Rates of Cardiac Catheterization Cancelation for ST-Segment Elevation Myocardial Infarction After Activation by Emergency Medical Services or Emergency Physicians

Results From the North Carolina Catheterization Laboratory Activation Registry

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Background—For patients with an acute ST-segment elevation myocardial infarction, cardiac catheterization laboratory (CCL) activation by emergency medical technicians or emergency physicians has been shown to substantially reduce treatment times. One drawback to this approach involves overtriage, whereby CCL staffs are activated for patients who ultimately do not require emergent coronary angiography or for patients who undergo angiography but are not found to have coronary artery occlusion.

Methods and Results—We examined CCL activation at 14 primary angioplasty hospitals to determine the course of management, including the rate of inappropriate activation. Among 3973 activations (29% by emergency medical technicians, 71% by emergency physicians) between December 2008 and December 2009, appropriate CCL activations occurred for 3377 patients (85%), with 2598 patients (76.9% of appropriate activations) receiving primary percutaneous coronary intervention. Reasons for inappropriate activations (596 patients; 15%) included ECG reinterpretations (427 patients; 72%) or the fact that the patient was not a CCL candidate (169 patients; 28%). The rate of cancellation because of reinterpretation of emergency medical technicians’ ECG (6% of all activations) was more common than for cancellation because of reinterpretation of emergency physicians’ ECG (4.6%).

Conclusions—This represents the first report of the rates of CCL cancellation for ST-segment elevation myocardial infarction system activation by emergency medical technicians and emergency physicians in a large group of hospitals organized within a statewide program. The high rate of coronary intervention and relatively low rate of inappropriate activation suggest that systematic CCL activation by emergency personnel on a broad scale is feasible and accurate, and these rates set a benchmark for ST-segment elevation myocardial infarction systems. (Circulation. 2012;125:308-313.)

Key Words: acute myocardial infarction ■ emergency department ■ emergency medical services ■ ST-segment elevation myocardial infarction ■ systems of care

On the basis of an association between faster treatment times and lower mortality, national ST-segment elevation myocardial infarction (STEMI) guidelines call for percutaneous coronary intervention (PCI) within 90 minutes of first medical contact. To expedite care and reduce treatment times, many hospitals and healthcare systems enable paramedics and emergency physicians to diagnose acute myocardial infarction and activate cardiac catheterization laboratories (CCLs) without cardiology consultation. Early CCL activation markedly reduces treatment times by preparing the team before patient arrival and by avoiding the additional time involved in formal consultation. A potential drawback to this approach involves overactivation, which refers to calling in CCL staff for patients who do not ultimately require emergent catheterization or performing angiography on patients who are ultimately found not to require coronary intervention.

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Such overactivations tax medical resources, particularly in off hours when staff must be frequently called in and when interventional cardiologists may not otherwise be present in the hospital. Overactivation may also weaken regional STEMI collaborations if physicians and laboratory staff become reluctant to respond to emergency physicians and paramedics because of a perception that emergency personnel...
too frequently activate catheterization laboratories for patients who ultimately do not require emergent catheterization. Conversely, by encouraging front-line caregivers to activate STEMI reperfusion systems designed to expedite care, a certain rate of overactivation will be expected to occur. The medical community has not yet determined the rate of such overactivation that is acceptable. Given the variability of emergency medical services (EMS) systems’ design, training, and protocols within the United States, it is particularly challenging to craft regional STEMI systems that optimize the appropriate activation of PCI center resources.

To date, reports of overactivation have involved single centers and focused primarily on emergency physicians. To establish benchmark rates of overactivation across the entire spectrum of early cardiac care and identify settings in which early activation systems may be improved, we analyzed CCL activation at 14 primary PCI hospitals participating in a statewide STEMI reperfusion system. The objective of this Catheterization Laboratory Activation Registry (CLAR) was to identify all CCL activations by paramedics or emergency physicians and to follow their course of treatment, including management strategies after cardiac catheterization and reasons for CCL cancellations.

Methods

Using laboratory and emergency department logs from December 2008 through December 2009, 14 PCI-capable hospitals participating in the Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments (RACE) initiative identified all instances of catheterization laboratories. This log included patients presenting directly to the PCI center as well as those patients transferred from 85 non-PCI centers for management of STEMI. A brief case report form was completed for each activation, including demographic characteristics, initial activation source (emergency physician or paramedic), subsequent findings and procedures, whether catheterization was cancelled, and the reason for cancellation. STEMI system activation followed the consensus guidelines developed with the RACE initiative (available at http://www.nccace.org/RACE/RACEOperationsManual Oct09.pdf). All patients had clinical scenarios in which an acute coronary syndrome was considered. The method of STEMI system activation was based primarily on emergency physician or paramedic interpretation of the ECG. Additionally, several EMS agencies use the combination of an ECG machine interpretation algorithm along with a paramedic visual interpretation. No EMS system or physician relied solely on an ECG machine interpretation algorithm as the determinant for STEMI system activation.

Variable Description

The outcome variable for this study was STEMI system activation, categorized as either appropriate or inappropriate. Activations were considered to be appropriate if catheterization was performed or if catheterization was cancelled because of a change in patient status (resolution of symptoms, resolution of ST elevation, or death). Activations were considered to be inappropriate or overactivation if catheterization was cancelled because of ECG reinterpretation or if the patient was deemed not to be a candidate for cardiac catheterization. All descriptive data are presented as categorical variables, with the findings stratified according to whether paramedics or emergency physicians initiated the system activation.

The main independent variable of interest in this analysis was the hospital type initiating STEMI system activation, according to PCI availability, and mode of hospital arrival. Patients were categorized as having STEMI system activation initiated by either EMS, a non-PCI facility physician, or a PCI facility physician. Furthermore, individuals were classified as arriving at their initial destination hospital by EMS or as a walk-in patient. Other independent variables examined included the demographic characteristics age, sex, and race.

Data Analysis

Data analysis included only those individuals with complete data for the outcome and main independent variables. In addition, individuals were excluded from analysis if documentation was not sufficient to abstract a final patient disposition. Initially means, SDs, and frequencies were utilized to describe patient demographic characteristics. Frequencies were also utilized to investigate the distribution of patients receiving an appropriate/inappropriate STEMI activation, the institution initiating STEMI system activation, and mode of hospital arrival.

Logistic regression analysis was conducted to demonstrate the relationship between activating institution, mode of hospital arrival, and appropriateness of STEMI system activation. A single 5-category independent variable, incorporating both activating institution and mode of hospital arrival, was utilized to determine initial measures of effect, reported as odds ratios. Adjusted odds ratios were also calculated by incorporating the demographic characteristics age, sex, and race in the final multivariable model. Model fit and discrimination were assessed with the Hosmer-Lemeshow goodness of fit test and area under the receiver operating characteristic curve. A similar analysis was conducted with a generalized linear model with PCI destination institution included as a random-effects term. All statistical tests were 2 sided and conducted at the α = 0.05 level. Data were abstracted from patient records and entered into Microsoft Excel (Redmond, WA). Statistical analyses were conducted with the use of Stata version 10 (College Station, TX).

Results

The data set under analysis was composed of 5073 STEMI-alert patients from 14 participating PCI centers. The reasons for exclusion from complete analysis are shown in Figure 1A. There were 106 patients (2%) who had STEMI activations initiated as inpatients and were excluded from this analysis. An additional 324 patients (6%) had inadequate data to determine their outcome, and 672 (13%) were missing some combination of their system activation and arrival data. There were 4087 individuals (80.6%) with complete outcome and independent variable data. An additional 114 individuals (2.7%) were removed from the analytical data set because sufficient data were not present to determine a final patient disposition, leaving 3973 individuals (78.3%) available for analysis. The average age of study participants was 60.3 (SD=13.5) years, with 79.5% of patients classified as non-minority and 70.3% male.

The distribution of cases included in the complete analysis is presented in Figure 1B. There were 3377 individuals (85.0%) who received appropriate CCL activation. PCI was performed in 2598 patients, representing 76.9% of appropriate activations and 65% of all activations. Surgical revascularization was undertaken in 3.5% of cases (all activations). There were also 365 patients (10.8% of those undergoing CCL evaluation) who were found to have no evidence of occlusive coronary artery disease on angiography. Few patients (1.4%) died during the course of emergent treatment. Those individuals with inappropriate STEMI system activation most often had CCL cancellation because of reinterpretation of EMS ECG (242 patients; 6% of all activations, 40.6% of inappropriate activations). One hundred seventy-one patients (4.3% of all activations) were deemed inappropriate for CCL management (eg, advanced age [>90 years], refusal of treatment, active bleeding, known terminal illness
STEMI system activation occurred relatively equally among EMS agencies, non-PCI, and PCI facilities, with roughly one third of activations originating from each respective organization. There were 2697 individuals (67.7%) transported to their initial hospital by EMS. EMS STEMI system activation with EMS transport was the most frequent combination of system activation and mode of arrival, with 1150 individuals (28.9%).

Results presented in Table 1 include the frequencies, crude odds ratios, and adjusted odds ratios for appropriate STEMI system activation by the method of system activation combined with the patient’s mode of arrival. With EMS system activation and EMS arrival as the reference group, patients with a STEMI system activation initiated by a non-PCI hospital with EMS transport were 2.1 (95% confidence interval [CI], 1.6–2.7) times more likely to have an appropriate activation, whereas those activations initiated by a PCI center with patient arrival by EMS were 3.3 (95% CI, 2.5–4.5) times more likely to have an appropriate activation. Compared with the reference group, patients who self-presented to a PCI hospital were 3.5 (95% CI, 2.5–5.0) times more likely to have an appropriate STEMI system activation. The likelihood of appropriate activation was also significantly higher when STEMI system activation was initiated by a PCI-capable hospital compared with a non-PCI-capable facility (P<0.01 for all comparisons). However, among facility types there was no difference in the likelihood of an appropriate activation based on mode of arrival. The multivariable model also indicated that whites were more likely to receive appropriate activation when the other variables in the random-effects model were controlled for than minorities
Table 1. ORs (Crude and Adjusted) for Appropriate STEMI System Activation by Method of System Activation and Patient’s Mode of Arrival

<table>
<thead>
<tr>
<th></th>
<th>Inappropriate Activation, n (%)</th>
<th>Appropriate Activation, n (%)</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted OR* (95% CI)</th>
<th>Random-Effect Crude OR (95% CI)</th>
<th>Random-Effect Adjusted OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMS activation with EMS arrival</td>
<td>284 (24.7)</td>
<td>866 (75.3)</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
<td>Referent</td>
</tr>
<tr>
<td>Non–PCI center activation with EMS arrival</td>
<td>107 (13.2)</td>
<td>706 (86.8)</td>
<td>2.2 (1.7–2.8)</td>
<td>2.1 (1.6–2.7)</td>
<td>3.2 (2.4–4.2)</td>
<td>3.1 (2.4–4.2)</td>
</tr>
<tr>
<td>Non–PCI center activation with walk-in arrival</td>
<td>90 (12.3)</td>
<td>644 (87.7)</td>
<td>2.3 (1.8–3.0)</td>
<td>2.0 (1.5–2.6)</td>
<td>3.0 (2.3–4.1)</td>
<td>2.8 (2.1–3.8)</td>
</tr>
<tr>
<td>PCI center activation with EMS arrival</td>
<td>72 (9.8)</td>
<td>662 (90.2)</td>
<td>3.0 (2.3–4.0)</td>
<td>3.3 (2.5–4.5)</td>
<td>2.9 (2.1–3.9)</td>
<td>3.3 (2.4–4.5)</td>
</tr>
<tr>
<td>PCI center activation with walk-in arrival</td>
<td>43 (7.9)</td>
<td>499 (92.1)</td>
<td>3.8 (2.7–5.3)</td>
<td>3.5 (2.5–5.0)</td>
<td>3.7 (2.6–5.3)</td>
<td>3.5 (2.4–5.1)</td>
</tr>
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</table>

OR indicates odds ratio; STEMI, ST-segment elevation myocardial infarction; CI, confidence interval; EMS, emergency medical services; and PCI, percutaneous coronary intervention. EMS activation of the STEMI system for patients arriving at the hospital by EMS is used as the reference group.

*OR adjusted for age, race, and sex.

Table 2. Patient Characteristics and Range of Appropriate Activations Grouped by Agency Activating STEMI System

<table>
<thead>
<tr>
<th></th>
<th>EMS</th>
<th>Non–PCI Center</th>
<th>PCI Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>61.1 (0.42)</td>
<td>59.7 (0.34)</td>
<td>60.2 (0.38)</td>
</tr>
<tr>
<td>Race, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minority</td>
<td>23.1</td>
<td>18.5</td>
<td>19.7</td>
</tr>
<tr>
<td>White</td>
<td>76.9</td>
<td>81.5</td>
<td>80.3</td>
</tr>
<tr>
<td>Sex, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>69.5</td>
<td>71.2</td>
<td>69.9</td>
</tr>
<tr>
<td>Female</td>
<td>30.5</td>
<td>28.8</td>
<td>30.1</td>
</tr>
<tr>
<td>Range of appropriate activation among institutions,* %</td>
<td>65.3–100</td>
<td>62.9–100</td>
<td>74.2–100</td>
</tr>
</tbody>
</table>

STEMI indicates ST-segment elevation myocardial infarction; EMS, emergency medical services; and PCI, percutaneous coronary intervention.

*Range determined from those hospitals with ≥10 patients by activating center.

(2.4; 95% CI, 1.9–3.0). Table 2 presents collected demographic data by activating center.

Table 1 also includes results from the generalized linear model in which PCI destination institution was modeled as a random-effects term. With destination hospital as a random effect and with other potential confounders controlled for, patients with a STEMI system activation initiated by a non-PCI hospital with EMS transport were 3.1 (95% CI, 2.4–4.2) times more likely to have an appropriate activation compared with the referent group, whereas those activations initiated by a PCI center with patient arrival by EMS were 3.3 (95% CI, 2.4–4.5) times more likely to have an appropriate activation. In this model, the likelihood of appropriate activation was not significantly different when PCI-capable hospitals were compared with non–PCI-capable hospitals.

An analysis of missing arrival/activation data was conducted and indicated that those individuals with missing data were more likely to have an appropriate activation compared with EMS activation and arrival but were no more likely to have an appropriate activation than any other mode of arrival/system activation combination.

**Discussion**

This report describes the course of care for patients within a statewide system for STEMI management. Although certain elements of the system vary among locations within the state, the overall state system design is uniform, incorporating resource mobilization and system activation by the first caregivers who recognize the ECG and clinical presentation of STEMI. It is expected that such a system will be imperfect and that some activations will be cancelled as additional providers evaluate the patient and ECGs and as additional clinical information becomes available. A balance must be struck between sensitivity in detecting all potential candidates who may benefit from such a program and the specificity of system activation and the resulting effect on resource mobilization. The accepted rate for such cancellations may vary by the level of experience of the initial providers activating the system.

National advocacy groups have recently focused on means to improve the care of STEMI patients. It has become apparent that major improvements are possible if systems of care are built that coordinate and integrate prehospital, emergency department, and cardiology services. In 2004, the American Heart Association formed an Advisory Working Group to determine means to increase the number of STEMI patients who would receive primary PCI, the preferred reperfusion strategy. Their consensus paper highlighted the lack of coordinated systems. Subsequent work by this group has focused on each component within STEMI systems of care, which form the core of the American Heart Association Mission: Lifeline program. The concept of “appropriate versus inappropriate” CCL activation is addressed within the Mission: Lifeline content.

The American College of Cardiology’s Door to Balloon Alliance was established in 2006 as a means to achieve timely reperfusion by PCI in STEMI cases. This initiative focuses on using 6 core strategies (emergency department physician activates the CCL, single-call activation system activates the CCL, CCL team is present in 20–30 minutes, prompt data feedback, senior management commitment, team-based approach) as the means to improve processes of STEMI care. A seventh optional strategy includes the use of prehospital ECG in programs for CCL activation. The prehospital ECG is now seen as critical for establishing STEMI diagnosis as early as possible in the prehospital environment, and its timely acquisition is key in prehospital STEMI system performance.
In an analysis of the Minneapolis Heart Institution’s Level One STEMI Program, the term false-positive was used to describe the 9.2% of CCL activations made by emergency physicians in which no culprit lesion was seen and the patient had no elevation of myocardial infarction biomarkers. Kontos et al described results of a single PCI institution’s system of emergency physician activation of the CCL for STEMI and found that 5% of these activations were ultimately classified as unnecessary. Recently, the American Heart Association Mission: Lifeline Science Task Force posted “Catheterization Laboratory Activation Registry Terminology” on the Mission: Lifeline Web site, suggesting nomenclature that may not reflect a negative connotation for EMS and STEMI system participants while cognizant of the need to define the most precise and widely applicable terminology available. The adoption of common definitions will allow comparisons and the ability to train and coordinate follow-up after measurement.

Overall system analysis should recognize that the acceptable rate of inappropriate activations may vary by the manner in which patients present to the hospital and by the type of hospital to which they present (EMS or direct arrival; PCI center or non–PCI center presentation). Specific quality improvement or educational interventions may then be targeted toward these specific groups. For example, in this series inappropriate STEMI system activation by EMS for patients delivered to a PCI center was 24.7%, whereas activations made by PCI center physicians for patients presenting directly to them was 7.9%. Although the frequency of inappropriate activation varies greatly between these 2 groups independently, these may be seen as acceptable rates of inappropriate activation for each group. Conversely, 1 or both of these rates may require that additional efforts be undertaken to further decrease the occurrence of inappropriate activations.

The issue of determining CCL candidacy for a particular patient is new for EMS providers and emergency physicians. This has typically been a determination made by the interventional cardiology staff. Education for emergency physicians and EMS providers regarding potential disqualifiers for CCL candidacy (eg, extremes of age, active bleeding, known terminal illness/do not resuscitate orders, severe comorbid conditions) may help to optimize appropriate system activations. Ongoing education regarding STEMI diagnosis and the various ECG mimics would also be expected to decrease the proportion of inappropriate system activations. Currently, there are no uniform standards for EMS training, competency assessment, or ongoing quality assurance efforts regarding the ECG diagnosis of STEMI. This illustrates an opportunity for system improvement within a regional or statewide program of STEMI system development.

The ability to generalize these findings may be limited. Our statewide STEMI system has been built over the past several years, with specific attention placed on the uniformity of evaluation and treatment strategies. EMS personnel have been afforded specific ECG educational resources as a part of this effort. However, no attempt was made to determine whether particular providers involved in STEMI system activations within this registry participated in this or other specific educational offerings. North Carolina is similar to other states in regard to the variability of EMS system design. Some systems are composed of all paramedic professional providers, and others rely on volunteer EMT-Basic responders. We did not evaluate the various EMS systems or components individually, nor did we record the input of first responders in systems with multitiered responders. ECGs were not archived, and therefore analysis of specific ECG findings that led to discrepancies and STEMI system cancellations cannot be detailed.

Resource utilization is cited as the reason for attention to overactivation of STEMI systems. We did not measure specific resource mobilizations in response to system activation, nor did we differentiate by time of day or day of week in regard to cancelled STEMI activations. It would be expected that resource use would vary by these confounders, and optimization of systems may require further attention to this issue.

Conclusions

The North Carolina CLAR data support paramedic activation of the CCL for STEMI patients in a coordinated system with physician oversight, training, and continuing education on 12-lead ECG STEMI identification and quality data feedback. Appropriate activation of the STEMI system occurred for the great majority of cases. Appropriate activations were most likely to occur for patients presenting directly to PCI-capable hospitals. EMS systems and hospital providers may be able to reduce the incidence of inappropriate STEMI system activation by continued improvement in regard to ECG diagnosis and by including CCL candidacy as a consideration.

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CLINICAL PERSPECTIVE

Regional ST-segment elevation myocardial infarction (STEMI) systems of care continue to develop and evolve, and now many metropolitan areas and states are organizing their efforts to provide timely reperfusion and intervention for an increasing number of patients. These systems now incorporate emergency medical services agencies and emergency departments as key drivers of their programs. It is important to acknowledge that activation of STEMI systems of care will inherently result in some degree of overtriage or false-positive activations if attempts are made to maximize the sensitivity in identifying all STEMI cases. In this statewide registry, including 14 percutaneous coronary intervention–capable hospitals, receiving STEMI patients from their emergency medical services providers and referral hospitals, >3000 patients were followed to determine whether STEMI system activation was deemed to be appropriate or inappropriate, and the ultimate manner of treatment was recorded. The odds of having an appropriate system activation varied by means of hospital presentation and institution type where the activation occurred, with the greatest odds of having an appropriate STEMI system activation occurring at percutaneous coronary intervention–capable hospitals. By better understanding these issues, particular system components such as ECG interpretation and catheterization laboratory candidacy issues can be identified and can serve as a focus of continued process improvement and education.
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