventricular hypertrophy (LVH) was defined as present if any of the following criteria were met: an R wave in lead aVL plus an S wave in lead $V_3$ more than 25 mm; an R wave in lead aVL more than 11 mm; an S wave in lead $V_1$ plus an R wave in leads $V_5$ or $V_6$ more than 35 mm; an R wave in lead I plus an S wave in lead III more than 25 mm; or an R wave in leads $V_5$ or $V_6$ more than 25. No sex-specific rules for LVH were applied because all ECGs were deidentified.

A negative biomarker assay was defined as a troponin I value lower than 0.2 ng/mL (to convert to micrograms per liter, multiply by 1). Troponin point-of-care testing was not used during the study period. No coronary artery disease was defined by angiography as no luminal diameter stenosis greater than 20%. Structural heart disease was defined as any abnormality of the cardiac valves or ventricular myocardium including left ventricular hypertrophy. After-hours presentation was defined as any weekend presentation or presentation from 7 PM to 7 AM on a weekday. An "anginal" chief complaint was a primary complaint recorded as chest pain or chest pressure. Patient race/ethnicity were collected from self-reporting in the hospital intake records.

### STATISTICAL ANALYSIS

Simple comparisons were performed using $\chi^2$ tests for categorical and binary data. *t* Tests and Wilcoxon rank sum tests were used for normally and nonnormally distributed continuous data respectively. For univariate and multivariate analyses, logistic regression was used with the primary outcome variable of a false-positive activation.

For analysis of factors associated with a false-positive activation, a manual backward-stepwise procedure was used. Covariates were selected using a directed acyclic graph[16] based on clinical knowledge and prior studies. Likely confounders (age, race, and sex) were locked in the model a priori, while others were kept if they were found to change the model in a significant manner ($P<.10$). The final regression model adjusted for age, race, sex, an anginal chief complaint, a known history of

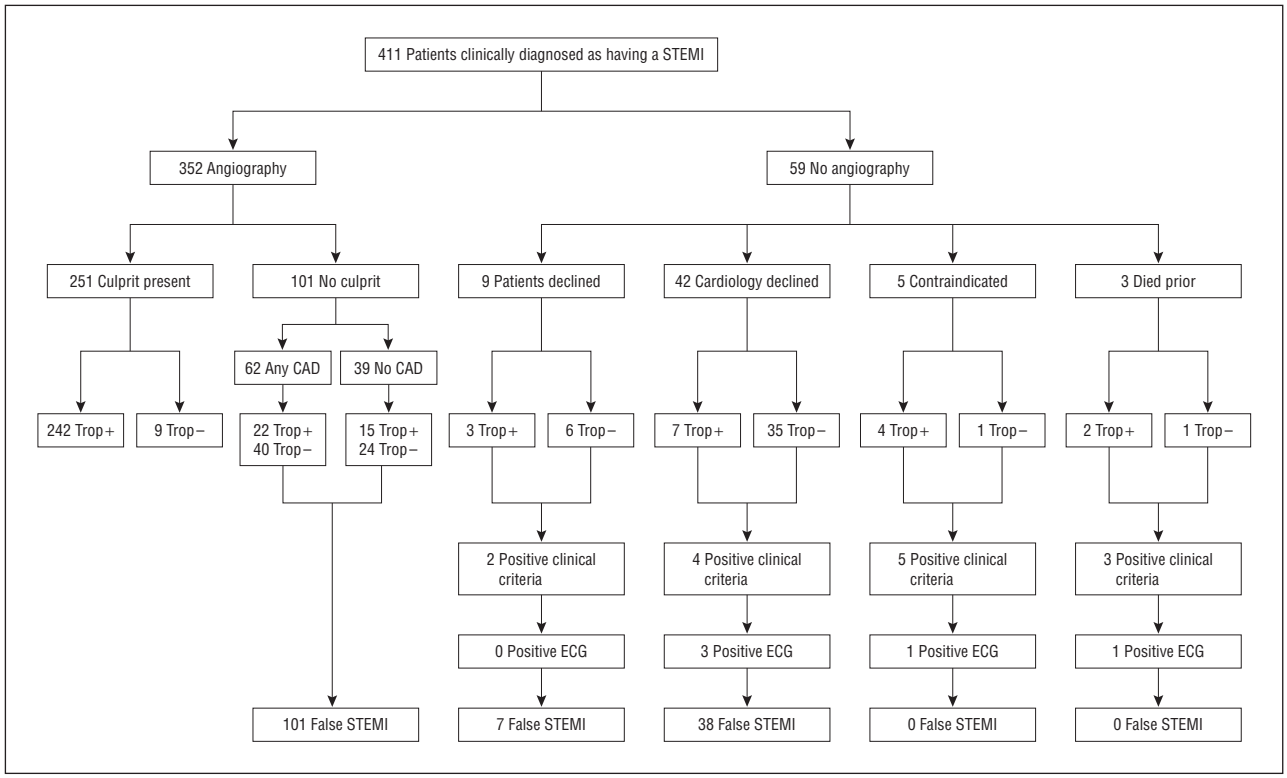


**Figure.** Schematic breakdown of the outcomes of all ST-segment elevation myocardial infarction (STEMI) diagnoses. "No CAD" is no stenosis greater than 20% of the intraluminal diameter. "Positive clinical criteria" is any case in which the patient was treated with therapies for acute myocardial infarction outside of the emergency department, did not receive an alternative primary diagnosis during the hospitalization, or died or was transferred to hospice care within the first hospital day. "Positive ECG" is any electrocardiogram that meets STEMI criteria by American College of Cardiology/American Heart Association guidelines. CAD indicates coronary artery disease; Trop+, troponin I value of 0.2 ng/mL or greater (to convert to micrograms per liter, multiply by 1); and Trop–, troponin I value lower than 0.2 ng/mL.

coronary artery disease or illicit drug abuse; cardiac arrest at presentation; body mass index; hypotension at presentation (systolic blood pressure <100 mm Hg), after-hours presentation, and the extent of the diagnostic ECG changes on the inciting ECG (maximum millimeters of ST-segment elevation, specific territory with greatest ST-segment elevations, number of leads with ST-segment elevations, and presence of LBBB).

The statistical output is reported as an odds ratio (OR) or adjusted odds ratio (AOR) and 95% confidence interval. Bootstrapping with 200 repetitions was used to generate confidence intervals and *P* values.[17,18] Continuous variables are presented as means and standard deviations or median values and interquartile ranges (IQRs) for nonnormally distributed data.

Sensitivity analyses performed with omission of highly influential points demonstrated no qualitative or statistically significant differences in outcomes (data not reported). All statistical analyses were performed with Stata version 11 (StataCorp).

## RESULTS

Among 411 consecutive ED STEMI diagnoses, 146 (36%) were adjudicated as false-positive. A total of 352 patients underwent diagnostic angiography (86% of total): 101 (29%) had no culprit lesion and 39 (9.5%) had no atherosclerotic stenosis greater than 20%. Among the 59 patients who did not receive angiography, 45 (75%) were considered to be false-positive STEMIs: 7 of 9 patients (78%) refused catheterization and 38 of 42 patients (88%) were declined by the cardiology service (0 of 5 patients with contraindications to catheterization due to intracranial processes [n=3], severe gastrointestinal tract bleeding [n=1], and alternative goals of care [n=1]; and 0 of 3 patients who died prior to angiography) (**Figure**). Among those who received PCI for a culprit lesion, 3 (1%) would have been labeled as a false-positive in the absence of angiography because of troponin values lower than 0.2 ng/mL and absence of STEMI criteria by ECG.

False-positive STEMI activations were broadly grouped by adjudicated hospital admission diagnosis (**Table 1**). There were no significant differences in false-positive activation rates (37% vs 34%; *P*=.60) or percentage of patients who did not receive angiography (17% vs 12%; *P*=.14) based on institution.

Patients with a false-positive STEMI were less frequently white or Asian. They had a lower mean body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared); less frequently presented with typical anginal symptoms, cardiac arrest, or hypotension; were more frequently diagnosed during standard working hours; used more illicit drugs; and more often had a known or reported history of coronary artery disease (**Table 2**). The ECG ST-segment elevations from patients with false-positive activations tended to be lower amplitude and in fewer leads, though more commonly localized in the anterior leads ($V_1$-$V_3$) (Table 2).

In univariate analysis, African American ethnicity (compared with a white, non-Hispanic population), a known

history of coronary artery disease, illicit drug abuse, and LVH by ECG or LBBB were each significantly associated with an increased odds of a false-positive STEMI activation. A chief complaint of chest pain or pressure, cardiac arrest in the ED or field, increased BMI, and hypotension on presentation were associated with a lower odds of false-positive STEMI activation (**Table 3**).

Electrocardiographically, each millimeter increase in the maximal height of the ST-segment elevations was associated with a 22% reduced odds of a false-positive activation, and there was a 30% decreased odds of false-positive activation per lead with diagnostic ST-segment elevations (Table 3). ST-segment elevations primarily affecting the inferior leads (II, III, and aVF) or lateral leads ($V_4$-$V_6$, I, and aVL) were also associated with reduced odds of false-positive activation (compared with the anterior territory). Method of hospital arrival (ambulance vs self presenting), patient age, and ED physician experience were not significantly associated with a change in the odds of a true- vs false-positive activation (Table 3).

After multivariate adjustment, LVH by ECG, a history of coronary artery disease, and illicit drug abuse were all independently associated with an increased odds of false-positive activation. Conversely, a chief complaint of chest pain or pressure was associated with a reduced odds of false-positive activation (compared with all other chief complaints), and each unit increase in BMI above the registry mean of 26.5 was associated a 9% reduced odds of a false-positive activation (Table 3).

A prespecified sensitivity analysis excluding patients who did not receive diagnostic angiography demonstrated qualitatively similar results: LVH by ECG (AOR, 4.28; 95% CI, 1.94-9.42; $P < .001$), a history of coronary artery disease (AOR, 2.05; 95% CI, 1.02-4.12; $P = .04$), or illicit drug abuse (AOR, 2.73; 95% CI, 1.06-7.07; $P = .04$) were associated with increased odds of a false-positive activation; a per-unit increase in BMI (AOR, 0.91; 95% CI, 0.85-0.98; $P = .01$) and a chief complaint of chest pain or pressure (AOR, 0.36; 95% CI, 0.15-0.84; $P = .019$) were both associated with decreasing odds of a false-positive activation.

During the study period, the percentage of false-positive activations increased slightly per year ($P = .03$ for trend) without significant change in door-to-balloon times ($P = .54$ for trend) or the percentage of STEMI activations aborted by the interventional cardiology team ($P = .13$ for trend).

True-positive STEMI diagnoses were triaged to the catheterization laboratory more quickly but had longer hospital stays, had a lower mean left ventricular ejection fraction by echocardiography, and were more often biomarker positive (**Table 4**). There were also numerically more deaths during the index hospitalization among true-positive activations (11% vs 6%) ($P = .07$).

**Table 1. Adjudicated Hospital Admission Diagnoses for False-Positive STEMI Activations**

| Adjudicated Diagnosis | No. (%) |
|---|---|
| Structural/valvular heart disease and/or acute heart failure exacerbation | 28 (19) |
| Nonspecific chest pain, including soft-tissue ailments | 25 (17) |
| Demand ischemia with severe concomitant illness | 20 (14) |
| Primary rhythm disturbances | 15 (10) |
| Metabolic derangements, including toxin and drug ingestion | 15 (10) |
| Out of hospital cardiac arrest | 9 (6) |
| Myocarditis/pericarditis | 8 (6) |
| Known coronary disease and stable symptoms without STEMI criteria | 6 (4) |
| Abdominal pathologic condition | 5 (3) |
| Hypertensive urgency/emergency | 4 (3) |
| Takotsubo cardiomyopathy | 2 (1) |
| Other diagnoses | 9 (6) |

Abbreviation: STEMI, ST-segment elevation myocardial infarction.

## COMMENT

This study demonstrated a 36% prevalence of false-positive STEMI team activations among patients presenting to the ED at 2 primary PCI-capable centers. Among patients who underwent emergent diagnostic angiography, 29% had no culprit lesion, and among those who did not undergo diagnostic angiography, 75% were considered false-positive by analysis of ECG, clinical, and serum biomarker data. Applying this analysis to cases that received PCI, 3 (1%) would have been reclassified as a false-positive STEMI activation in the absence of angiography. All results were consistent between institutions.

The term *false-positive STEMI diagnosis* lacks a consistent definition in the literature.[8,9] Conceptually, the STEMI activation system was established to provide universally rapid reperfusion therapy in the form of PCI to patients with transmyocardial infarctions. As such, we have chosen to define the term *false-positive* to represent a patient for whom emergent coronary reperfusion therapy is not indicated to favorably impact the clinical course of the acute illness. This is most easily established for patients who receive diagnostic angiography. However, in real-world practice, emergent angiography may not be universally used even when reperfusion therapy is ideally indicated. For such cases, we have limited the term *false-positive* activation to situations where the majority of the ECG, serum biomarker, and clinical evidence suggests a diagnosis other than a STEMI.

By any scheme, false-positive activations are defined relative to clinical outcomes that are unknown at presentation. Thus, *false-positive* activations are not necessarily unwarranted, nor should they suggest a de facto error in judgment.

A number of other overlapping terms have also been introduced into the literature, which, in addition to false-positive activation[8,19] include *overactivation*[20] and *inappropriate activation*.[9,15,20,21] "Overactivation" has been defined as "calling in [cardiac catheterization laboratory] staff for patients who do not ultimately require emergent catheterization or performing angiography on patients who are ultimately found not to require coronary intervention."[20(p308)] By this definition, the overactivation rate of our cohort was 39%. "Appropriateness," on the other hand, has been variously applied but generally seeks to weigh specific cases against certain established STEMI activation criteria. "Appropriateness" is unique insofar as it is generally

**Table 2. Baseline Characteristics Divided by True- and False-Positive STEMI Activation**

| Variable | True-Positive STEMI Activation (n = 265) | False-Positive STEMI Activation (n = 146) | *P* Value |
|---|---|---|---|
| Demographic | | | |
| Female sex, No. (%) | 66 (25) | 43 (29) | .32 |
| Age, mean (SD), y | 60 (15) | 61 (15) | .65 |
| Race, No. (%) | | | |
| White, non-Hispanic | 106 (40) | 50 (34) | .002 |
| African American | 33 (12) | 40 (27) | |
| Asian | 75 (28) | 30 (20) | |
| White-Hispanic or other | 51 (19) | 27 (18) | |
| BMI, mean (SD) | 27 (6) | 25 (5) | <.001 |
| ED presentation | | | |
| Anginal chief complaint, No. (%)[a] | 211 (80) | 98 (67) | .004 |
| Brought by ambulance, No. (%) | 156 (59) | 77 (53) | .26 |
| After-hours presentation, No. (%) | 175 (66) | 82 (56) | .048 |
| Any cardiac arrest, No. (%) | 55 (21) | 15 (10) | .006 |
| Intubated in the field or ED, No. (%) | 41 (15) | 18 (12) | .37 |
| CT scan in the ED, No. (%) | 30 (11) | 20 (14) | .50 |
| Systolic BP <100 mm Hg, No. (%) | 49 (18) | 12 (8) | .005 |
| Pressor requirement, No. (%) | 42 (16) | 15 (10) | .12 |
| Heart rate <50/min, No. (%) | 15 (6) | 7 (5) | .70 |
| Troponin assay result known in ED, No. (%)[b] | 50 (19) | 34 (23) | .29 |
| Cardiology service contacted prior to activation, No. (%)[c] | 44 (17) | 24 (16) | .99 |
| Diagnosing ED physician experience, mean (SD), y | 12.3 (9) | 11.7 (9) | .56 |
| Risk factors known in ED | | | |
| Diabetes mellitus, No. (%) | 59 (22) | 35 (24) | .72 |
| Hypertension, No. (%) | 129 (49) | 84 (57) | .10 |
| Dyslipidemia, No. (%) | 73 (28) | 48 (33) | .28 |
| Prior coronary disease, No. (%)[d] | 67 (25) | 65 (44) | <.001 |
| Illicit drug use, No. (%) | 25 (9) | 38 (26) | <.001 |
| Active tobacco use, No. (%) | 79 (30) | 37 (25) | .34 |
| STEMI ECG characteristics | | | |
| Arrhythmia present, No. (%)[e] | 24 (9) | 8 (5) | .15 |
| Primary territory affected, No. (%) | | | |
| Anterior | 104 (41) | 87 (68) | <.001 |
| Lateral | 22 (9) | 5 (4) | |
| Inferior | 97 (38) | 20 (16) | |
| Posterior | 16 (6) | 0 | |
| None | 15 (6) | 16 (13) | |
| Left bundle branch block, No. (%) | 10 (4) | 16 (11) | .004 |
| Height of ST-segment elevations, median (IQR), mm | 2 (1.0-3.5) | 1.5 (0.5-2.0) | <.001 |
| Leads with ST-segment elevations on ECG, median (IQR), No. | 3 (1.5-5.0) | 1.5 (0-2.5) | <.001 |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BP, blood pressure; CT, computed tomographic; ECG, electrocardiographic; ED, emergency department; IQR, interquartile range; STEMI, ST-segment elevation myocardial infarction.

[a] Anginal chief complaint is any primary complaint of chest pain or pressure.

[b] Based on troponin assay result documentation in the responsible emergency physician note.

[c] Includes all forms of contact (eg, telephone conversation, ECG fax, in-person patient evaluation) with any member of the cardiology consult team.

[d] Includes any reported or documented history of atherosclerotic heart disease.

[e] Includes any rhythm other than sinus rhythm, sinus tachycardia, sinus bradycardia, or complete heart block.

defined against metrics that are available at the time of the initial decision to activate the STEMI team. Whether these metrics fully and effectively circumscribe the decision-making process remains unclear.

Our data suggest that after adjusting for patient, physician, and ECG factors, LVH by ECG voltage criteria, a chief complaint other than chest pain or pressure, and a patient history of coronary artery disease or illicit drug abuse are all associated with significantly greater false-positive STEMI activation rates. These associations maintain clinical plausibility. Electrocardiographic LVH is well known to perturb the ST-segment and can cause ST-segment elevations, particularly in the anterior leads.[22-25] A history of coronary disease may lower the diagnostic threshold for interpreting an equivocal presentation or equivocal ECG as consistent with a STEMI. The association between recreational drug use, notably cocaine use, and acute coronary syndromes is well described, particularly among a relatively young and otherwise low-risk cohort.[26] It is therefore plausible that generally lower-risk patients with a history of recreational drug abuse may be more frequently diagnosed as having a STEMI despite a lower pretest probability. Similarly, non–chest pain "anginal-equivalent" presentations are well described,[27] but these symptoms also lack specificity and may suggest a more difficult diagnostic algorithm.

Conversely, an elevated body mass index was strongly associated with increasing true-positive STEMI activation

**Table 3. Univariate and Multivariate Analysis of Factors Associated With a False-Positive STEMI Activation**

| Variable | Univariate Analysis | | Multivariate Analysis | |
|---|---|---|---|---|
| | OR (95% CI) | *P* Value | Adjusted OR (95% CI) | *P* Value |
| Demographic | | | | |
| Female sex | 1.26 (0.80-1.98) | .32 | 1.24 (0.62-2.48) | .53 |
| Age, per year | 1.00 (0.99-1.02) | .65 | 0.99 (0.97-1.01) | .37 |
| Race | | | | |
| White, non-Hispanic | 1 [Reference] | | 1 [Reference] | |
| African American | 2.56 (1.45-4.55) | <.001 | 1.04 (0.42-2.58) | .93 |
| Asian | 0.85 (0.49-1.46) | .55 | 0.65 (0.29-1.45) | .30 |
| White-Hispanic or others | 1.12 (0.63-1.99) | .69 | 1.16 (0.48-2.80) | .73 |
| BMI, per unit kg/m$^2$ | 0.91 (0.87-0.96) | <.001 | 0.91 (0.86-0.97) | .004 |
| ED presentation | | | | |
| Anginal chief complaint[a] | 0.51 (0.32-0.80) | .004 | 0.28 (0.14-0.57) | <.001 |
| Brought by ambulance | 0.79 (0.52-1.19) | .26 | NA | |
| Any cardiac arrest | 0.43 (0.24-0.80) | .007 | 0.40 (0.14-1.10) | .08 |
| Intubated in the ED or field | 0.76 (0.42-1.38) | .37 | NA | |
| CT scan in the ED | 1.23 (0.67-2.26) | .50 | NA | |
| Systolic BP <100 mm Hg | 0.39 (0.20-0.76) | .006 | 0.62 (0.25-1.58) | .32 |
| Pressor requirement | 0.60 (0.32-1.13) | .12 | NA | |
| Heart rate <50/min | 0.83 (0.33-2.09) | .70 | NA | |
| Interpreter required | 0.78 (0.46-1.31) | .35 | NA | |
| After-hours presentation | 0.65 (0.44-0.99) | .048 | 0.65 (0.36-1.17) | .16 |
| ED physician experience, per year | 0.99 (0.97-1.02) | .56 | NA | |
| ED physician case volume, per STEMI diagnosis | 1.02 (0.98-1.07) | | | |
| Risk factors known in ED | | | | |
| Diabetes mellitus | 1.09 (0.68-1.76) | .72 | NA | |
| Hypertension | 1.41 (0.94-2.11) | .10 | 1.12 (0.57-2.22) | .73 |
| Dyslipidemia | 1.28 (0.82-1.98) | .28 | NA | |
| Prior coronary disease[b] | 2.34 (1.53-3.59) | <.001 | 1.93 (1.04-3.59) | .04 |
| Illicit drug abuse | 3.34 (1.92-5.81) | <.001 | 2.67 (1.13-6.26) | .02 |
| Active tobacco use | 0.80 (0.51-1.26) | .34 | NA | |
| STEMI ECG characteristics | | | | |
| Arrhythmia present[c] | 0.58 (0.25-1.32) | .19 | NA | |
| Primary territory affected | | | | |
| Anterior | 1 [Reference] | | 1.47 (0.62-3.52) | .38 |
| Lateral | 0.27 (0.10-0.75) | .01 | NA | |
| Inferior | 0.25 (0.14-0.43) | <.001 | 0.44 (0.16-1.18) | .10 |
| None | 1.48 (0.81-2.70) | .20 | NA | |
| Left bundle branch block | 3.11 (1.37-7.06) | .006 | 2.18 (0.55-8.58) | .27 |
| Height of ST-segment elevations, per mm | 0.78 (0.69-0.89) | <.001 | 0.90 (0.61-1.34) | .62 |
| No. of leads with ST-segment elevations, per lead | 0.70 (0.63-0.79) | <.001 | 0.85 (0.65-1.10) | .22 |
| Left ventricular hypertrophy by ECG criteria | 4.80 (2.86-8.05) | <.001 | 3.15 (1.55-6.40) | .001 |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CT, computed tomographic; BP, blood pressure; ECG, electrocardiographic; ED, emergency department; IQR, interquartile range; NA, not applicable; OR, odds ratio; STEMI, ST-segment elevation myocardial infarction.

[a] Anginal chief complaint is any primary complaint of chest pain or pressure.

[b] Includes any reported or documented history of atherosclerotic heart disease.

[c] Includes any rhythm or heart block other than sinus rhythm, sinus tachycardia, sinus bradycardia, or 1st degree heart block.

**Table 4. Index Hospitalization Outcomes by True- vs False-Positive STEMI Activation**

| Outcome Measure | True-Positive STEMI | False-Positive STEMI | *P* Value |
|---|---|---|---|
| Door-to-catheterization laboratory arrival time, median (IQR), min | 49 (37-75) | 75 (55-126) | <.001 |
| Any troponin I value >0.2 ng/mL, No. (%) | 254 (96) | 41 (28) | <.001 |
| Highest tertile peak troponin value, No. (%) | 121 (50) | 0 | <.001 |
| Peak creatinine, mean (SD), mg/dL | 1.26 (0.77) | 1.33 (0.96) | .46 |
| Required new hemodialysis | 3 (1) | 3 (2) | .42 |
| Left ventricular ejection fraction, mean (SD), % | 48 (13.3) | 53 (14.9) | .001 |
| Length of hospital stay, median (IQR), d | 3 (3-5) | 2 (1-4) | .05 |
| Death during index hospitalization | 29 (11) | 8 (6) | .07 |

Abbreviations: IQR, interquartile range; STEMI, ST-segment elevation myocardial infarction.

SI conversion factor: To convert troponin I to micrograms per liter, multiply by 1.

rates compared with lower body mass index levels. The mechanism for this association is unclear. Increased ECG voltages in thinner individuals may lead to more false-positive interpretations, or it may simply reflect a lower likelihood of a true STEMI in thinner individuals.[28]

Our data suggest that contemporary false-positive STEMI team activation rates at primary PCI-capable centers are more than double the 14% rate reported among a large network of referral hospitals by Larson and colleagues.[8] This discrepancy may be the result of temporal changes from continued emphasis on door-to-balloon metrics, a greater willingness to activate the interventional cardiology team for equivocal diagnoses at PCI-capable centers where rapid angiography is more easily performed relative to regional referral networks, differences in registry inclusion criteria, and/or differences in regional STEMI incidence leading to differences in pretest probability of a STEMI diagnosis. More recently, a single-center study noted that 166 of 249 STEMI team activations (67%) received PCI,[9] and the RACE (Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments) network reported 2598 of 3973 STEMI activations (65%) received PCI[20]; percentages more consistent with the findings of our registry.

Our study has some important limitations. The Activate-SF registry is composed of a diverse, urban patient population. These data may not reflect processes of care in other settings. In addition, we have chosen a conservative strategy for defining our false-positive STEMIs to emphasize the value of diagnostic sensitivity. Differences in the diagnostic algorithm used could affect outcomes, but we expect this would only result in higher false-positive rates given the conservative nature of our approach.

Our registry demonstrated a higher rate of false-positive STEMI activations by emergency physicians at primary PCI centers than has been documented previously. We have also demonstrated a number of clinical and ECG factors associated with increased rates of false-positive activations. While a certain percentage of false-positive STEMI activations are essential to ensuring adequate diagnostic sensitivity, the point of equipoise between necessary diagnostic sensitivity and patient safety requires further investigation, particularly in light of increasing resource limitations.

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**Author Affiliations:** Division of Cardiology, Brigham and Women's Hospital, and Harvard Medical School, Boston, Massachusetts (Drs McCabe and Kinlay); Division of Cardiology, University of California, Davis (Dr Armstrong); Division of Cardiology (Drs Kulkarni, Hoffmayer, MacGregor, Hsue, and Ganz), Department of Medicine (Drs Garg and Patel), and Department of Emergency Medicine (Dr Stein), University of California, San Francisco; Division of Cardiology, Northwestern University, Chicago, Illinois (Dr Bhave); Division of Cardiology, San Francisco General Hospital, San Francisco (Drs MacGregor, Hsue, and Ganz); and Cardiovascular Division, VA Boston Healthcare System, West Roxbury, Massachusetts (Dr Kinlay).
**Correspondence:** James M. McCabe, MD, Brigham and Women's Hospital, Shapiro 5, 75 Francis St, Boston, MA 02115 (mccabe@aya.yale.edu).
**Author Contributions:** *Study concept and design:* McCabe, Armstrong, Hoffmayer, Patel, MacGregor, Hsue, and Ganz. *Acquisition of data:* Armstrong, Kulkarni, Bhave, Garg, Patel, MacGregor, and Stein. *Analysis and interpretation of data:* Armstrong, Kulkarni, Hoffmayer, Bhave, MacGregor, Kinlay, and Ganz. *Drafting of the manuscript:* McCabe, Armstrong, and Garg. *Critical revision of the manuscript for important intellectual content:* Armstrong, Kulkarni, Hoffmayer, Bhave, Patel, MacGregor, Hsue, Stein, and Kinlay. *Statistical analysis:* McCabe, Armstrong, Kulkarni, Hoffmayer, Bhave, Patel, and Ganz. *Administrative, technical, and material support:* Armstrong, Kulkarni, Hoffmayer, Bhave, Stein, and Ganz. *Study supervision:* Armstrong, MacGregor, Hsue, Kinlay, and Ganz.
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**INVITED COMMENTARY**

# Activating Primary Percutaneous Coronary Intervention for STEMI That Is Not

## *The Collateral Damage of Improving Door-to-Balloon Time*

Coronary arterial thrombosis secondary to plaque rupture (most common), erosion, or calcified nodule often results in acute ischemic symptoms and electrocardiographic (ECG) changes, specifically ST-segment elevation. Timely clinical identification of ST-segment elevation myocardial infarction (STEMI) is based on acute symptoms and ECG changes. Prompt and effective revascularization of the infarct-related artery can save myocardium and reduce morbidity and mortality.[1] The Door-to-Balloon (D2B) Alliance recognizes the importance of door-to-balloon time (DBT) as a core measure of quality for primary percutaneous coronary intervention (PCI) and emphasizes methods to decrease DBT.[2] Multiple strategies to reduce DBT include a dedicated on-call (24 hours per day/7 days per week) cardiac catheterization laboratory (CCL) team activated by a single page, acquisition of an ECG at the scene with "computer" interpretation with or without electronic transmission to an emergency department (ED), autonomous activation of the CCL by ED staff or emergency medical service, and organized review of experience with direct feedback to all involved in STEMI recognition and treatment.[3] These strategies decrease DBT, but a potential downside to this increasingly fast process is more inappropriate CCL use. This occurs for multiple reasons including "misinterpretation" of clinical findings, primarily of the ECG, alternative diagnosis discovered after activation, activation protocol violation, and morbid conditions with ECG changes mimicking myocardial infarction for which a coronary angiogram would be contraindicated. Inappropriate CCL activation increases cost and exposes patients to unnecessary risk. Frequent, inappropriate CCL activation may result in interdisciplinary distrust, disinterest, and tension. A variety of terms have been proposed to report CCL activation that did not result in CCL use. These have been variably defined as "inappropriate activation," "overactivation," "unnecessary activation," and "false-positive activation"; hence, reports of their occurrence vary widely.

In this issue of the *Archives,* McCabe et al[4] report that 36% of autonomous ED physician CCL activations for STEMI were false-positive STEMI diagnosis. In their registry, patients with angiography that did not show a "culprit" lesion (total or subtotal occlusion) and had Thrombolysis in Myocardial Infarction (TIMI) grade III flow in all coronary arteries were considered false-positive STEMI