Rates of Cardiac Catheterization Cancelation for ST Elevation Myocardial Infarction after Activation by Emergency Medical Services or Emergency Physicians: Results from the North Carolina Catheterization Laboratory Activation Registry (CLAR)

Running title: Garvey et al.; STEMI cath lab activation registry

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Journal Subject Codes: [4] Acute myocardial infarction
Abstract:

**Background** - For patients with an acute ST segment elevation myocardial infarction (STEMI), cardiac catheterization laboratory (CCL) activation by emergency medical technicians (EMTs) or emergency physicians has been shown to substantially reduce treatment times. One drawback to this approach involves “over-triage” 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 EMTs, 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 PCI. Reasons for inappropriate activations (596 patients, 15%) included ECG reinterpretations (427 patients, 72%) or the patient was not a CCL candidate (169 patients, 28%) The rate of cancellation due to reinterpretation of EMT’s ECG (6% of all activations) was more common than for cancellation due to reinterpretation of emergency physicians’ ECG (4.6%).

**Conclusions** - This represents the first report of the rates of cardiac catheterization laboratory cancellation for STEMI system activation by EMTs and emergency physicians in a large group of hospitals organized within a state-wide program. The high rate of coronary intervention and relatively low rate of inappropriate activation suggests that systematic CCL activation by emergency personnel on a broad scale is feasible and accurate, and these rates set a benchmark for STEMI systems.

**Key words:** acute myocardial infarction; emergency department; ST-segment elevation myocardial infarction; systems of care; emergency medical services
Introduction

Based upon an association between faster treatment times and lower mortality, national ST elevation myocardial infarction (STEMI) guidelines call for percutaneous coronary intervention (PCI) within 90 minutes of first medical contact\textsuperscript{1}. 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 (CCL) without cardiology consultation\textsuperscript{2-8}. Early CCL activation markedly reduces treatment times by preparing the team prior to patient arrival and by avoiding the additional time involved in formal consultation. A potential drawback to this approach involves “over-activation,” 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.

Such over-activations 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. Over-activation may also weaken regional STEMI collaborations if physicians and laboratory staffs become reluctant to respond to emergency physicians and paramedics due to 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 over-activation will be expected to occur. The medical community has not yet determined what rate of such over-activation is acceptable. Given the variability of emergency medical services (EMS) systems’ design, training, and protocols within the US, it is particularly
challenging to craft regional STEMI systems which optimize the appropriate activation of PCI center resources.

To date, reports of over-activation have involved single centers and focused primarily on emergency physicians\(^9\)-\(^{12}\). In order to establish benchmark rates of over-activation 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 Catherization 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 following 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\(^6\) identified all instances of catheterization laboratory activation. 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, if catheterization was cancelled, and the reason for cancellation. STEMI system activation followed the consensus guidelines developed with the North Carolina RACE initiative (available at [http://www.nccacc.org/RACE/RACEOperationsManualOct.09.pdf](http://www.nccacc.org/RACE/RACEOperationsManualOct.09.pdf)) All patients had clinical scenarios in which an acute coronary syndrome was considered. The method of STEMI
system activation was primarily based on emergency physician or paramedic interpretation of the ECG. Additionally, several EMS agencies use the combination of ECG machine interpretation algorithm along with a paramedic visual interpretation. No EMS system or physician relied solely on 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 due to a change in patient status (resolution of symptoms, resolution of ST elevation, or death). Activations were considered to be inappropriate or “over activation” if catheterization was cancelled due to 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 either having STEMI system activation initiated by EMS, a non-PCI facility physician, or a PCI facility physician. Further, individuals were classified as arriving at their initial destination hospital by EMS or walk in. 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. Also, individuals were excluded from analysis if documentation
was not sufficient to abstract a final patient disposition. Initially means, standard deviations (SD), 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 five 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 using the Hosmer-Lemeshow goodness of fit test and area under the receiver operating characteristic (ROC) curve\textsuperscript{13}. A similar analysis was conducted utilizing a generalized linear model with PCI destination institution included as a random effects term. All statistical tests were two sided and conducted at $\alpha=0.05$ level. Data were abstracted from patient records and entered into Microsoft Excel (Redmond, WA). Statistical analyses were conducted using Stata v.10 (College Station, TX).

Results

The data set under analysis was comprised of 5,073 STEMI alert patients from 14 participating PCI centers. The reasons for exclusion from complete analysis are shown in Figure 1A. There were 106 (2%) patients who had STEMI activations initiated as inpatients and were excluded from this analysis. A further 324 (6%) patients had inadequate data to determine their 

\begin{figure}[h]
  \centering
  \includegraphics[width=\textwidth]{Figure1A.png}
  \caption{Reasons for exclusion from complete analysis.}
  \label{fig:figure1a}
\end{figure}
outcome and 672 (13%) were missing some combination of their system activation and arrival data. There were 4,087 (80.6%) individuals with complete outcome and independent variable data. A further 114 (2.7%) individuals were removed from the analytic dataset as sufficient data was not present to determine a final patient disposition, leaving 3,973 (78.3%) individuals 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 3,377 (85.0%) individuals who received appropriate cardiac cath lab activation. PCI was performed in 2,598 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 upon angiography. Few patients (1.4%) died during the course of emergent treatment. Those individuals with inappropriate STEMI system activation most often had CCL cancellation due to reinterpretation of EMS ECG (242 patients, 6% of all activations, 40.6% of inappropriate activations). 171 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 and/ or a ‘Do Not Resuscitate’ order, severe co-morbid conditions).

**Figure 2** presents the distribution of patients by method of STEMI system activation and initial mode of hospital arrival. 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 2,697 (67.7%) individuals 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 1,150 (28.9%) individuals. 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% CI = 1.6 - 2.7) times more likely to have an appropriate activation, while 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 to 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 to 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 Caucasians were more likely to receive appropriate activation when controlling for the other variables in the random effects model than minorities (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 where PCI destination institution was modeled as a random effects term. With destination hospital as a random effect and controlling for other potential confounders 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 to the referent group, while 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 comparing PCI capable to 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 when compared to 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 state-wide system for STEMI management. While 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 care givers 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 that would receive primary PCI, the preferred reperfusion strategy. Their consensus paper highlighted the lack of coordinated systems\textsuperscript{14}. Subsequent work by this group has focused on each component within STEMI systems of care\textsuperscript{15}, which form the core of the AHA Mission: LifeLine\textsuperscript{TM} program. The concept of ‘appropriate versus inappropriate’ CCL activation is addressed within the Mission: LifeLine\textsuperscript{TM} content\textsuperscript{16}. The American College of Cardiology’s Door to Balloon Alliance (D2B) was established in 2006 as a means to achieve timely reperfusion by PCI in STEMI cases. This initiative focuses on using 6 core strategies (ED physician activates the CCL, single call activation system activates the CCL, CCL team present in 20-30 minutes, prompt data feedback, senior management commitment, team based approach) as the means to improve processes of STEMI care\textsuperscript{2}. A 7th “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\textsuperscript{8,17,18,19}.

In an analysis of the Minneapolis Heart Institution’s Level One STEMI Program\textsuperscript{11}, the term “false positive” was used to describe the 9.2% of CCL activations made by emergency physicians where no culprit lesion was seen and the patient had no elevation of myocardial infarction biomarkers. Kontos\textsuperscript{9} described results of a single PCI institution’s system of emergency physician activation of the CCL for STEMI and found 5% of these activations were ultimately classified as unnecessary. Recently, the American Heart Association (AHA) Mission: Lifeline Science Task Force posted “Catheterization Laboratory Activation Registry Terminology” on the Mission: Lifeline website\textsuperscript{16} 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 ability to train and coordinate follow up after measurement.

Overall system analysis should recognize that the acceptable rate of inappropriate activations may vary by how 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 towards these specific groups. For example, in this series inappropriate STEMI system activation by EMS for patients delivered to a PCI center was 24.7%, while activations made by PCI center physicians for patients presenting directly to them was 7.9%. While the frequency of inappropriate activation varies greatly between these two groups independently, these may be seen as acceptable rates of inappropriate activation for each group. Conversely, one 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, etc) may help 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 state-wide program of STEMI system development.
The ability to generalize these findings may be limited. Our state-wide 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 if 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 regarding 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 multi-tiered responders. ECGs were not archived, so analysis of specific electrocardiographic findings that led to discrepancies and STEMI system cancellations cannot be detailed.

Resource utilization is cited as the reason for attention to over-activations 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 regarding 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 NC 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 hospitals. EMS systems and hospital providers may be able to
reduce the incidence of inappropriate STEMI system activation by continued improvement regarding ECG diagnosis and by including CCL candidacy as a consideration.

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**Conflict of Interest Disclosures:** J. Lee Garvey MD has served as a consultant to Abbott Vascular in their Women’s Heart Health Initiative. James G. Jollis MD has received grant support from Medtronic Foundation and Sanofi-Aventis.

**References:**


Strategies for reducing the door-to-balloon time in acute myocardial infarction. NEJM. 2006;355:2308-2320.


Table 1. Odds Ratios (crude and adjusted) for appropriate STEMI system activation by the method of system activation and the patient’s mode of arrival. EMS activation of the STEMI system for patients arriving at the hospital by EMS is used as the reference group.

<table>
<thead>
<tr>
<th></th>
<th>Inappropriate Activation</th>
<th>Appropriate Activation</th>
<th>Crude OR</th>
<th>Adjusted OR*</th>
<th>Random Effect Crude OR</th>
<th>Random Effect Adjusted OR*</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>
</tbody>
</table>

* 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>Mean Age (SD)</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>

*Range determined from those hospitals with 10 or more patients by activating center

Figure Legends:

Figure 1. Panel A. Reasons that cases were excluded from the complete analysis are listed. Panel B. Course of patients’ care following STEMI system activation. Activations were considered to be appropriate if catheterization was performed, or if catheterization was cancelled due to a change in patient status (resolution of symptoms, resolution of ST elevation, or death). Activations were considered to be inappropriate if catheterization was cancelled due to ECG reinterpretation, or if the patient was deemed not to be a candidate for cardiac catheterization.

Figure 2. STEMI system activation was made by EMS personnel or by physicians at the PCI center or referral hospital (non PCI facility). The mode of arrival at the presenting hospital is also used to stratify patients.
Total Activations
n = 5073

- Inpatients excluded
  n = 106

- System Activation Unknown
  n = 613

- Mode of Arrival Unknown
  n = 267

- Other unspecified reason to exclude
  n = 71

- No record available for review
  n = 31

- Error (EMS activation/Walk-in Arrival)
  n = 12

Included in Analysis
n = 3973
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