ORIGINAL CONTRIBUTION

Implementation of a Statewide System for Coronary Reperfusion for ST-Segment Elevation Myocardial Infarction

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Context Despite 2 decades of evidence demonstrating benefits from prompt coronary reperfusion, registries continue to show that many patients with ST-segment elevation myocardial infarction (STEMI) are treated too slowly or not at all

Objective To establish a statewide system for reperfusion, as exists for trauma care, to overcome systematic barriers

Design and Setting A quality improvement study that examined the change in speed and rate of coronary reperfusion after system implementation in 5 regions in North Carolina involving 65 hospitals and associated emergency medical systems (10 percutaneous coronary intervention [PCI] hospitals and 55 non-PCI hospitals)

Patients A total of 1164 patients with STEMI (579 preintervention and 585 postintervention) eligible for reperfusion were treated at PCI hospitals (median age 61 years, 31% women, 4% Killip class III or IV) A total of 925 patients with STEMI (518 preintervention and 407 postintervention) were treated at non-PCI hospitals (median age 62 years, 32% women, 4% Killip class III or IV)

Interventions Early diagnosis and the most expedient coronary reperfusion method at each point of care: emergency medical systems, emergency department, catheterization laboratory, and transfer Within 5 regions, PCI hospitals agreed to provide single-call catheterization laboratory activation by emergency medical personnel, accept patients regardless of bed availability, and improve STEMI care for the entire region regardless of hospital affiliation.

Main Outcome Measures Reperfusion times and rates 3 months before (July to September 2005) and 3 months after (January to March 2007) a year-long implementation

Results Median reperfusion times significantly improved according to first door-to-device (presenting to PCI hospital 85 to 74 minutes, $P < .001$; transferred to PCI hospital 165 to 128 minutes, $P < .001$), door-to-needle in non-PCI hospitals (35 to 29 minutes, $P = .002$), and door-in to door-out for patients transferred from non-PCI hospitals (120 to 71 minutes, $P < .001$) Nonreperfusion rates were unchanged (15%) in non-PCI hospitals and decreased from 23% to 11% in the PCI hospitals For patients presenting to or transferred to PCI hospitals, clinical outcomes including death, cardiac arrest, and cardiogenic shock did not significantly change following the intervention

Conclusions A statewide program focused on regional systems for reperfusion for STEMI can significantly improve quality of care Further research is needed to ensure that programs that result in improved application of reperfusion treatments will lead to reductions in mortality and morbidity from STEMI.

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CORONARY HEART DISEASE, including myocardial infarction as its acute manifestation, is the leading cause of death worldwide.[1] In the United States, 3 times as many adults die from acute myocardial infarction as from motor vehicle crashes.[2] Similar to trauma, ST-segment elevation myocardial infarction (STEMI) is a potentially lethal condition for which specific therapies, administered rapidly, reduce mortality and morbidity. Despite more than 2 decades of clinical trial evidence demonstrating significant benefits from prompt coronary reperfusion, regis-

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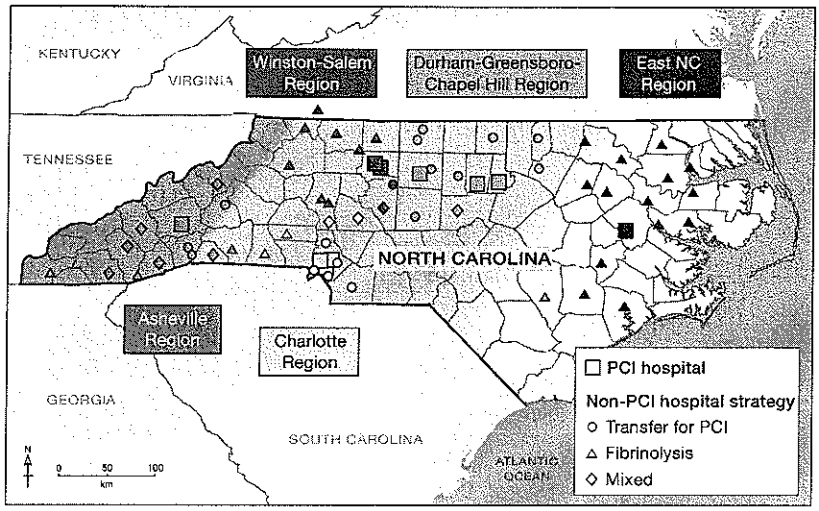
Figure 1. RACE Regions and Hospitals According to Reperfusion System



RACE indicates Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments; PCI, percutaneous coronary intervention. Color gradient in map indicates major topographical differences from mountains in the west to coastal plains in the east. Mixed non-PCI hospital strategy selected fibrinolysis or transfer for PCI depending on whether expedient transfer was possible according to local weather and equipment availability.

tries continue to show that most patients are still treated too slowly for reperfusion to be of maximal benefit, and many are not treated at all.[3-5] The reasons for this are largely related to systematic barriers.[6-9]

We hypothesized that the establishment of a coordinated statewide system of reperfusion therapy for STEMI (Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments [RACE] study), as exists for trauma, would overcome systematic barriers and both decrease delays in administering reperfusion therapy and increase the frequency with which reperfusion was provided to eligible patients. We focused on the coordination of each aspect of care from the initial emergency medical response to reperfusion itself, be it fibrinolytic therapy or primary percutaneous coronary intervention (PCI), whichever was most appropriate for a given setting. An important focus was to reduce the time to primary PCI for patients transferred from hospitals that did not perform primary PCI (non-PCI hospitals) to those that offered this procedure (PCI hospitals), a parameter not included in current Centers for Medicare & Medicaid Services (CMS) and Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) performance measures, which include reperfusion times only for patients presenting to the treating hospital.[10,11]

METHODS

The design and methods for this study have been previously published.[12] This quality improvement study had institutional review board approval for analyses and publication of the findings. To collect data from all patients without need for informed consent, protected health information was removed before data collection, and the study was monitored by an independent oversight board.

Five regions in North Carolina were selected covering approximately two-thirds of the state's hospitals and population to provide broad geographic distribution, include both rural and urban populations, and follow established hospital networks and patient referral patterns (FIGURE 1). Each region had physician representation in the North Carolina chapter of the American College of Cardiology, which supported this quality improvement program, and from emergency medicine at the participating regional PCI hospitals. These regions also had at least 1 full-time RACE nurse regional coordinator primarily dedicated to this quality improvement initiative.

Participating Hospitals

Within each region, all hospitals that routinely performed primary PCI agreed to participate according to the following requirements: each had to have a system by which a single telephone call by emergency physicians or paramedics could activate the catheterization laboratory 24 hours, 7 days per week; acceptance of patients with STEMI regardless of bed availability; establishment of a leadership team including all personnel and administrators involved in STEMI care; a willingness to improve care for patients with STEMI in all hospitals and emergency medical systems (EMS) within the region regardless of affiliation; participation in a national data registry; and partial financial support of a regional coordinator. Once the PCI hospitals had established the above systems for rapid primary PCI, the regional coordinators and supporting PCI hospital colleagues approached the remaining hospitals (non-PCI hospitals) in the region and their associated EMS to further coordinate care. A full list of participating hospitals with driving times in minutes to PCI hospitals is listed in the Acknowledgment section.

Intervention

Working with the appropriate administrators, nurses, physicians, and technicians, a coronary reperfusion plan was established for each hospital according to medical evidence, published guidelines, available resources, and regional and local practice patterns.[13] Although the most appropriate system varied from hospital to hospital, an overall set of recommendations was provided in an operations manual.[14] The interventions focused on each component of the reperfusion process: the EMS, the emergency department, the

catheterization laboratory, and interhospital transfer. Systematic plans were established and supported through numerous local, regional, and statewide meetings and conference calls with local leaders involved in each component of the plan. All progress was reviewed in at least weekly conference calls among RACE leadership.

Data Collection

The non-PCI hospitals participated in an abbreviated data collection process performed by regional coordinators for 10 consecutive patients with STEMI in the quarter preceding and following the RACE intervention (preintervention data were collected up to 5 months before enrollment, with enrollment between July 2005 and March 2006, and postintervention data were collected between January 1, 2007, and March 31, 2007), and a detailed inventory to determine what resources and processes were in place for coronary reperfusion.

All PCI hospitals agreed to collect data for consecutive patients using the 5th National Registry of Myocardial Infarction (NRMI, directly presenting to or transferred to their centers) and allow for an aggregate system report in the quarter before and the quarter after the 1-year intervention (preintervention data were collected for all consecutive patients hospitalized between July 1, 2005, and September 30, 2005, and postintervention data were collected for all consecutive patients hospitalized between January 1, 2007, and March 31, 2007). All patients with STEMI were included as identified through emergency department registration data and hospital discharge data.

At non-PCI centers, hospital charts were then reviewed and data abstracted regarding presenting characteristics, times and type of reperfusion therapy, and whether and how transferred. Clinical outcome data from non-PCI hospitals were not available because most patients were transferred, and patients were de-identified. At PCI centers, data were abstracted from hospital charts including outcomes according to standard procedures used in the NRMI registry. Data specific to the RACE program were shared with participating centers in an aggregate fashion at the beginning and end of the intervention. Participating hospitals and EMS reviewed their own performance data on a much more frequent basis, most commonly at monthly or quarterly meetings.

Statistical Methods

Descriptive statistics for continuous and categorical variables were presented as median (interquartile range) and number (percentage), respectively. For patient characteristics and process measures (unpaired observations), the statistical comparisons were based on Wilcoxon Mann-Whitney and χ^2 tests as appropriate. Comparisons of paired hospital-level process measures in the preintervention and postintervention periods were based on McNemar tests.

For the PCI hospitals, the primary hypothesis was that the RACE intervention would reduce door-to-device times. For the non-PCI hospitals, the primary hypothesis was that the RACE system would reduce the door-in to door-out times for patients who were transferred to undergo PCI elsewhere and door-to-needle times for those receiving fibrinolysis. A coprimary hypothesis was an increased rate of reperfusion among eligible patients in both hospital settings. $P<.05$ was considered statistically significant. Secondary analyses using linear mixed models were performed to adjust for clustering of patients within hospitals. SAS version 8.2 (SAS Institute Inc, Cary, North Carolina) was used for all analyses.

RESULTS

Patient Characteristics

Between July 1, 2005, and September 30, 2005 (preintervention period), 579 patients with acute STEMI were treated at PCI hospitals, including transfer and nontransfer patients (FIGURE 2). Following the RACE intervention between January 1, 2007, and March 31, 2007, the corresponding number of patients was 585.

Demographic characteristics for patients treated at PCI hospitals and non-PCI hospitals are shown in TABLE 1. Among PCI hospitals, the median age of patients was 61 years, 226 patients (19.4%) were 75 years or older, 356 patients (30.6%) were women, 1082 (94.2%) had chest pain on admission, and 52 (4.5%) were Killip class III or IV at presentation. Six hundred sixty-two patients (56.9%) were transferred from other hospitals, including 526 (45.2%) from hospitals participating in RACE. Of the patients arriving by EMS who were not transfers, use of prehospital electrocardiogram increased from 68 (40.5%) to 122 patients (61.3%) ($P<.001$). Following the intervention, the proportion of eligible patients who did not receive reperfusion decreased from 23% to 11%, while the proportion of patients undergoing primary PCI increased from 48% to 63% (χ^2_4=42.0, $P<.001$). Fibrinolysis was mainly administered at non-PCI hospitals before transfer.

Among non-PCI hospitals, 518 patients with STEMI were treated in the pre-RACE period (July 2005 to March 2006) and 407 were treated in the post-RACE intervention period (January 1, 2007, to March 31, 2007) (Table 1). Demographic and clinical characteristics were similar to those patients treated in PCI hospitals except for a slightly lower rate of chest pain on admission (813 patients [89.1%]). Five hundred twenty-five patients (56.8%) presented to non-PCI hospitals by self-transport. Of those arriving by ambulance, there was an increase in prehospital electrocardiogram from 38.1% to 42.6% that was not statistically significant ($P=.37$). Following the intervention, the proportion of eligible patients who did not receive reperfusion remained at 15%, although there was a nonsignificant reduction in administering less fibrinolytic therapy (45.0% to 39.1%) and an increase in transfer for PCI (39.6% to 46.0%) (χ^2_2=4.1, $P=.13$). The majority of patients were transferred to PCI hospitals (91.7% to 95.1%, $P=.04$), including those patients treated with fibrinolysis. Trans-

fer by helicopter increased somewhat during the study period from 24.6% to 32.6% (χ^2_3=14.4, P= 003).

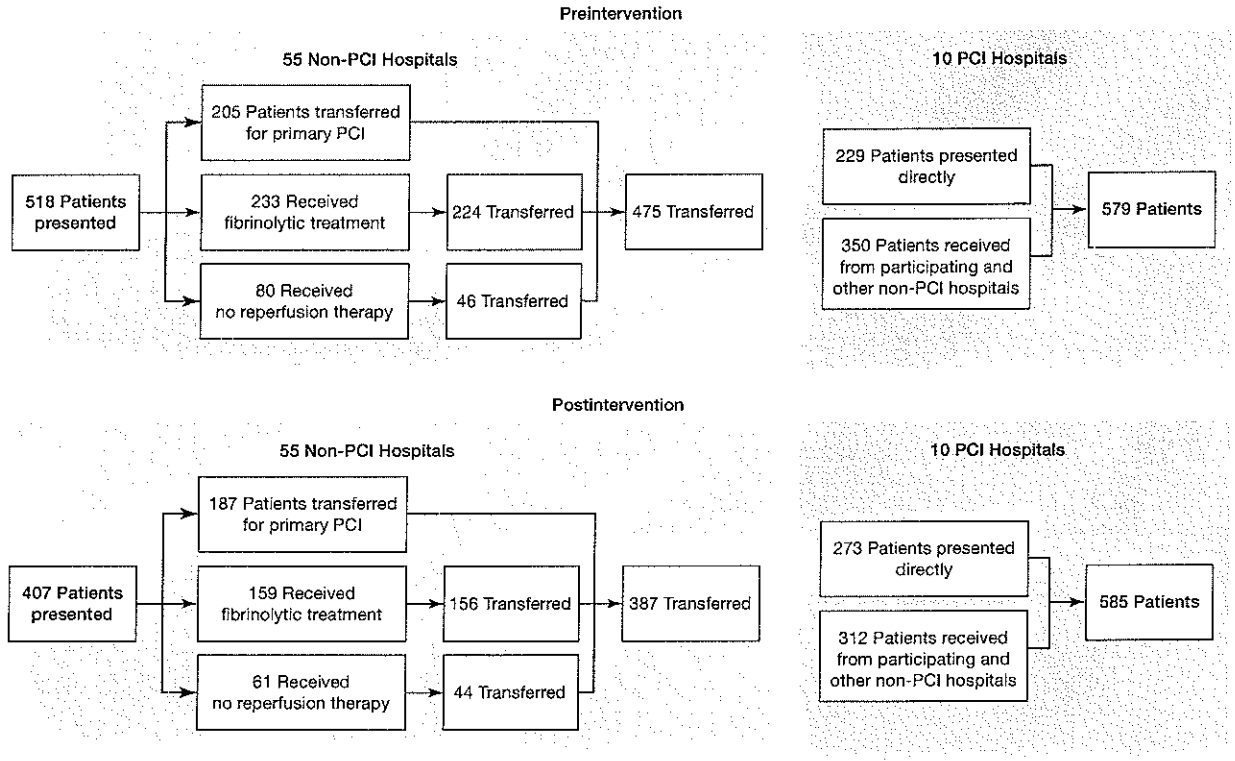
Interventions

TABLE 2 and TABLE 3 show the proportion of hospitals that adopted general recommendations from the operations manual. All PCI hospitals established leadership teams, a common reperfusion plan, and single-number activation of the catheterization laboratory as directed. The number of PCI hospitals using helicopters remained constant at 7 of 10 facilities, and only 3 of 10 hospitals adopted the strategy of imaging the infarct-related artery first with a PCI catheter.

Among the 55 non-PCI hospitals, 28 (51%) adopted a fibrinolysis strategy, 16 (29%) adopted a transfer for PCI strategy, and 11 (20%) adopted a mixed strategy that selected fibrinolysis or transfer for PCI depending on whether expedient transfer was possible according to local weather and equipment availability. Regarding the statewide recommendations, 51 hospitals (93%) gave authority to the emergency physician to initiate reperfusion including single-call catheterization laboratory activation, 49 (89%) adopted a common reperfusion plan, 37 of 46 hospitals (80%) established local EMS electrocardiogram training programs, 28 of 50 hospitals (56%) used the local ambulance for transfer to another hospital and 26 of 39 hospitals (67%) eliminated intravenous drips for transfers. Among non-PCI hospitals, the number of hospitals that left patients "on the stretcher" who presented via ambulance and were likely to be transferred for PCI increased from 2 (4%) to 11 (28%).

In addition to these common interventions, each participating hospital made a number of system changes that were specific to their institution or local circumstances. Examples of such interventions included establishing an Internet site identifying the single interventional cardiologist on call for the entire hospital when previously reperfusion was delayed while trying to determine which cardiologist from several competing groups would intervene, and using intensive care unit nurses to staff catheterization laboratories on an emergency basis when rapid coverage during nights and weekends by the staff who usually covered the day shift could not be arranged.

Figure 2. Patient Flow Diagram



Percutaneous coronary intervention (PCI) hospital patient population derived from National Registry of Myocardial Infarction database of all patients with ST-segment elevation myocardial infarction during 3-month time frames preintervention and postintervention. Non-PCI hospital population is overlapping but distinct and is derived from a separate nonlinked database using abbreviated consistent forms and definitions including approximately 10 consecutive patients per hospital preintervention and postintervention. A stipulation of the institutional review board for collecting data was removal of identifiers that would allow linkage.

Reperfusion Times

Following implementation of the recommendations of the RACE initiative, reperfusion times improved for almost all measured criteria. Among patients presenting to PCI hospitals who underwent primary PCI, the proportion with first door-to-device times of less than 90 minutes increased from 56.7% to 72.0%, with a decrease in median time from 85 minutes to 74 minutes ($P < .001$) (TABLE 4). In a secondary analysis accounting for clustering of patients within hospitals, the results remained statistically significant ($P = .01$). For patients transferred from one hospital to another for primary PCI, median time from first door-to-device decreased from 165 minutes to 128 minutes ($P < .001$). The median time from first door-to-device for patients transferred from hospitals with a transfer for PCI strategy decreased from 149 to 106 minutes ($P = .01$).

For patients presenting to the 55 non-PCI hospitals, median door-in to door-out times decreased from 120 minutes to 71 minutes, one of the greatest time reductions observed in the study ($P < .001$). In the analysis accounting for clustering of patients within hospitals, the results remained statistically significant ($P < .001$). For the subset of patients presenting to hospitals with a transfer for PCI strategy, median door-in to door-out times decreased from 97

Table 1. Patient Characteristics[a]

Characteristic	PCI Hospitals			Non-PCI Hospitals		
	Preintervention (n = 579)	Postintervention (n = 585)	P Value	Preintervention (n = 518)	Postintervention (n = 407)	P Value
Age, median (IQR), y	60 (51-72)	61 (52-71)	.67	62 (53-74)	61 (52-72)	.42
Age ≥75 y	116 (20.0)	110 (18.8)	.60	114 (22.0)	80 (19.7)	.39
Male sex	388 (67.0)	420 (71.8)	.08	346 (66.8)	289 (70.1)	.29
Blood pressure, median (IQR), mm Hg						
Systolic	136 (116-158)	138 (116-160)	.43	141 (121-160)	141 (120-164)	.82
Diastolic	80 (67-94)	82 (67-95)	.39	82 (70-96)	83 (68-98)	.97
Pulse, median (IQR), beats/min	78 (65-90)	78 (65-92)	.69	78 (65-91)	79 (66-95)	.23
Chest pain at presentation	534 (92.9)	548 (95.5)	.06	460 (89.5)	353 (88.5)	.63
Killip class[b]						
I	508 (88.1)	538 (92.1)	.04	468 (90.4)	361 (88.9)	.03
II	42 (7.3)	21 (3.6)		36 (7.0)	23 (5.7)	
III	14 (2.4)	11 (1.9)		10 (1.9)	8 (2.0)	
IV	13 (2.3)	14 (2.4)		4 (0.8)	14 (3.5)	
Initial reperfusion strategy						
No initial reperfusion strategy	132 (22.8)	63 (10.8)	< .001	80 (15.4)	61 (15.0)	.13
Fibrinolysis	162 (28.0)	144 (24.6)		233 (45.0)	159 (39.1)	
Primary PCI or transfer for PCI	275 (47.5)	369 (63.1)		205 (39.6)	187 (46.0)	
CABG surgery	10 (1.7)	9 (1.5)				
Arrival mode						
Self-transport	61 (10.5)	72 (12.3)	.07	297 (57.3)	228 (56.0)	.68
Ambulance	408 (70.5)	370 (63.3)		218 (42.1)	178 (43.7)	
Unknown[c]	17 (2.9)	20 (3.4)		3 (0.6)	1 (0.3)	
Air ambulance/helicopter	93 (16.1)	123 (21.0)				
Prehospital electrocardiogram[d]	68 (40.5)	122 (61.3)	<.001	78 (38.1)	72 (42.6)	.37
Transferred from another hospital	350 (60.5)	312 (53.3)	.02			
Transferred from a RACE hospital	279 (48.2)	247 (42.2)	.04			
Transferred to PCI hospital				475 (91.7)	387 (95.1)	.04
Transfer mode						
EMS ground				188 (39.6)	166 (42.9)	.003
Critical care transport				162 (34.1)	92 (23.8)	
Air ambulance/helicopter				117 (24.6)	126 (32.6)	
Unknown[c]				8 (1.7)	3 (0.8)	
AMI hotline				152 (32.1)	319 (84.6)	<.001

Abbreviations: AMI, acute myocardial infarction; CABG, coronary artery bypass graft; EMS, emergency medical systems; IQR, interquartile range; NA, not applicable; PCI, percutaneous coronary intervention; RACE, Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments.

[a] Data presented as number (percentage) unless otherwise specified. Empty cells indicate not applicable for either PCI hospitals or non-PCI hospitals interventions.

[b] Killip class was assigned on the basis of the severity of signs of heart failure at first assessment. Killip class I indicates absence of rales in the lung fields and the absence of an S_3 heart sound; class II, rales in ≤50% of the lung fields, the presence of an S_3, or jugular venous distention; class III, rales in >50% of the lung fields; class IV, presence of pulmonary edema with hypotension or shock.

[c] The mode of arrival could not be determined by chart review.

[d] For PCI hospitals, limited to the subset of patients using EMS as the arrival mode and not transferred; for non-PCI hospitals, limited to the subset of patients arriving by ambulance.

minutes to 45 minutes ($P < .001$). Among patients undergoing fibrinolysis, the proportion with door-to-needle times of less than 30 minutes increased from 34.8% to 51.9% ($P < .001$), with a decrease in median time from 35 minutes to 29 minutes ($P = .002$).

Clinical Outcomes

For patients directly presenting to or transferred to PCI hospitals, clinical outcomes including death, stroke, cardiac arrest, and cardiogenic shock did not significantly change following the intervention (Table 4). Stratified by transfer status, patients presenting directly to PCI centers had nonsignificantly lower mortality (8.7% to 7.3%, $P = .57$) and a lower stroke rate (0.4% to 0) after the intervention. Patients transferred in to PCI hospitals had nonsignificantly higher mortality (4.6% to 7.7%, $P = .09$) and lower stroke rate (1.4% to 0.3%, $P = .14$) after the intervention.

COMMENT

This study represents one of the largest and most extensive regional systems to our knowledge for the reperfusion of STEMI developed in the United States, including 65 of 100 acute care hospitals in North Carolina in which 8 million people live. By coalescing and coordinating EMS, emergency departments, and catheterization laboratories, the interventions promoted by the RACE initiative increased the frequency of reperfusion and substantially reduced time to treatment across 65 hospitals, including 10 PCI centers. The greatest improvements occurred in the times of patients transferred for PCI, a large group of patients currently excluded from CMS and JCAHO performance measures. The improvements appeared greater than those reported by the NRMI for US hospitals during a similar period (first door-to-device presenting to PCI hospital: median time, 88 to 81 minutes for NRMI and 85 to 74 minutes for RACE; first door-to-device transferred to PCI hospital: median time, 150 to 143 minutes for NRMI and 165 to 128 minutes for RACE; door-to-needle: median time, 30 to 30 minutes for NRMI and 35 to 29 minutes for RACE; and no reperfusion: 17% to 17% for NRMI, 23% to 11% for RACE PCI hospitals, and 15% to 15% for RACE non-PCI hospitals).[15,16]

However, despite improvements in reducing times to reperfusion therapy we did not identify lower mortality following the intervention. Given the preponderance of clinical trial evidence adopted by practice guidelines that timely reperfusion reduces mortality, our study was not designed to examine mortality or test treatment regimens. The complication and mortality rates in this study are similar to those in national registries, suggesting that our intervention was applied to a comparable population.[3-5] Given the characteristics of our study, including lack of randomization, relatively small sample size, and significant confounding introduced by an intervention designed to expand reperfusion to more eligible patients, inferences based on outcomes must be made with great caution. Nevertheless, systems for STEMI reperfusion such as RACE should continue to monitor and report outcomes to identify potential problems, avoid spurious associations related to publication bias, and to examine the effectiveness of clinical trial–based guidelines in more widespread application.

Having asked all hospitals and EMS to adopt a common set of recommendations, we cannot determine which of the RACE

Table 2. PCI Hospital Processes[a]

Characteristic	No. of Hospitals	
	Preintervention (n = 10)	Postintervention (n = 10)
Create RACE leadership team	7	10
For patients who walk into the ED first person encountered		
Triage nurse	4	3
Nursing assistant	1	1
Registration personnel	5	4
Greeter	0	2
Separate system for obtaining ECGs on patients with chest pain in the ED within 10 min of arrival	5	9
Formal orders for suspected MI with a diagnostic ECG	9	10
Formal orders for suspected MI without a diagnostic ECG	9	10
Dedicated ECG machine for ED use only	10	10
ECG obtained by EMS used to treat patient	1	8
Establish single-designated hospital-specific reperfusion plan	7	10
PCI center has a helicopter	7	7
Code STEMI designation	3	9
Someone other than an interventional cardiologist starts the case	2	4
All transfers have to stop in the ED/critical care unit	6	2
Foley catheter is routinely placed before primary PCI	3	0
Image infarct-related artery with PCI catheter first	2	3
Record EMS non-PCI calls and playback for quality improvement	1	3
Provide standardized feedback for ED	1	8
Provide standardized feedback for EMS	0	8
Establish a single call number that automatically activates catheterization laboratory	4	9
ECG equipment for EMS to do prehospital ECG	9	10
Use of prehospital ECG		
Interpreted by emergency medical technician	6	5
Transmitted to hospital	4	5
Program for paramedics to recognize ST-elevation on ECG	7	8

Abbreviations: ECG, electrocardiogram; ED, emergency department; EMS, emergency medical systems; MI, myocardial infarction; PCI, percutaneous coronary intervention; RACE, Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments; STEMI, ST-segment elevation MI.
[a] *P* values were not generated due to the small number of observations.

initiative interventions were most effective in improving care There were, however, a number of specific aspects of the study that likely contributed to the success. First, the RACE study moved beyond the catheterization laboratory and the venue of PCI hospitals to focus on emergency departments, EMS, and hospital networks and their associated communication and transportation systems This intentional focus was based on observations that many treatment delays are most likely to be overcome by early intervention in the process of STEMI recognition. By 'moving care forward," emergency physicians and emergency medical technicians were empowered to institute coronary reperfusion algorithms without antecedent cardiology consultation

A second critical aspect involved implementation of systems designed to capitalize on and leverage preexistent local resources In particular, for regions of the state in which primary PCI could not be instituted within 120 minutes despite maximum system efficiency, we recommended the rapid administration of fibrinolysis according to existing guidelines Hospitals and regions implementing this approach generally involved mountainous and sparsely populated regions of the state where transportation options were limited or travel times to PCI hospitals were prohibitive. The fact that the median first door-to-device time for transferred patients was 128 minutes despite our concerted intervention in the most suitable hospitals indicates that fibrinolytic therapy should remain an important treatment option in less accessible parts of the United States However, even in such rural locales where fibrinolysis is the primary reperfusion strategy, systems for the rapid transfer of patients remain important for patients ineligible for fibrinolysis and patients who do not reperfuse with fibrinolysis

The simplification of reperfusion approaches to the greatest possible extent possible, particularly in the transfer setting, was a crucial aspect of our systems approach. For example, intravenous drips such as heparin or nitroglycerin were minimized because we had determined that establishing continuous infusions led to substantial delays. In some regions, intravenous tubing differed by hospital and EMS, such that tubing and pumps had to be changed between transfers, significantly increasing treatment delays Additionally, some emergency transporters were restricted in their ability to run multiple drips due to equipment and personnel limitations Other simplifications that were recommended included relying on local ambulances rather than helicopters or mobile critical care units, leaving patients "on the stretcher" when appropriate for more rapid evaluation and transfer, and agreeing to accept all patients requiring PCI by the nearest participating facility without having to check for bed availability

Perhaps the most controversial recommendation aimed at simplifying STEMI treatment to allow more rapid reperfusion involved the establishment of a specific reperfusion plan for each emergency department and EMS. Based on our experience that STEMI was a relatively infrequent event for most emergency personnel, we believed that the potential benefit from individualizing treatment for each patient according to duration of symptoms, catheterization

Table 3. Non-PCI Hospital Processes

Characteristic	No./Total No. (%) of Hospitals		
	Preintervention	Postintervention	*P* Value[a]
Create RACE leadership team	14/55 (25)	36/55 (65)	<.001
For patients who walk into the ED first person encountered			
Triage nurse	39/55 (71)	31/55 (56)	.01
Nursing assistant	1/55 (2)	1/55 (2)	>.99
Registration personnel	12/55 (22)	20/55 (36)	.01
Greeter	3/55 (5)	3/55 (5)	>.99
Separate system for obtaining ECGs on patients with chest pain in the ED within 10 min of arrival	15/55 (27)	20/55 (36)	03
Formal orders for suspected MI with a diagnostic ECG	41/55 (75)	38/55 (69)	55
Formal orders for suspected MI without a diagnostic ECG	33/55 (60)	35/55 (64)	73
Dedicated ECG machine for ED use only	51/55 (93)	52/54 (96)	.16
ECG obtained by EMS before hospitalization is used to treat patient	0	1/55 (2)	NA
Establish single-designated hospital-specific reperfusion plan	11/55 (20)	49/55 (89)	< 001
Hospital designation[b]			
Fibrinolysis hospital	38/55 (69)	28/55 (51)	.002
Transfer for PCI hospital	8/55 (15)	16/55 (29)	.01
Mixed hospital[c]	9/55 (16)	11/55 (20)	.57
Eliminate intravenous drips for transfer	0	26/39 (67)	NA
ED physician has authority to initiate reperfusion without consulting cardiologist	41/52 (79)	51/55 (93)	02
Use a single call number that automatically activates catheterization team	9/55 (16)	51/53 (96)	< 001
Local ambulance for transfer within 50 miles	13/38 (34)	28/50 (56)	.11
Keep patient on local ambulance stretcher	2/45 (4)	11/39 (28)	.009
ECG equipment for EMS to do prehospital ECG	41/55 (75)	45/51 (88)	.046
Program for paramedics to recognize ST-elevation on 12-lead ECGs	25/55 (45)	37/46 (80)	< 001
Predestination protocol for EMS with patients with STEMI	6/55 (11)	28/46 (61)	< 001

Abbreviations: ECG, electrocardiogram; ED, emergency department; EMS, emergency medical systems; MI, myocardial infarction; NA, not applicable; PCI, percutaneous coronary intervention; RACE, Reperfusion of Acute Myocardial Infarction in North Carolina Emergency Departments; STEMI ST-segment elevation MI

[a] *P* values are based on McNemar test for matched pairs.

[b] Preintervention designation according to the predominant approach to reperfusion before the RACE intervention.

[c] Selected fibrinolysis or transfer for PCI depending on whether expedient transfer was possible according to local weather and equipment availability

laboratory proximity, and bleeding risk was outweighed by the benefit of selecting the best reperfusion strategy for most patients and avoiding delay resulting from indecision and the time required to individualize a treatment plan. Emergency physicians appeared to favor a predetermined algorithm-directed approach to reperfusion that resulted in rapid, coordinated treatment and an expedient patient disposition.

We elected to include all hospital and EMS within a given region when possible. This approach was facilitated by meetings with administration and physicians at all institutions designing the interventions around existing referral lines, and developing reperfusion strategies according to consensus. STEMI care was approached from a hospital quality perspective, with blinded data collection, and use of professional organizations and academic medical centers in the state to facilitate collaborative interaction and decision making.

The final and perhaps most important aspect of our intervention involved the facilitation of regional and statewide systems by full-time nurse coordinators. For each region, a coordinator funded by both the PCI hospitals and by the RACE program was responsible for overseeing every aspect of the intervention including PCI hospital catheterization activation systems, emergency department and EMS STEMI plans, and data collection by chart review preintervention and postintervention. They were also involved in local as well as regional education of EMS, nursing, other emergency department and catheterization laboratory personnel, and administrators. These regional coordinators were largely responsible for improvements in care and the overall success of the program.

Table 4. Treatment Times and Outcomes for Patients at PCI Hospitals and Non-PCI Hospitals

	Preintervention	Postintervention	*P* Value
Primary PCI Hospitals			
All patients undergoing primary PCI	(n = 266)	(n = 359)	
First door-to-device, median (IQR), min	108 (77-159)	90 (65-129)	<.001
Patients <90 min, No. (%)	97 (36.5)	185 (51.3)	<.001
Patients presenting directly to PCI hospital	(n = 164)	(n = 232)	
First door-to-device, median (IQR), min	85 (67-117)	74 (53-94)	<.001
Patients <90 min, No. (%)	93 (56.7)	167 (72.0)	.002
Patients transferred to PCI hospital	(n = 102)	(n = 127)	
First door-to-device, median (IQR), min	165 (129-229)	128 (102-195)	<.001
Patients <90 min, No. (%)	4 (3.9)	17 (13.4)	.01
Clinical outcomes (overall), No. (%)	(n = 579)	(n = 585)	
Death	36 (6.2)	44 (7.5)	.38
Stroke	6 (1.0)	1 (0.2)	.06
Cardiac arrest	24 (4.2)	18 (3.1)	.33
Cardiogenic shock	46 (7.9)	45 (7.7)	.88
Non-PCI Hospitals			
All patients	(n = 515)	(n = 404)	
Door-in to door-out, median (IQR), min	120 (77-248)	71 (45-110)	<.001
Patients <60 min, No. (%)	81 (15.7)	152 (37.6)	<.001
Patients <30 min, No. (%)	16 (3.1)	41 (10.2)	<.001
Patients at fibrinolysis hospitals[a]	(n = 239)	(n = 201)	
Door-in to door-out, median (IQR), min	125 (87-217)	87 (65-124)	<.001
Patients <60 min, No. (%)	13 (5.4)	37 (18.4)	<.001
Patients <30 min, No. (%)	2 (0.8)	1 (0.5)	.67
Patients at transfer for PCI hospitals[a]	(n = 178)	(n = 130)	
Door-in to door-out, median (IQR), min	97 (49-281)	45 (29-70)	<.001
Patients <60 min, No. (%)	57 (32.0)	85 (65.4)	<.001
Patients <30 min, No. (%)	13 (7.3)	34 (26.2)	<.001
Patients at mixed strategy hospitals[a]	(n = 98)	(n = 73)	
Door-in to door-out, median (IQR), min	120 (89-306)	71 (42-154)	<.001
Patients <60 min, No. (%)	11 (11.2)	30 (41.1)	<.001
Patients <30 min, No. (%)	1 (1.0)	6 (8.2)	.02
Fibrinolysis	(n = 233)	(n = 158)	
Door-to-needle, median (IQR), min	35 (25-55)	29 (21-46)	.002
Patients <30 min, No. (%)	81 (34.8)	82 (51.9)	< 001

Abbreviations: IQR, interquartile range; PCI, percutaneous coronary intervention.
[a] Each hospital's initial reperfusion strategy is defined based on the postintervention period

The system has some similarities to and substantial differences from other STEMI reperfusion systems. The successful Minnesota Level 1 Heart Attack Program served as a model for many of our system transfer interventions.[17] Focus on the "golden" first hour and extensive urgent coordination of transport and specialty hospital services mirrored that of nationwide trauma system and the Minnesota Heart Attack system. Unlike our intervention, the Minnesota approach relies heavily on helicopter transport, provides PCI to all patients at a single center, and uses a facilitated approach combining half-dose fibrinolysis and PCI for patients initially presenting to hospitals more than 60 miles of the catheterization laboratory. Pending clinical trial evidence, we emphasized reperfusion approaches supported by existing data and established guidelines. Given the scope of our intervention area and the wide array of regional capabilities, a single approach to reperfusion was simply not feasible in our system.

Numerous other systems in the country similarly use emergency medical technicians to perform electrocardiograms and transport patients directly to centers with primary PCI capability, including the bypass of non-PCI centers.[18-20] In our geographically, economically, and demographically diverse state, the best approach to prehospital electrocardiography varied according to the region and hospital. Rather than attempt to expand the availability of paramedics in rural regions with limited financial resources, a member of our oversight board

successfully lobbied to alter state regulations that now allow intermediate-level emergency medical technicians to perform electrocardiograms in regions in which paramedics are not available. The same regional variation in resources led us to rely on a number of approaches for electrocardiographic interpretation, including paramedic interpretation, computer algorithm interpretation, electrocardiogram transmission, and, if none of these approaches were feasible, simply showing the electrocardiogram to emergency physicians as the patients arrived at the emergency department.

Recent professional association initiatives share features of our program. The American College of Cardiology Door to Balloon (D2B) program focuses on improved catheterization laboratory system performance.[21] In fact, all 10 of our PCI hospitals joined the D2B initiative at the end of the RACE initiative; the final proportion of patients at participating RACE hospitals undergoing PCI within 90 minutes approaches the D2B goal of 75%. Our concept of designing different regional STEMI systems based on whether nearby hospitals offer primary PCI has been formally codified by the American Heart Association Mission Lifeline approach.[7] Hospitals and regions that focused on transfer for PCI in our system most closely reflect the American Heart Association approach. Although interhospital transfer times were significantly reduced by our interventions, greater than optimal delays persisted despite an intense and well-funded effort in regional coordination. This indirectly suggests that even with improvement in application of rapid and high-quality primary PCI, fibrinolytic therapy will continue to play an important role in many parts of the country.

Our experience and an Institute of Medicine report[22] suggest that more resources should be applied to EMS and emergency departments to treat STEMI, as has occurred to develop trauma systems throughout the United States. In particular, with a lack of federal standards and reliance on local government for funding and support, EMS in many locales lack adequate resources, personnel, or training to consistently apply emergency STEMI care.[22] Minimum national standards for EMS training and response should be established and adequate funding provided to ensure uniform application. Additional barriers to rapid care that must be addressed include modification of reimbursement systems to remove financial penalties for transferring patients and revision of Emergency Medical Treatment and Active Labor Act (EMTALA) statutes such that there is less ambiguity regarding the importance of transfer in the case of STEMI.

This study has several limitations. There was no regional or national comparator by which to judge the relative improvement in STEMI care. The long-running NRMI was closed in December 2006, before our postdata collection period. Comparison with NRMI reports was further limited by the lack of availability of continuous data distributions and the reporting of treatment times in a rolling 12-month fashion. With these significant caveats in mind, a comparison with NRMI during a similar period suggests larger improvements with the RACE intervention.

Additional limitations of our study are also related to data. Although non-PCI hospital data were collected by independent study personnel, it is possible that these hospitals did not make charts available for select patients. For PCI hospitals, we were not able to audit data feeds to NRMI, further allowing for bias in self-reported data. During the time period, CMS audited a small sample of hospital records related to reperfusion times, possibly leading to more accurate data reporting by participating hospitals.

The limitations in data illustrate a major national issue in establishing systems of STEMI care. Performance measurement and feedback represents one of the most effective tools for motivating change and improving systems. With the discontinuation of the NRMI registry, there are plans for the American College of Cardiology National Cardiovascular Data Registry ACTION registry to begin measuring reperfusion parameters of STEMI. We have urged all hospitals participating in our system to participate in this registry. Data auditing the availability of regional and national benchmarks, and tracking of transferred patients including deaths in transfer will be essential components of this registry.

Another limitation of the hospital registries used in our study is that deaths that occurred during transfer were not systematically identified in data from the transferring or the receiving hospital. We are currently establishing an approach to routinely identify all deaths in transfer according to cardiac catheterization laboratory activation calls for which the patient does not arrive at the catheterization laboratory. As the greatest opportunity for improvement lies in the "front lines" of cardiac care, access to or merger of hospital registries with EMS data such as the National EMS Information System will be important to fully assess impact on clinical outcomes.

CONCLUSION

We have demonstrated that a statewide program focused on the development of regional systems for STEMI reperfusion can significantly improve quality of care. Further research is needed to ensure that this and other programs that demonstrate improvement in application of reperfusion therapies lead to reduced mortality and morbidity from acute myocardial infarction.

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