The Impact of a Statewide Pre-Hospital STEMI Strategy to Bypass Hospitals without Percutaneous Coronary Intervention Capability on Treatment Times

Running title: Fosbol et al.; Impact of Statewide EMS Bypass

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Abstract:

Background—The ultimate treatment goal for ST-segment elevation myocardial infarction (STEMI) is rapid reperfusion via primary percutaneous intervention (PCI). North Carolina has adopted a statewide STEMI referral strategy that advises paramedics to “bypass” local hospitals and transport STEMI patients directly to a PCI-capable hospital, even if a non-PCI-capable hospital is closer.

Methods and Results—We assessed emergency medical services (EMS) adherence to this STEMI protocol, as well as subsequent associations with patient treatment times and outcomes by linking data from the ACTION Registry-GWTG and a statewide EMS data system from 06/2008-09/2010 for all STEMI patients. Patients were divided into those: (1) transported directly to a PCI hospital, thereby bypassing a closer non-PCI hospital; and (2) first taken to a closer non-PCI center and later transferred to a PCI hospital. Among 6010 STEMI patients, 1288 were eligible and included in our study cohort. Of these, 826 (64%) were transported directly to a PCI facility, whereas 462 (36%) were first taken to a non-PCI hospital and later transferred. In a multivariable model, increase in differential driving time and cardiac arrest were associated with a lesser likelihood of being taken directly to a PCI center, whereas a history of PCI was associated with a higher likelihood of being taken directly to a PCI center. Patients sent directly to a PCI center were more likely to have first medical contact-to-PCI times within guideline recommendations.

Conclusions—We found that patients who were sent directly to a PCI center had significantly shorter time to reperfusion.

Key words: STEMI; EMS transport; reperfusion time
Cardiovascular disease continues to be a leading cause of death in western countries, and ST-segment elevation myocardial infarction (STEMI) remains the key acute presentation. Rapid reperfusion by primary percutaneous coronary intervention (PCI) has become the treatment foundation for STEMI. Unfortunately, the availability of PCI is limited, given that only 25% of hospitals are PCI-capable facilities.1,2

Regional and statewide systems for rapid STEMI care are being developed3-6 to improve the overall use of and timing of PCI and improve patient outcomes.7-10 The American Heart Association’s Mission Lifeline initiative is part of this national effort to regionalize STEMI care and shorten reperfusion times.11 Major problems still exist for patients who are transferred by emergency medical services (EMS) from a non-PCI-capable hospital to a PCI-capable facility. In fact, only 13% of these transferred patients are treated with PCI within 90 minutes of arrival at the first hospital12 and only 11% have door-in-door-out times below the recommended 30 minutes.13

The choice by EMS to bypass hospitals without primary PCI capabilities has been proposed as one means of achieving more rapid reperfusion in STEMI.14 The Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments (RACE) program was a statewide regionalization program to improve STEMI care that began in 2006.12,15 Beginning in 2008, RACE and the North Carolina Office of EMS began implementing pre-hospital care protocols that encouraged EMS to bypass non-PCI facilities when transporting STEMI patients, even if a non-PCI-capable hospital is closer.

However, it is not known whether the implementation of these protocols has improved patient treatment times or outcomes. Using a novel linkage of statewide EMS collected data and in-hospital treatment and outcomes data for patients with STEMI, we sought out to: (1) describe
the overall adoption of a statewide strategy to improve treatment times by sending STEMI patients directly to PCI hospitals even when a non-PCI hospital is closer; (2) identify predictors of which patients were more likely to undergo direct transport to a PCI facility; and (3) compare treatment delay and clinical outcomes among those patients sent directly to PCI centers versus those who were first taken to a non-PCI facility, and then subsequently transferred.

Methods

Design and Data Sources

We identified all STEMI patients in North Carolina who arrived at the final destination hospital (a RACE PCI center) by EMS using RACE data from June 1, 2008 to Sep 30, 2010. Using deterministic linkage, we matched data from the RACE registry to data containing identifiable patient information from the statewide Prehospital Medical Information System (PreMIS). The linkage has been described previously. In brief, four key variables were used for the linkage: (1) date of birth; (2) gender; (3) destination arrival time (within a five-hour time window); and (4) date and location of destination. Sixty-nine percent of all EMS-transported patients in the RACE database were successfully linked with PreMIS with good generalizability (similar baseline characteristics and similar inhospital mortality). For transfer patients, we used the PreMIS database to identify multiple EMS runs for the same patient in order to have data for the entire continuum of care.

The data foundation for the RACE program is the National Cardiovascular Data Registry® (NCDR) Acute Coronary Treatment and Intervention Outcomes Network Registry®-Get With the Guidelines™ (ACTION Registry-GWTG). This is a voluntary quality improvement registry, so participation is open to all hospitals in the United States. In brief, participating
hospitals collect detailed information on baseline demographics and clinical characteristics, processes of care, and in-hospital outcomes using a standardized set of data elements and definitions, as previously described. All PCI and non-PCI hospitals in North Carolina participate in the RACE program and data are collected using the NCDR data collection tool.

The PreMIS database contains tools for data entry, reporting, and the evaluation of EMS quality and performance throughout North Carolina. PreMIS is an Internet-based EMS electronic patient care reporting system that serves as the electronic health care record for the documentation of EMS care delivery. In 2008, PreMIS collected 1.2 million EMS records, representing virtually 100% of the EMS events and more than 900,000 patient contacts in North Carolina obtained from more than 540 licensed EMS agencies. Our study includes data from 178 different EMS agencies that transported a STEMI patient to one of the 21 PCI hospitals in our analysis. The PreMIS dataset is based on a national standardized dataset called the National EMS Information System (NEMSIS), which is currently used widely throughout the United States.

Definition of “Bypass” and Study Groups
In 2008, RACE and the North Carolina office of EMS implemented protocols for statewide pre-hospital STEMI care systems in North Carolina. These protocols encouraged EMS to take patients directly to PCI centers, even if this meant passing a closer non-PCI center. Paramedics were encouraged to bypass non-PCI centers if total treatment times were estimated to meet guideline recommendations. In instances with excessive drive times or no prehospital electrocardiogram (ECG), patients were generally transported to local hospitals.

The incident location (address) for each STEMI patient was obtained from PreMIS. By accessing Google Maps via the internet-based uniform resource locator (URL) with SAS
statistical software,\textsuperscript{20} we obtained the Google driving time from the incident address (i.e., STEMI) to all acute general medical hospitals in North Carolina. Hospitals were classified as PCI-capable or non-PCI-capable based on available RACE and American Hospital Association data. Drive times were classified according to hospital PCI capability. We calculated the differential driving time from where the patient was transported by EMS to all other hospitals by simple subtraction of driving times. We divided patients into three groups: (1) those who bypassed a closer non-PCI hospital and went directly to a PCI hospital (minimum differential driving time = 10 minutes); (2) those who were first taken to a non-PCI center and subsequently transferred to a PCI hospital; and (3) those who were taken directly by EMS to a PCI hospital when it was the closest facility (<10 minutes of differential driving time). For the main analysis, we only included patients who were “eligible” for bypass (groups 1 and 2), meaning that patients who were closest to a PCI center (group 3) were excluded, along with those who self-transported to the first hospital. Patient selection is shown in Figure 1.

Endpoints

We first examined which patient-level factors (e.g., demographics, past medical history, presenting complaint) were associated with EMS’ decision to bypass a non-PCI facility and transport the patient directly to a PCI hospital. Second, we assessed the association of direct transport to a PCI hospital with time from first medical contact (FMC) to PCI among patients undergoing PCI. First medical contact was defined as the time of EMS personnel arrival at the patient. Time from FMC to reperfusion was assessed using the RACE data as collected via ACTION-GWTG. Adherence to guideline goals was defined for those who were treated with primary PCI as a FMC-to-PCI time <90 minutes for those patients who were taken directly to a PCI center and <120 minutes for those who were transferred from an interim hospital.\textsuperscript{14} Finally,
we compared in-hospital mortality and an in-hospital composite outcome of death, stroke (including both hemorrhagic and ischemic), or shock between the two groups.

**Statistics**

We described the sample patients’ characteristics using median with interquartile range (IQR) or frequency as appropriate and tested for differences between groups using the Wilcoxon rank sum test for continuous variables and the $\chi^2$ test for categorical variables. The trend in proportion of bypass over time was examined by using the Cochran-Armitage test. Associations between available factors (**Table 1**) and direct transport to a PCI hospital were assessed using multivariable logistic regression with generalized estimating equations (GEE) accounting for data dependency within hospital referral regions in North Carolina, which were derived from the Dartmouth Atlas\textsuperscript{21} using zip codes. The binary responses within individual hospital referral regions were assumed to be equally correlated and an exchangeable correlation structure was applied. Treatment delay was measured as time from FMC to PCI hospital arrival, time from FMC to reperfusion therapy (PCI or fibrinolysis), time from FMC to PCI, and time from interim hospital arrival to fibrinolysis therapy. Crude differences in treatment delay between the groups were examined using Wilcoxon rank sum tests. The relationship between actual driving time to the PCI center and the estimated Google driving time to the nearest non-PCI hospital was plotted. The predicted probability of reaching guideline goals was estimated from the data and was illustrated by a regression line on the figure. This allowed us to determine the proportion of patients reaching guideline goals as a function of differential driving time (i.e., left y-axis in conjunction with the x-axis). For this we used a univariable logistic regression model to predict the probability of reaching the guideline goal. The Hosmer-Lemeshow goodness-of-fit statistic showed a reasonable fit of the model (value of 9.3 and p-value of 0.32 while small p-values
(<0.1) indicate a lack of fit of the model). To determine how direct transport to a PCI center versus transport to a non-PCI center was associated with the outcome of adherence to guideline goals and in-hospital mortality or composite outcomes, we conducted χ² tests for direct comparisons as well as GEE modeling for the adjusted effect of bypassing. We used a previously derived ACTION Registry-GWTG mortality model to select variables for adjustment. We included the following variables: age, gender, race, insurance-status, chest pain at presentation, shock at presentation (time of FMC), prehospital ECG, prehospital cardiac arrest, and history of heart failure, coronary artery bypass surgery, PCI, chronic lung disease, diabetes, dyslipidemia, hypertension, myocardial infarction, and smoking. We tested for interactions between direct transport to a PCI hospital and gender, age, and cardiac arrest. A p-value of <0.05 was considered statistically significant. We also performed sensitivity analyses among patients without pre-hospital cardiac arrest or shock and with a pre-hospital ECG recorded in the dataset. All analyses were performed using SAS statistical software (SAS 9.2, SAS Institute, Cary, North Carolina, United States).

Results

A total of 6010 STEMI patients from the RACE database between June of 2008 and September of 2010 were successfully linked with PreMIS and were assessed for inclusion in the present study. After applying selection criteria we identified 1288 patients eligible for direct transport to a PCI hospital; of whom, 826 (64%) patients were included in the direct transport to a PCI hospital group and 462 (36%) in the transport to a non-PCI hospital group (Figure 1).

Geographical information for transport strategy and placement of PCI-capable centers in North Carolina is illustrated by Figure 2. During our study period, the rate of bypass increased slightly
from 60.7% in the first quarter to 65.5% in the last quarter (p for trend 0.0008).

Patient characteristics are shown in Table 1. In brief, compared with those first taken to a non-PCI center, patients who were taken directly to a PCI center were more likely to be white, have a history of PCI and dyslipidemia, have chest pain listed as a chief complaint, and receive a prehospital ECG. Prehospital cardiac arrest was more common in those transported to a non-PCI hospital (Table 1). There was no difference between the groups for receiving any reperfusion therapy overall (i.e., fibrinolysis or PCI); however, substantially more patients were treated with fibrinolysis in the group that was first brought to a non-PCI facility. All patients were eventually taken to a PCI center, yet 35% of those first brought to a non-PCI hospital were given fibrinolysis, and 26% received both fibrinolysis and PCI. Overall, fibrinolysis use was low in the group that was directly transported to a PCI facility (only 8 patients).

Factors Associated with the Decision to Bypass Non-PCI Centers

Odds ratios for factors related to being taken directly to a PCI center versus a non PCI center are shown in Table 2. In our multivariable model, increase in differential driving time and cardiac arrest were associated with a lesser likelihood of being taken directly to a PCI center, whereas a history of PCI was associated with a higher likelihood of being taken directly to a PCI center. A multivariable model using backward selection produced nearly identical results.

Treatment Delay

Treatment delay according to group is shown in Table 3. Patients taken directly to a PCI hospital had substantially longer transportation times, relative to those first taken to a geographically closer non-PCI hospital (median 42 minutes vs. 26 minutes). Time from FMC to reperfusion (PCI or fibrinolysis) and FMC-to-PCI (primary PCI only) were significantly shorter in patients taken directly to a PCI hospital compared with patients first taken to a non-PCI hospital. In those
patients taken to a PCI hospital, 46.0% reached the goal of FMC-to-PCI<90 minutes, whereas only 21.5% of those first taken to a non-PCI hospital reached the goal of FMC-to-PCI<120 minutes (adjusted odds ratio [OR] for reaching guideline goals was 2.82 for direct to PCI hospital vs. non-PCI hospital, 95% confidence interval [CI] 1.96-4.07, p 0.005). Among those taken directly to a PCI facility only, Figure 3 illustrates the relationship between estimated Google driving time to nearest non-PCI hospital, actual driving time to the PCI center, and the probability of receiving PCI within the 90 minute goal. The figure illustrates the relationship between differential driving time (left y-axis in conjunction with the x-axis) and the univariate logistic model predicted probability of reaching the guideline goal. Our results suggest that even with actual driving times of less than 45 minutes, the majority of patients still have FMC-to-PCI times of <90 minutes. The probability of making the FMC-to-PCI<90 minutes goal drops to <20% when the actual driving time was more than 60 minutes.

For purposes of this sensitivity analyses, we examined patients without pre-hospital cardiac arrest or shock and with a pre-hospital ECG (269 patients taken to the nearby non-PCI hospital and 582 patients taken directly to the PCI center). The results were similar, showing a median time from FMC to arrival at the PCI center of 43 min (IQR 33-57) among those taken directly to a PCI center vs. 135 min (IQR 107-178) for those who were taken to a non-PCI hospital first. Time from FMC to PCI among those treated with PCI only was 95 min (IQR 77-117) in those who were transported directly vs. 152 min (IQR 120-203) for those who were taken to the non-PCI hospital first. Time from FMC to any reperfusion therapy (fibrinolysis or PCI, whichever came first) was also faster in the bypass group (94 min vs. 116 min).

For the overall analysis, we excluded patients who were taken directly to a PCI center when it was the closest facility (i.e., EMS bypass was not a treatment option [<10 min...
differential driving time, n=2171]). For comparison purposes, we also examined these patients’
treatment times. Their median time from FMC to PCI was 90 minutes (IQR 72-112) meaning
that half of all patients reached the 90 minute goal. Hence, time from FMC to PCI was similar to
that of those who underwent EMS bypass to a PCI facility (90 minutes vs. 93 minutes). Median
time from FMC to hospital arrival was 31 minutes (IQR 24-40), which was faster than in those
who underwent EMS bypass to a PCI facility (42 minutes).

Clinical Outcomes

Table 4 also shows the clinical inhospital outcomes according to group (direct to PCI hospital;
i.e., EMS bypass vs. non-PCI hospital). Overall unadjusted inhospital mortality and a composite
outcome of inhospital mortality, shock, or stroke were lower in those transported directly to PCI
hospitals versus non-PCI hospitals (6.3% vs. 9.3% and 11.4% vs. 15.6%, respectively). Odds
ratios for the adjusted associations between direct to PCI hospital relative to non-PCI hospital
and the examined outcomes are also shown in Table 4. After adjusting for confounders in the
model, direct transport to a PCI hospital was not associated with statistically significant lower
rates of clinical inhospital outcomes (OR for death was 0.87, 95% CI 0.68-1.11 and 0.86, 95% CI
0.62-1.18 for the composite outcome).

Cardiac arrest was an important determinant of the decision to bypass a geographically
closer non-PCI hospital for direct transport to a PCI hospital. Cardiac arrest was also strongly
related with mortality; however, cardiac arrest did not modify the observed effect of those
transported directly to a PCI hospital in our models (p for interaction >0.05) and the overall
results were similar after excluding patients with cardiac arrest (data not shown). Similarly, after
excluding patients with prehospital shock or cardiac arrest, the results were similar: 6.9%
mortality in those transported to a non-PCI facility versus 5.2% in those transported directly to a
PCI hospital (adjusted OR 0.81; 95% CI 0.51-1.29, p=0.4). Time from FMC-to-PCI was also similar to the overall results (data not shown).

Discussion

Quality improvement efforts aimed at reducing time to reperfusion in STEMI have emphasized that rapid reperfusion might be more easily achieved if EMS takes patients directly to a PCI hospital, even if this PCI hospital is farther away than a closer non-PCI hospital. To our knowledge, no previous study has evaluated whether this EMS bypass approach can reduce patient treatment times for STEMI. This study examines how EMS strategies for bypassing local hospitals that cannot perform PCI as part of a statewide STEMI regionalization program were associated with a reduction in total treatment times in patients with STEMI. Our study has several major findings. First, approximately two-thirds of STEMI patients eligible for EMS bypass are actually sent directly to PCI centers, rather than stopping at their local non-PCI hospital. Longer differential driving times and cardiac arrest were inversely associated with the decision to bypass, whereas a history of PCI was associated with a higher likelihood of bypass. Second, compared with those patients who were first sent to non-PCI centers, those patients who were sent directly to PCI hospitals had faster reperfusion times and were almost three times more likely to reach the target guideline of FMC-to-PCI in <90 minutes. Finally, the decision to bypass a non-PCI center was associated with better overall inhospital mortality; however, after adjusting for case-mix, this did not reach statistical significance.

The decision to bypass non-PCI centers is emphasized by EMS guidelines as an approach to reduce treatment delay, especially when cognizant of the substantial delays that occur in the inter-hospital setting. Wang et al. recently showed that only 11% of patients with STEMI who
are transferred from an interim hospital have a door-in-door-out time of less than the recommended 30 minutes—this delay inevitably translates into worse outcomes.\textsuperscript{13} Similarly, the RACE program showed that only 13\% of transfer patients in North Carolina reached the 90 minute metric from first door to PCI;\textsuperscript{12} therefore, EMS bypass appears to be a practical approach to solving the inherent time delays associated with inter-hospital transfers. Our current results suggest that even with differential driving times of 20 minutes, the majority of patients who are sent directly to PCI-capable hospitals can still have FMC-to-PCI times of <90 minutes.

Prior studies have shown that PCI is superior to fibrinolysis, even after transportation over long distances,\textsuperscript{23} and is the preferred treatment strategy for high-risk patients (e.g., cardiogenic shock).\textsuperscript{24} EMS triage and destination protocols for North Carolina generally recommend bypassing a non-PCI center if a PCI center is located within 30 minutes transportation time of the incident address.\textsuperscript{25} Nevertheless, patient characteristics and hospital-specific primary PCI-related delay should be considered before choosing a reperfusion strategy.\textsuperscript{26,27} Pinto et al. recently showed in a large analysis of STEMI transfer patients that the mortality benefit of primary PCI over on-site fibrinolysis disappeared when the PCI-related delay (door-to-balloon time minus door-to-needle time in matched pairs) were 120 minutes or longer.\textsuperscript{28} In addition, recent updates in STEMI guidelines changed the goal for time from FMC-to-PCI from 90 to 120 minutes in transfer patients. As a result of these guideline changes, one could expect an increase in the number of transfer patients who undergo PCI versus fibrinolysis as a primary reperfusion strategy. Our results highlight the feasibility of EMS bypass to achieve this reperfusion goal, especially in less populated areas where the closest hospital may be a non-PCI-capable facility. Furthermore, our results also emphasize that there is still room for improvement, given that less than half of patients who were taken directly to a PCI center received PCI within
the 90-minute guideline goal. Other studies have shown that door-to-balloon times are improving over time, yet out study—as well as others—suggest that time to reperfusion when measured from FMC is far from guideline goals.\textsuperscript{29,30}

Hard clinical inhospital endpoints like death, stroke, or shock were associated with bypass in unadjusted analyses; however, after accounting for confounders (especially prehospital cardiac arrest) this association did not reach statistical significance. Larger future studies are warranted to assess whether the decision to bypass a non-PCI hospital is associated with improved survival. This is an important association observed in the prehospital setting, for which a trial is unlikely to be carried out, which even further underlines the importance of accumulating evidence across different geographies and systems. Although the bypass strategy was not statistically significantly associated with a lower risk of inhospital outcomes after accounting for confounders, we believe that our results are encouraging. Other outcomes, such as left ventricular ejection fraction and 30-day mortality, could be impacted by shorter reperfusion times and require further study. Our study was not powered in order to reliably assess differences in mortality; for that, larger studies are warranted.

We believe that our analysis further emphasizes the importance of rapid reperfusion. In the prehospital setting, bypassing non-PCI hospitals should be a goal to strive towards, as this method has already been successfully implemented in other countries.\textsuperscript{31,32} One exception to this goal could be in patients who are very unstable (i.e., those in cardiac arrest)—with these patients, it might be more appropriate to take them to the nearest hospital (PCI-capable or not) depending on the capabilities of the closest hospital (i.e. therapeutic hypothermia, circulatory assistance, etc.) and the differential driving time. Yet these patients may also benefit from going directly to the larger PCI-capable center as part of a regionalized system of care.\textsuperscript{33} Nevertheless, these
exceptions are relatively small, and it seems there is a great potential for extending the decision to bypass non-PCI hospitals to about one-third of all patients with STEMI.

Furthermore, we found that approximately 35% of those patients who first went to a non-PCI facility were given fibrinolysis before being transferred for PCI to a PCI hospital. As demonstrated by the North Carolina RACE project, the standardization of EMS destination and treatment plans helps facilitate better care coordination between EMS systems in rural areas with more distant PCI-capable centers; however, it is critical for future studies to examine which factors determine the decision for patients to be transported to a non-PCI hospital when a PCI hospital is attainable within transport guideline goals. Important variables likely include missing prehospital ECG (either due to lack of equipment or paramedic training), missed STEMI in the field assessment, lack of EMS resources preventing an ambulance to leave the county, and poor (or no) destination plan. For example, we found that 35% of patients in the no-bypass group did not receive a pre-hospital ECG. One would expect that more patients would be taken directly to PCI centers instead of closer non-PCI centers if pre-hospital ECGs were obtained more frequently.

**Limitations**

Our study had several limitations. First, this was an observational study using data from an administrative database and a voluntary clinical registry; therefore, we cannot prove causality between the decision to bypass non-PCI hospitals and endpoints. The lack of a significant difference in outcomes between study groups could be due to inadequate risk adjustment and/or unmeasured confounding. Second, our data only included those patients who were transported to a hospital participating in the RACE program which included 21 PCI-capable centers; therefore, patients who were transported to the closest hospital (regardless of the hospital’s PCI
capacities), those who died, or those who were never transferred, were not included in this analysis. Hence, differences between groups seen in our analysis are conservative estimates being that these groups of patients are known to have worse prognosis (e.g., patients with post-fibrinolysis intra cranial hemorrhage or other complications). Third, we identified factors associated with the decision by EMS to bypass non-PCI facilities, but we did not have specific information regarding the details of paramedic decision-making. Fourth, we excluded 491 transfer patients for whom we had no information regarding the initial EMS run (from incident address to interim hospital); therefore, the proportion of patients who were transported directly to a PCI center may be lower than two-thirds. Fifth, this analysis was conducted in a novel-linked database, which could reduce its generalizability. We have previously shown that our linkage did not introduce systematic bias and that the overall cohort of STEMI patients is representative of other STEMI cohorts. Finally, some data was missing from our analysis. For example, 20% of the patients who underwent EMS bypass to a PCI-capable facility did not have a prehospital ECG recorded in our dataset. In addition, we did not have information regarding eligibility for fibrinolysis treatment at presentation. Despite this, our linked database draws information from two different sources (i.e., PreMIS and RACE), therefore providing more complete information than either data source in isolation. Additionally, we performed sensitivity analysis on the subset of patients in our dataset who were recorded as receiving a prehospital ECG and our main study findings were nearly identical.

Conclusions

In a novel contemporary linked database of prehospital and inhospital registry data; two-thirds of eligible patients with STEMI in North Carolina were taken directly to a PCI center, bypassing a
geographically closer, non-PCI center. This prehospital EMS approach was associated with markedly faster reperfusion times and a higher likelihood of meeting treatment guidelines. Our results suggest that when logistically feasible, EMS should transport STEMI patients directly to the nearest PCI-capable hospital. Opportunities for encouraging this transport decision in the remaining one-third of patients could help reduce reperfusion times even further.

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**References:**


Table 1. Patient Characteristics at Presentation According to Group.

<table>
<thead>
<tr>
<th>Transport to Non-PCI Hospital N=462</th>
<th>Transport to PCI Hospital N=826</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (IQR)</td>
<td>61 (51-71)</td>
<td>60 (52-71)</td>
</tr>
<tr>
<td>Females, %</td>
<td>34.9</td>
<td>31.4</td>
</tr>
<tr>
<td>Caucasian, %</td>
<td>81.0</td>
<td>87.8</td>
</tr>
<tr>
<td>Insurance type</td>
<td></td>
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<tr>
<td>None</td>
<td>17.5</td>
<td>16.8</td>
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<tr>
<td>Private</td>
<td>40.3</td>
<td>35.0</td>
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<tr>
<td>Non-private</td>
<td>42.2</td>
<td>48.2</td>
</tr>
<tr>
<td>History of, %</td>
<td></td>
<td></td>
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<tr>
<td>Myocardial infarction</td>
<td>21.2</td>
<td>24.8</td>
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<tr>
<td>Hypertension</td>
<td>68.1</td>
<td>64.4</td>
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<tr>
<td>Diabetes</td>
<td>22.8</td>
<td>22.9</td>
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<tr>
<td>Dyslipidemia</td>
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<td>Heart failure</td>
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<tr>
<td>Smoking (current/recent)</td>
<td>51.3</td>
<td>50.9</td>
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<td>PCI</td>
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<td>26.6</td>
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<tr>
<td>CABG</td>
<td>6.2</td>
<td>7.7</td>
</tr>
<tr>
<td>At presentation, %</td>
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<td></td>
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<tr>
<td>Shock</td>
<td>6.4</td>
<td>7.6</td>
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<tr>
<td>Cardiac arrest</td>
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<td>Prehospital ECG</td>
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<td>Chief complaint of chest pain</td>
<td>71.7</td>
<td>81.1</td>
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<td>Reperfusion strategy, %</td>
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<tr>
<td>Fibrinolysis only</td>
<td>9.3</td>
<td>0.4</td>
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<tr>
<td>PCI only</td>
<td>54.3</td>
<td>89.8</td>
</tr>
<tr>
<td>PCI and/or fibrinolysis</td>
<td>89.2</td>
<td>90.8</td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass grafting; ECG, electrocardiogram; IQR, interquartile range; PCI, percutaneous coronary intervention.
Table 2. Multivariable Adjusted Factors Associated with Direct Transport to PCI Hospital

<table>
<thead>
<tr>
<th>Factor</th>
<th>Adjusted OR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, per 1 year increment</td>
<td>1.00 (0.99-1.01)</td>
<td>0.75</td>
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<tr>
<td>Gender (male vs. female)</td>
<td>1.09 (0.92-1.29)</td>
<td>0.36</td>
</tr>
<tr>
<td>Race (white vs. others)</td>
<td>1.12 (0.88-1.44)</td>
<td>0.39</td>
</tr>
<tr>
<td>Insurance type</td>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>Not private vs. private</td>
<td>1.18 (0.96-1.46)</td>
<td></td>
</tr>
<tr>
<td>None vs. private</td>
<td>1.13 (0.91-1.41)</td>
<td></td>
</tr>
<tr>
<td>History of:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>0.87 (0.63-1.20)</td>
<td>0.42</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.86 (0.63-1.17)</td>
<td>0.33</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.14 (0.75-1.73)</td>
<td>0.55</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>1.11 (0.78-1.59)</td>
<td>0.55</td>
</tr>
<tr>
<td>Heart failure</td>
<td>0.85 (0.51-1.44)</td>
<td>0.55</td>
</tr>
<tr>
<td>Smoking (current/recent)</td>
<td>0.94 (0.70-1.28)</td>
<td>0.72</td>
</tr>
<tr>
<td>PCI</td>
<td>1.65 (1.25-2.18)</td>
<td>0.041</td>
</tr>
<tr>
<td>CABG</td>
<td>1.11 (0.74-1.67)</td>
<td>0.63</td>
</tr>
<tr>
<td>Prehospital setting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>1.64 (0.95-2.82)</td>
<td>0.11</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>0.30 (0.17-0.50)</td>
<td>0.032</td>
</tr>
<tr>
<td>Prehospital ECG, %</td>
<td>1.44 (0.68-3.06)</td>
<td>0.38</td>
</tr>
<tr>
<td>Differential driving time, per 1 minute increment</td>
<td>0.97 (0.96-0.99)</td>
<td>0.036</td>
</tr>
<tr>
<td>Chief complaint of chest pain, %</td>
<td>1.27 (0.64-2.53)</td>
<td>0.48</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; OR, odds ratio; All other abbreviations can be found in Table 1.

Table 3. Comparison of Treatment Delay.

<table>
<thead>
<tr>
<th>Time interval, minutes (IQR)</th>
<th>Transport to non-PCI Hospital</th>
<th>Transport to PCI Hospital</th>
<th>Difference in Time, non-PCI vs. PCI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMC to arrival at first hospital†</td>
<td>26 (19-33)</td>
<td>42 (32-55)</td>
<td>16 min</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FMC to arrival at PCI center</td>
<td>137 (109-199)</td>
<td>42 (32-55)</td>
<td>95 min</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FMC to PCI, among PCI only treated patients</td>
<td>161 (124-220)</td>
<td>93 (76-115)</td>
<td>68 min</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FMC to PCI, all patients</td>
<td>179 (137-287)</td>
<td>94 (76-116)</td>
<td>85 min</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FMC to any reperfusion therapy‡</td>
<td>124 (67-179)</td>
<td>93 (75-115)</td>
<td>31 min</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Interim hospital arrival to fibrinolytic therapy (door-to-needle time)</td>
<td>30 (19-50)</td>
<td>---</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FMC, first medical contact; All other abbreviations can be found in Table 1.
†Difference in time between non-PCI and PCI was calculated as the median difference between median times.
‡First hospital means the interim hospital for the non-bypass group and the PCI-center for the bypass group.
§Reperfusion therapy means fibrinolysis or PCI—whichever came first.
**Table 4.** Comparison of Adherence to Guideline Goals for Primary PCI and Clinical Inhospital Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Transport to Non-PCI Hospital N=462</th>
<th>Unadjusted Transport to PCI Hospital N=826</th>
<th>OR (95% CI) for PCI vs. Non-PCI p-value</th>
<th>Adjusted OR (95% CI) for PCI vs. Non-PCI p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence to guideline goals for primary PCI*</td>
<td>21.5% (19.5% among non-missing)</td>
<td>46.0% (52.8% among non-missing)</td>
<td>3.11 (2.22 - 4.35) &lt;0.0001</td>
<td>2.82 (1.96-4.07) 0.005</td>
</tr>
<tr>
<td>Death</td>
<td>43 (9.3%)</td>
<td>52 (6.3%)</td>
<td>0.65 (0.43 - 0.99) 0.047</td>
<td>0.87 (0.68-1.11) 0.34</td>
</tr>
<tr>
<td>Death, stroke, or shock</td>
<td>72 (15.6%)</td>
<td>94 (11.4%)</td>
<td>0.70 (0.50 - 0.97) 0.031</td>
<td>0.86 (0.62-1.18) 0.41</td>
</tr>
</tbody>
</table>

Abbreviations can be found in Table 1.

*Adherence to guideline goals for primary PCI is defined as <90 minutes from first-medical contact to PCI for bypass patients and <120 minutes for non-bypass patients.*
Figure Legends:

**Figure 1.** Patient Selection. This figure displays patient selection inclusion and exclusion criteria, and the final study population.

**Figure 2.** Map of North Carolina, United States. This figure displays types of transport and center capabilities. A red man symbolizes a patient who was transported by EMS directly to a PCI center. A blue man symbolized a patient who was transported to the nearest hospital (non-PCI center), and a red heart identifies PCI centers.

**Figure 3.** Driving Times. This figure displays the relationship between estimated Google driving time from incident address to the nearest non-PCI center, actual driving time from incident address to the PCI center, and the probability of making the guideline goal of <90 minutes from FMC-to-PCI among patients transported directly to a PCI center. The figure illustrates the relationship between differential driving time (left y-axis in conjunction with the x-axis showing estimated Google driving time to the nearest non-PCI hospital and the actual driving time to the PCI center, respectively) and the probability of reaching the guideline goal.
STEMI patients in RACE (06/2008 to 09/2009) linked with PreMIS
N=6010

Excluded:
1) Patients who were transferred from an interim hospital who transported themselves to that first hospital (n=1958)
2) Misclassification:
   i. Patients going from incident address to first hospital who bypassed a PCI center (n=11)
   ii. Data entry error regarding EMS run destination (n=11)

Patients transported directly from incident address to PCI center or non-PCI center by EMS
N=4030

Excluded:
1) Patients transported by EMS from the incident address to a PCI-center with a differential driving time <10 min compared with nearest non-PCI center (n=2171)
2) Patients who were transported by helicopter (n=80)
3) Patients transferred from interim hospital to PCI center for whom we had no first EMS-run information (N=491)

Patients “eligible” for bypassing a non-PCI center
N=1288

Bypass group
N=826

Non-Bypass group
N=462

Figure 1
Figure 3
The Impact of a Statewide Pre-Hospital STEMI Strategy to Bypass Hospitals without Percutaneous Coronary Intervention Capability on Treatment Times
Emil L. Fosbol, Christopher B. Granger, James G. Jollis, Lisa Monk, Li Lin, Barbara L. Lytle, Ying Xian, J. Lee Garvey, Greg Mears, Claire C. Corbett, Eric D. Peterson and Seth W. Glickman

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