Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association®

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

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://circ.ahajournals.org/content/127/5/604

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

Emil L. Fosbol, MD, PhD; Christopher B. Granger, MD; James G. Jollis, MD; Lisa Monk, RN, MSN; Li Lin, MS; Barbara L. Lytle, MS; Ying Xian, MD, PhD; J. Lee Garvey, MD; Greg Mears, MD; Claire C. Corbett, MMS, NREMT-P; Eric D. Peterson, MD, MPH; Seth W. Glickman, MD

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 the adherence of emergency medical services to this STEMI protocol, as well as subsequent associations with patient treatment times and outcomes by linking data from the Acute Coronary Treatment and Intervention Outcomes Network Registry®—Get With the Guidelines™ and a statewide emergency medical services data system from June 2008 to September 2010 for all patients with STEMI. 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 patients with STEMI, 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 times between first medical contact and PCI within guideline recommendations.

Conclusions—We found that patients who were sent directly to a PCI center had significantly shorter time to reperfusion. (***Circulation***. 2013;127:604-612.)

Key Words: EMS transport ■ reperfusion time ■ STEMI

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 capable of performing PCI.[1,2]

Clinical Perspective on p 612

Regional and statewide systems for rapid STEMI care are being developed[3–6] 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 hospital[12] and only 11% have door-in–door-out times less than 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 prehospital care protocols that encouraged EMS to bypass non-PCI facilities when transporting patients with STEMI, 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 data collected by EMS

statewide 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 patients with STEMI 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 taken first to a non-PCI facility and then subsequently transferred.

Methods

Design and Data Sources

We identified all patients with STEMI in North Carolina who arrived at the final destination hospital (a RACE PCI center) by EMS using RACE data from June 1, 2008, to September 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.[16] In brief, 4 key variables were used for the linkage: (1) date of birth; (2) sex; (3) destination arrival time (within a 5-hour time window); and (4) date and location of destination. Of all patients in the RACE database who were transported by EMS, 69% were linked successfully with PreMIS, with good generalizability (similar baseline characteristics and similar in-hospital mortality).[16] For patients who were transferred we used the PreMIS database to identify multiple EMS runs for the same patient to have data for the entire continuum of care.

The data foundation for the RACE program is the National Cardiovascular Data Registry® 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.[17] All PCI and non-PCI hospitals in North Carolina participate in the RACE program, and data are collected using the National Cardiovascular Data Registry data collection tool.[18]

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 delivery of EMS care. In 2008, PreMIS collected 1.2 million EMS records, representing virtually 100% of the EMS events and >900,000 patient contacts in North Carolina obtained from >540 licensed EMS agencies.[19] Our study includes data from 178 different EMS agencies that transported a patient with STEMI to 1 of the 21 PCI hospitals in our analysis. The PreMIS dataset is based on a national standardized dataset called the National EMS Information System, 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 prehospital 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 ECG, patients generally were transported to local hospitals.

The incident location (address) for each patient with STEMI was obtained from PreMIS. By accessing Google Maps via the Internet-based uniform resource locator with SAS statistical software,[20] we obtained the Google driving time from the incident address (ie, STEMI) to all acute general medical hospitals in North Carolina.

Hospitals were classified as PCI capable or not PCI capable based on available RACE and American Hospital Association data. Drive times were classified according to hospitals' 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 3 groups: (1) those who bypassed a closer non-PCI hospital and went directly to a PCI hospital (minimum differential driving time of 10 minutes); (2) those who were taken first 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 included only 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 transported themselves to the first hospital. Patient selection is shown in Figure 1.

Endpoints

We first examined which patient-level factors (eg, demographics, medical history, presenting complaint) were associated with the decision by EMS 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. FMC was defined as the time of EMS personnel arrival at the patient's location. Time from FMC to reperfusion was assessed using the RACE data as collected via ACTION Registry-GWTG. Adherence to guideline goals was defined for those who were treated with primary PCI as an 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.[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 2 groups.

Statistics

We described the characteristics of the sample patients 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 χ^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 accounting for data dependency within hospital referral regions in North Carolina, which were derived from the Dartmouth Atlas[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 arrival at the PCI hospital, time from FMC to reperfusion therapy (PCI or fibrinolysis), time from FMC to PCI, and time from arrival at the interim hospital 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 (ie, 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; P=0.32; 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 χ^2 tests for direct comparisons as well as generalized estimating equations modeling for the adjusted effect of bypassing. We used a previously
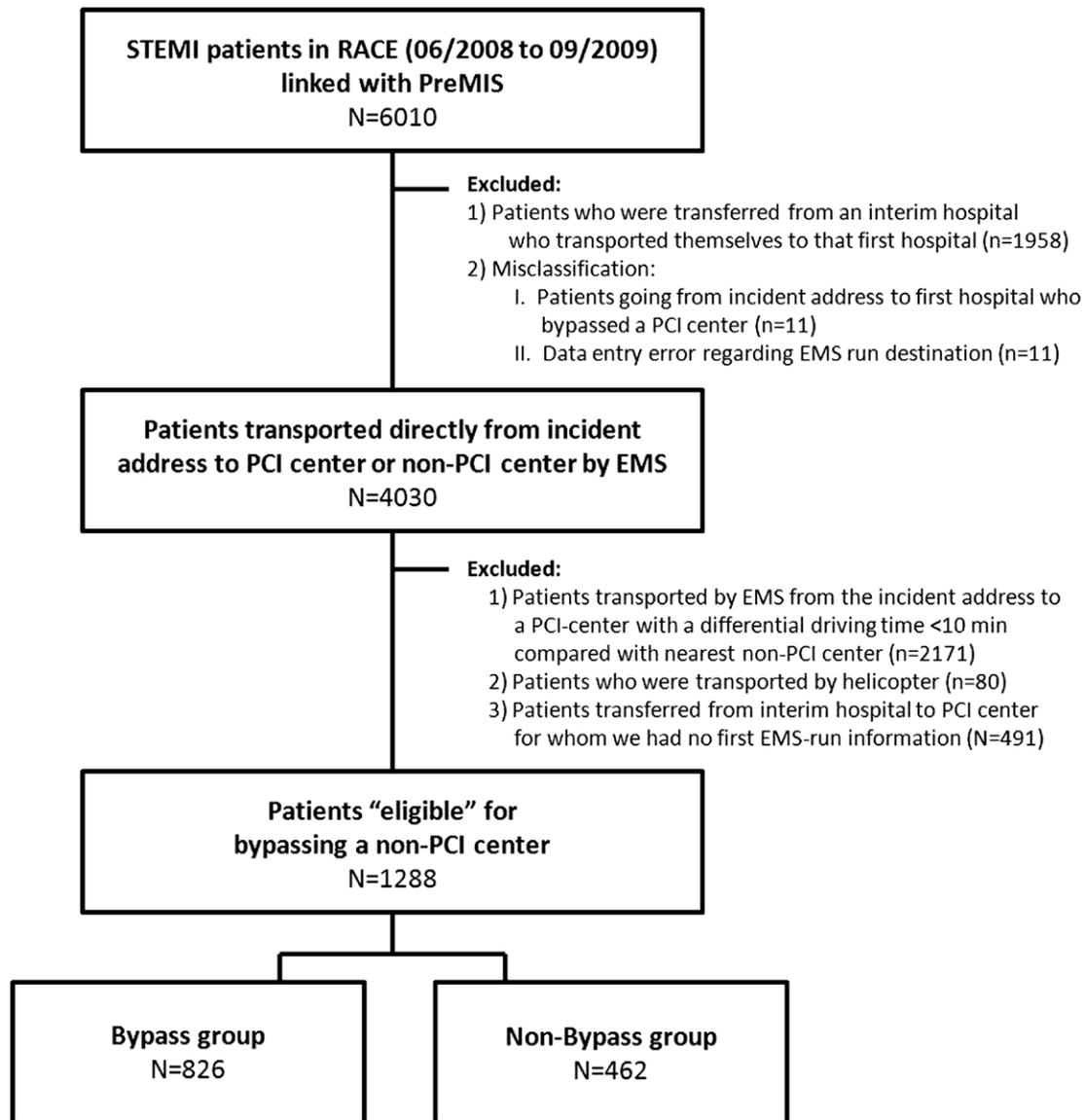
Figure 1. Patient selection indicating inclusion and exclusion criteria and the final study population. EMS indicates emergency medical services; PCI, percutaneous intervention; PreMIS, Prehospital Medical Information System; RACE, Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments; and STEMI, ST-segment elevation myocardial infarction.

derived ACTION Registry-GWTG mortality model to select variables for adjustment.[22] We included the following variables: age, sex, 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 sex, age, and cardiac arrest. $P<0.05$ was considered statistically significant. We also performed sensitivity analyses among patients without prehospital cardiac arrest or shock and with a prehospital ECG recorded in the dataset. All analyses were performed using SAS statistical software (SAS 9.2, SAS Institute, Cary, NC).

Results

A total of 6010 patients with STEMI from the RACE database between June 2008 and September 2010 were linked successfully with PreMIS and were assessed for inclusion in this study. After applying selection criteria we identified 1288

patients eligible for direct transport to a PCI hospital, of whom 826 (64%) were included in the direct transport to a PCI hospital group and 462 (36%) were included 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 in 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 (ie, fibrinolysis or PCI); however, substantially
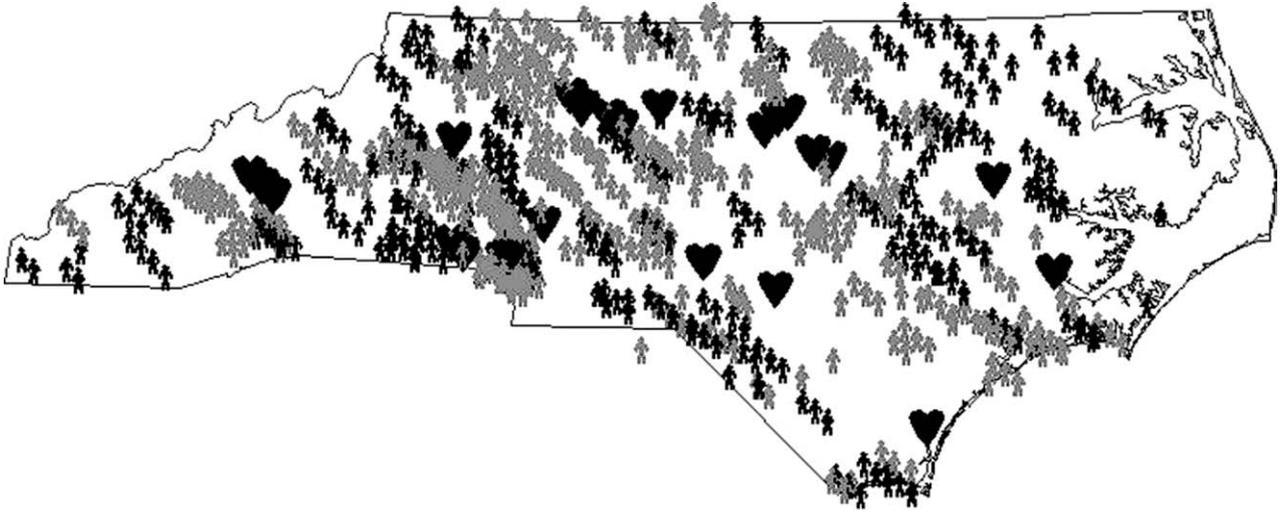
Figure 2. Map of North Carolina displaying types of transport and center capabilities. A gray man symbolizes a patient who was transported by EMS directly to a PCI-capable center. A black man symbolizes a patient who was transported to the nearest hospital (non-PCI center), and a heart identifies PCI centers. EMS indicates emergency medical services; and PCI, percutaneous intervention.

more patients were treated with fibrinolysis in the group that was first brought to a non-PCI facility. All patients eventually were taken to a PCI center, yet 35% of those first brought to a non-PCI hospital received fibrinolysis, and 26% received both fibrinolysis and PCI. Overall, use of fibrinolysis was low in the group that was transported directly to a PCI facility (only 8 patients).

Table 1.   Patient Characteristics at Presentation, by Group

	Transport to Non-PCI Hospital (n=462)	Transport to PCI Hospital (n=826)	P value
Median age (IQR), y	61 (51–71)	60 (52–71)	0.79
Women, %	34.9	31.4	0.20
White, %	81.0	87.8	0.0009
Insurance type, %			0.10
None	17.5	16.8	
Private	40.3	35.0	
Nonprivate	42.2	48.2	
History, %			
Myocardial infarction	21.2	24.8	0.15
Hypertension	68.1	64.4	0.18
Diabetes	22.8	22.9	0.97
Dyslipidemia	48.0	56.0	0.007
Heart failure	6.2	4.6	0.21
Smoking (current/recent)	51.3	50.9	0.89
PCI	19.5	26.6	0.005
CABG	6.2	7.7	0.32
At presentation, %			
Shock	6.4	7.6	0.07
Cardiac arrest	9.5	2.8	<0.0001
Prehospital ECG	64.9	79.3	<0.0001
Chief complaint of chest pain	71.7	81.1	<0.0001
Reperfusion strategy, %			
Fibrinolysis only	9.3	0.4	<0.0001
PCI only	54.3	89.8	<0.0001
PCI and/or fibrinolysis	89.2	90.8	0.35

CABG indicates coronary artery bypass graft; IQR, interquartile range; and PCI, percutaneous coronary intervention.

Factors Associated with the Decision to Bypass Non-PCI Centers

Odds ratios [ORs] 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 taken first to a geographically closer non-PCI hospital (median, 42 minutes versus 26 minutes). Time from FMC to reperfusion (PCI or fibrinolysis) and from 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. Among those patients taken to a PCI hospital, 46.0% reached the goal of <90 minutes from FMC to PCI, whereas only 21.5% of those first taken to a non-PCI hospital reached the goal of <120 minutes from FMC to PCI (adjusted OR for reaching guideline goals was 2.82 for direct to PCI hospital versus non-PCI hospital; 95% CI, 1.96–4.07; P=0.005). 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 among those taken directly to a PCI facility. 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

Table 2.   Multivariable Adjusted Factors Associated with Direct Transport to PCI Hospital

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

CABG indicates coronary artery bypass graft; OR, odds ratio; and PCI, percutaneous coronary intervention.

guideline goal. Our results suggest that even with actual driving times of <45 minutes, the majority of patients still have times of FMC to PCI of <90 minutes. The probability of making the goal of <90 minutes from FMC to PCI drops to <20% when the actual driving time was >60 minutes.

For purposes of this sensitivity analyses, we examined patients without prehospital cardiac arrest or shock and with a prehospital ECG (269 patients taken to a nearby non-PCI hospital and 582 patients taken directly to a PCI center). The results were similar, showing a median time from FMC to arrival at the PCI center of 43 minutes (IQR, 33–57) among those taken directly to a PCI center versus 135 minutes (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 minutes (IQR, 77–117) among those who were transported directly versus 152 minutes (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 versus 116 minutes).

For the overall analysis, we excluded patients who were taken directly to a PCI center when it was the closest facility (ie, EMS bypass was not a treatment option [<10 minutes differential driving time; n=2171]). For purposes of comparison, 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 versus 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 in-hospital outcomes according to group (direct to PCI hospital; ie, EMS bypass versus transport to a non-PCI hospital). Overall unadjusted in-hospital mortality and a composite outcome of in-hospital mortality, shock, or stroke were lower among those transported directly to PCI hospitals versus non-PCI hospitals (6.3% versus 9.3% and 11.4% versus 15.6%, respectively). ORs for the adjusted associations between direct transport to a PCI hospital relative to a non-PCI hospital and the examined outcomes also are 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 in-hospital outcomes (OR for death, 0.87; 95% CI, 0.68–1.11; OR for composite outcome, 0.86; 95% CI, 0.62–1.18).

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

Table 3.   Comparison of Treatment Delay

	Transport to Non-PCI Hospital (min [IQR])	Transport to PCI Hospital (min [IQR])	Difference in Time, Non-PCI vs. PCI* (min)	*P* value
FMC to arrival at first hospital†	26 (19–33)	42 (32–55)	16	<0.0001
FMC to arrival at PCI center	137 (109–199)	42 (32–55)	95	<0.0001
FMC to PCI among patients treated with only PCI	161 (124–220)	93 (76–115)	68	<0.0001
FMC to PCI in all patients	179 (137–287)	94 (76–116)	85	<0.0001
FMC to any reperfusion therapy‡	124 (67–179)	93 (75–115)	31	<0.0001
Interim hospital arrival to fibrinolytic therapy (door-to-needle time)	30 (19–50)	—	—	—

IQR indicates interquartile range; FMC, first medical contact; and PCI, percutaneous coronary intervention.

*Difference in time between non-PCI and PCI was calculated as the median difference between median times.

†First hospital indicates the interim hospital for the nonbypass group and the PCI center for the bypass group.

‡Reperfusion therapy refers to fibrinolysis or PCI, whichever came first.
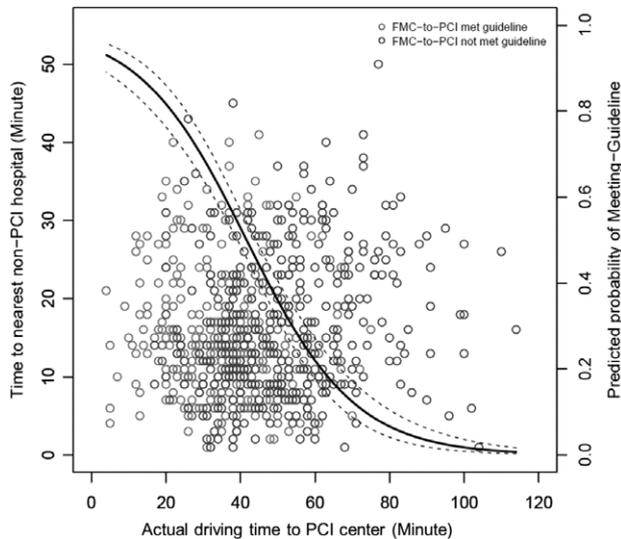
Figure 3. Driving times. The relationship between the estimated Google driving time from incident address to the nearest non-PCI center, actual driving time from incident address to the PCI center, and the probability of making the guideline goal of <90 minutes from FMC to PCI among patients transported directly to a PCI center. The graph 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.

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% mortality 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 patients with 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 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 patients with STEMI who are 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 sent to non-PCI centers first, those patients who were sent directly to PCI hospitals had faster reperfusion times and were almost 3 times more likely to reach the target guideline of <90 minutes from FMC to PCI. Finally, the decision to bypass a non-PCI center was associated with better overall in-hospital 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,[14] especially when cognizant of the substantial delays that occur in the interhospital setting.[10] Wang et al[13] 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. Similarly, the RACE program showed that only 13% of transfer patients in North Carolina reached the 90-minute metric from the door of the first hospital to PCI[12]; therefore, EMS bypass seems to be a practical approach to solving the inherent time delays associated with interhospital 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,[23] and is the preferred treatment strategy for high-risk patients (eg, those with cardiogenic shock).[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.[25] Nevertheless, patient characteristics and hospital-specific primary PCI-related delay should be considered before choosing a reperfusion strategy.[26,27] In a large analysis of transfer patients with STEMI, Pinto et al[28] recently showed 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. 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

Table 4. Comparison of Adherence to Guideline Goals for Primary PCI and Clinical In-hospital Outcomes

	Unadjusted				Adjusted	
	Transport to Non-PCI Hospital (n=462)	Transport to PCI Hospital (n=826)	OR (95% CI) for PCI vs. Non-PCI	*P* value	OR (95% CI) for PCI vs. Non-PCI	*P* value
Adherence to guideline goals for primary PCI*	21.5% (19.5% among nonmissing)	46.0% (52.8% among nonmissing)	3.11 (2.22–4.35)	<0.0001	2.82 (1.96–4.07)	0.005
Death	43 (9.3%)	52 (6.3%)	0.65 (0.43–0.99)	0.047	0.87 (0.68–1.11)	0.34
Death, stroke, or shock	72 (15.6%)	94 (11.4%)	0.70 (0.50–0.97)	0.031	0.86 (0.62–1.18)	0.41

OR indicates odds ratio; and PCI, percutaneous coronary intervention.

*Adherence to guideline goals for primary PCI is defined as <90 min from first medical contact to PCI for bypass patients and <120 min for nonbypass patients.

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 fewer 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.[29,30]

Hard clinical in-hospital 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; this 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 in-hospital 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 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 toward; this method already has been implemented successfully in other countries.[31,32] One exception to this goal could be in patients who are very unstable (ie, those in cardiac arrest); it might be more appropriate to take these patients to the nearest hospital (PCI capable or not), depending on the capabilities of the closest hospital (eg, therapeutic hypothermia, circulatory assistance) 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.[33] Nevertheless, these exceptions are relatively small, and it seems there is 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 went to a non-PCI facility first were given fibrinolysis before being transferred for PCI to a PCI hospital. As demonstrated by the North Carolina RACE project, the standardization of the destination and treatment plans of EMS helps facilitate better coordination of care 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 because of a lack of equipment or paramedic training), STEMI missed during 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 prehospital ECG. One would expect that more patients would be taken directly to PCI centers instead of closer non-PCI centers if prehospital 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, unmeasured confounding, or both. Second, our data included only 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 PCI capabilities of the hospital), 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 because these groups of patients are known to have worse prognosis (eg, patients with intracranial hemorrhage or other complications after fibrinolysis). 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 previously have shown that our linkage did not introduce systematic bias and that the overall cohort of patients with STEMI is representative of other STEMI cohorts.[16] Finally, some data were 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 2 different sources (ie, PreMIS and RACE), therefore providing more complete information than either data source in isolation. In addition, 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 in-hospital 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 patients with STEMI 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.

Acknowledgments

Sources of Funding

Disclosures

References

1. Jacobs AK, Antman EM, Faxon DP, Gregory T, Solis P. Development of systems of care for ST-elevation myocardial infarction patients: executive summary. *Circulation*. 2007;116:217–230.

2. Solis P, Amsterdam EA, Bufalino V, Drew BJ, Jacobs AK. Development of systems of care for ST-elevation myocardial infarction patients: policy recommendations. *Circulation*. 2007;116:e73–e76.

3. Antman EM, Hand M, Armstrong PW, Bates ER, Green LA, Halasyamani LK, Hochman JS, Krumholz HM, Lamas GA, Mullany CJ, Pearle DL, Sloan MA, Smith SC Jr, Anbe DT, Kushner FG, Ornato JP, Jacobs AK, Adams CD, Anderson JL, Buller CE, Creager MA, Ettinger SM, Halperin JL, Hunt SA, Lytle BW, Nishimura R, Page RL, Riegel B, Tarkington LG, Yancy CW; 2004 Writing Committee Members. 2007 Focused Update of the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the Canadian Cardiovascular Society endorsed by the American Academy of Family Physicians: 2007 Writing Group to Review New Evidence and Update the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction, Writing on Behalf of the 2004 Writing Committee. *Circulation*. 2008;117:296–329.

4. Van de Werf F, Bax J, Betriu A, Blomstrom-Lundqvist C, Crea F, Falk V, Filippatos G, Fox K, Huber K, Kastrati A, Rosengren A, Steg PG, Tubaro M, Verheugt F, Weidinger F, Weis M. Management of acute myocardial infarction in patients presenting with persistent ST-segment elevation: the Task Force on the Management of ST-segment Elevation Acute Myocardial Infarction of the European Society of Cardiology. *Eur Heart J*. 2008;29:2909–2945.

5. Henry TD, Sharkey SW, Burke MN, Chavez IJ, Graham KJ, Henry CR, Lips DL, Madison JD, Menssen KM, Mooney MR, Newell MC, Pedersen WR, Poulose AK, Traverse JH, Unger BT, Wang YL, Larson DM. A regional system to provide timely access to percutaneous coronary intervention for ST-elevation myocardial infarction. *Circulation*. 2007;116:721–728.

6. Jacobs AK. Regional systems of care for patients with ST-elevation myocardial infarction: being at the right place at the right time. *Circulation*. 2007;116:689–692.

7. De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: every minute of delay counts. *Circulation*. 2004;109:1223–1225.

8. De Luca G, van 't Hof AW, de Boer MJ, Ottervanger JP, Hoorntje JC, Gosselink AT, Dambrink JH, Zijlstra F, Suryapranata H. Time-to-treatment significantly affects the extent of ST-segment resolution and myocardial blush in patients with acute myocardial infarction treated by primary angioplasty. *Eur Heart J*. 2004;25:1009–1013.

9. Nallamothu BK, Bates ER. Percutaneous coronary intervention versus fibrinolytic therapy in acute myocardial infarction: is timing (almost) everything? *Am J Cardiol*. 2003;92:824–826.

10. Wang TY, Nallamothu BK, Krumholz HM, Li S, Roe MT, Jollis JG, Jacobs AK, Holmes DR, Peterson ED, Ting HH. Association of door-in to door-out time with reperfusion delays and outcomes among patients transferred for primary percutaneous coronary intervention. *JAMA*. 2011;305:2540–2547.

11. American Heart Association. Mission Lifeline [homepage]. Available at: http://www.heart.org/HEARTORG/HealthcareResearch/MissionLifeline-HomePage/Mission-Lifeline-Home-Page_UCM_305495_SubHomePage.jsp. Accessed April 1, 2012.

12. Jollis JG, Roettig ML, Aluko AO, Anstrom KJ, Applegate RJ, Babb JD, Berger PB, Bohle DJ, Fletcher SM, Garvey JL, Hathaway WR, Hoekstra JW, Kelly RV, Maddox WT Jr, Shiber JR, Valeri FS, Watling BA, Wilson BH, Granger CB; Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments (RACE) Investigators. Implementation of a statewide system for coronary reperfusion for ST-segment elevation myocardial infarction. *JAMA*. 2007;298:2371–2380.

13. Wang TY, Nallamothu BK, Krumholz HM, Li S, Roe MT, Jollis JG, Jacobs AK, Holmes DR, Peterson ED, Ting HH. Association of door-in to door-out time with reperfusion delays and outcomes among patients transferred for primary percutaneous coronary intervention. *JAMA*. 2011;305:2540–2547.

14. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, Chambers CE, Ellis SG, Guyton RA, Hollenberg SM, Khot UN, Lange RA, Mauri L, Mehran R, Moussa ID, Mukherjee D, Nallamothu BK, Ting HH. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. *Circulation*. 2011;124:e574–e651.

15. Jollis JG, Mehta RH, Roettig ML, Berger PB, Babb JD, Granger CB. Reperfusion of acute myocardial infarction in North Carolina emergency departments (RACE): study design. *Am Heart J*. 2006;152:851.e1–851.e11.

16. Fosbol EL, Granger C, Lin L, Lytle BL, Mears G, Jollis JG, Peterson ED, Glickman S. Using novel emergency medical services data-linkage to evaluate the timing and quality of pre-hospital ST-elevation myocardial infarction care [American Heart Association Scientific Sessions 2011 Abstract 16674]. *Circulation*. 2011;124:A16674. Abstract. Published online November 22, 2011. Available at: http://circ.ahajournals.org/cgi/content/meeting_abstract/124/21_MeetingAbstracts/A16674. Accessed December 31, 2012.

17. Peterson ED, Dai D, DeLong ER, Brennan JM, Singh M, Rao SV, Shaw RE, Roe MT, Ho KK, Klein LW, Krone RJ, Weintraub WS, Brindis RG, Rumsfeld JS, Spertus JA; NCDR Registry Participants. Contemporary mortality risk prediction for percutaneous coronary intervention: results from 588,398 procedures in the National Cardiovascular Data Registry. *J Am Coll Cardiol*. 2010;55:1923–1932.

18. Jollis JG, Al-Khalidi HR, Monk L, Roettig ML, Garvey JL, Aluko AO, Wilson BH, Applegate RJ, Mears G, Corbett CC, Granger CB; Regional Approach to Cardiovascular Emergencies (RACE) Investigators. Expansion of a regional ST-segment-elevation myocardial infarction system to an entire state. *Circulation*. 2012;126:189–195.

19. Mears GD, Pratt D, Glickman SW, Brice JH, Glickman LT, Cabañas JG, Cairns CB. The North Carolina EMS Data System: a comprehensive integrated emergency medical services quality improvement program. *Prehosp Emerg Care*. 2010;14:85–94.

20. Zdeb M. Driving distances and times using SAS® and Google maps. Available at: http://support.sas.com/resources/papers/proceedings10/050-2010.pdf. Accessed April 6, 2012.

21. Wennberg J. *The Dartmouth Atlas of Health Care in the United States*. Chicago, IL: American Hospital Publishing Inc.; 1996.

22. Chin CT, Chen AY, Wang TY, Alexander KP, Mathews R, Rumsfeld JS, Cannon CP, Fonarow GC, Peterson ED, Roe MT. Risk adjustment for in-hospital mortality of contemporary patients with acute myocardial infarction: the Acute Coronary Treatment and Intervention Outcomes Network (ACTION) Registry-Get With the Guidelines (GWTG) acute myocardial infarction mortality model and risk score. *Am Heart J*. 2011;161:113–122.e2.

23. Andersen HR, Nielsen TT, Rasmussen K, Thuesen L, Kelbaek H, Thayssen P, Abildgaard U, Pedersen F, Madsen JK, Grande P, Villadsen AB, Krusell LR, Haghfelt T, Lomholt P, Husted SE, Vigholt E, Kjaergard HK, Mortensen LS; DANAMI-2 Investigators. A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. *N Engl J Med*. 2003;349:733–742

24. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, Chambers CE, Ellis SG, Guyton RA, Hollenberg SM, Khot UN, Lange RA, Mauri L, Mehran R, Moussa ID, Mukherjee D, Nallamothu BK, Ting HH. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the

Society for Cardiovascular Angiography and Interventions. *Circulation*. 2011;124:e574–e651.

25. Lee PY, Alexander KP, Hammill BG, Pasquali SK, Peterson ED. Representation of elderly persons and women in published randomized trials of acute coronary syndromes. *JAMA*. 2001;286:708–713.

26. Pinto DS, Kirtane AJ, Nallamothu BK, Murphy SA, Cohen DJ, Laham RJ, Cutlip DE, Bates ER, Frederick PD, Miller DP, Carrozza JP Jr, Antman EM, Cannon CP, Gibson CM. Hospital delays in reperfusion for ST-elevation myocardial infarction: implications when selecting a reperfusion strategy. *Circulation*. 2006;114:2019–2025.

27. Studnek JR, Garvey L, Blackwell T, Vandeventer S, Ward SR. Association between prehospital time intervals and ST-elevation myocardial infarction system performance. *Circulation*. 2010;122:1464–1469.

28. Pinto DS, Frederick PD, Chakrabarti AK, Kirtane AJ, Ullman E, Dejam A, Miller DP, Henry TD, Gibson CM; National Registry of Myocardial Infarction Investigators. Benefit of transferring ST-segment-elevation myocardial infarction patients for percutaneous coronary intervention compared with administration of onsite fibrinolytic declines as delays increase. *Circulation*. 2011;124:2512–2521.

29. Krumholz HM, Herrin J, Miller LE, Drye EE, Ling SM, Han LF, Rapp MT, Bradley EH, Nallamothu BK, Nsa W, Bratzler DW, Curtis JP. Improvements in door-to-balloon time in the United States, 2005 to 2010. *Circulation*. 2011;124:1038–1045.

30. Studnek JR, Garvey L, Blackwell T, Vandeventer S, Ward SR. Association between prehospital time intervals and ST-elevation myocardial infarction system performance. *Circulation*. 2010;122:1464–1469.

31. Terkelsen CJ, Sørensen JT, Maeng M, Jensen LO, Tilsted HH, Trautner S, Vach W, Johnsen SP, Thuesen L, Lassen JF. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA*. 2010;304:763–771.

32. Sørensen JT, Terkelsen CJ, Nørgaard BL, Trautner S, Hansen TM, Bøtker HE, Lassen JF, Andersen HR. Urban and rural implementation of prehospital diagnosis and direct referral for primary percutaneous coronary intervention in patients with acute ST-elevation myocardial infarction. *Eur Heart J*. 2011;32:430–436.

33. Donnino MW, Rittenberger JC, Gaieski D, Cocchi MN, Giberson B, Peberdy MA, Abella BS, Bobrow BJ, Callaway C. The development and implementation of cardiac arrest centers. *Resuscitation*. 2011;82:974–978.

CLINICAL PERSPECTIVE

The Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments (RACE) program was a statewide regionalization program to improve ST-segment elevation myocardial infarction (STEMI) care that began in 2006. In 2008, RACE and the North Carolina Office of Emergency Medical Services (EMS) implemented prehospital care protocols that encouraged EMS to bypass non-percutaneous coronary intervention (PCI) facilities when transporting patients with STEMI, even if a non-PCI-capable hospital was closer. Here we sought to examine whether these protocols have improved patient treatment times and outcomes. We linked data from the ACTION Registry-GWTG to a statewide EMS data system, Prehospital Medical Information System , and found that two thirds of eligible patients with STEMI were taken directly to a PCI center, bypassing a geographically closer non-PCI center. This approach was associated with markedly faster reperfusion times and a higher likelihood of treatment guidelines being met. Our study results prove that, when logistically feasible, EMS should transport patients with STEMI directly to the nearest PCI-capable hospital, even if it means bypassing a geographically closer non-PCI-capable hospital. We need to encourage this protocol in the remaining one third of patients with the hope of improving treatment times and creating better outcomes for more patients.