Original Article

Bypassing the Emergency Department and Time to Reperfusion in Patients With Prehospital ST-Segment Elevation

Findings From the Reperfusion in Acute Myocardial Infarction in Carolina Emergency Departments Project

Akshay Bagai, MD, MHS; Hussein R. Al-Khalidi, PhD; Daniel Muñoz, MD, MPA; Lisa Monk, RN, MSN; Mayme L. Roettig, RN, MSN; Claire C. Corbett, MMS, NREMT-P; J. Lee Garvey, MD; B. Hadley Wilson, MD; Christopher B. Granger, MD; James G. Jollis, MD

Background—Among patients identified prehospital with ST-segment–elevation myocardial infarction, emergency medical service transport from the field directly to the catheterization laboratory, thereby bypassing the emergency department (ED), may shorten time to reperfusion.

Methods and Results—We studied 1687 patients identified prehospital with ST-segment elevation myocardial infarction from the Reperfusion in Acute Myocardial Infarction in Carolina Emergency Departments (RACE) project, transported via emergency medical service directly to 21 North Carolina hospitals for primary percutaneous coronary intervention between July 2008 and December 2009. Treatment time intervals were compared between patients evaluated in the ED (ED evaluation) and those transported directly to the catheterization laboratory (ED bypass). Emergency medical service transported 1401 (83.0%) patients to the ED, whereas the ED was bypassed for 286 (17.0%) patients. Overall, first medical contact to device activation within 90 minutes was achieved in 913 (54.1%) patients. Among patients evaluated in the ED, median time (25th–75th percentiles) from ED arrival to catheterization laboratory arrival was 30 (20–41) minutes. First medical contact to device activation occurred faster (75 [59–93] versus 90 [76–109] minutes; $P<0.001$) and was more frequently achieved within 90 minutes (74.1% versus 50.1%; $P<0.001$) among ED bypass patients.

Conclusions—Among patients identified prehospital with ST-segment–elevation myocardial infarction and transported directly to a percutaneous coronary intervention hospital, only 1 in 2 achieve device activation within 90 minutes. A median of 30 minutes is spent in the ED, contributing significantly to the failure to achieve timely reperfusion. The strategy to bypass the ED is used infrequently and represents a potential opportunity to improve reperfusion times. (***Circ Cardiovasc Interv*. 2013;6:00-00.)**

Key Words: health care systems ■ myocardial infarction ■ percutaneous coronary intervention

Faster time to reperfusion results in less myocardial damage and lower mortality in patients with ST-segment–elevation myocardial infarction (STEMI).[1,2] The American College of Cardiology/American Heart Association (ACC/AHA) guidelines recommend that for STEMI patients treated by emergency personnel, device activation should occur within 90 minutes of first medical contact.[3] Several strategies,[4,5] including use of prehospital ECGs[6] and direct transport to an interventional center,[7,8] are recommended to achieve timely reperfusion with primary percutaneous coronary intervention (PCI). Although increased adoption of these strategies[9] and widespread establishment of regionalized STEMI care systems[10] has yielded significant improvement in national reperfusion metrics, guideline-based reperfusion goals have not yet been systematically achieved.[11] Recent studies suggest that time delays associated with triage and evaluation in the emergency department (ED) may contribute significantly to the failure to achieve timely reperfusion.[12,13]

The Reperfusion in Acute Myocardial Infarction in Carolina Emergency Departments (RACE) project[14–16] is a statewide quality improvement initiative establishing standardized approaches to diagnosis and reperfusion of STEMI. RACE integrates the data collection efforts of all 21 full time primary PCI hospitals, the majority of non-PCI hospitals, and emergency medical service (EMS) agencies in North Carolina. The data permit examination of processes of care for patients

Received November 12, 2012; accepted May 23, 2013.

From the Department of Cardiology, Duke Clinical Research Institute, Duke University, Durham, NC (A.B., H.R.A.-K, D.M., L.M., M.L.R., C.B.G., J.G.J.); New Hanover Regional Medical Center, Wilmington, NC (C.C.C.); and Departments of Emergency Medicine (J.L.G.), and Cardiology (B.H.W.), Carolinas Medical Center, Charlotte, NC.

Correspondence to Akshay Bagai, MD, MHS, Duke Clinical Research Institute, Room 0311 Terrace Level, 2400 Pratt St, Durham, NC 27705. E-mail akshay.bagai@duke.edu

Circ Cardiovasc Interv **is available at http://circinterventions.ahajournals.org** **DOI: 10.1161/CIRCINTERVENTIONS.112.000136**

WHAT IS KNOWN

- Among patients diagnosed prehospital with ST-segment–elevation myocardial infarction, routine stopover for evaluation in the emergency department before the catheterization lab may be associated with delay in reperfusion therapy.

WHAT THE STUDY ADDS

- Direct transport from the prehospital setting to the catheterization laboratory, thereby bypassing the emergency department occurs infrequently in North Carolina.
- Median time of 30 minutes is spent in the emergency department, which contributes significantly to the failure to achieve timely reperfusion.
- Compared with stopover for evaluation in the emergency department, direct transport from the prehospital setting to the catheterization laboratory is associated with faster reperfusion times, and greater achievement of guideline-based reperfusion targets.

identified prehospital with STEMI brought directly to a primary PCI hospital, and to probe the magnitude of treatment delay associated with triage and evaluation in the ED of the PCI hospital before transport to the catheterization laboratory. In this study, we describe the statewide use of the strategy to transport such patients directly from the field to the catheterization laboratory, thereby bypassing the PCI hospital ED and compare treatment time intervals for patients taken directly to the catheterization laboratory with patients triaged and evaluated in the ED.

Methods

Patient Population

The population for this analysis was drawn from 3908 STEMI patients from the RACE project between July 2008 and December 2009 presenting directly to 1 of the 21 hospitals in North Carolina equipped to perform primary PCI on a 24 hours per day/7 days per week basis. Patients who underwent transfer from a non-PCI capable hospital to a PCI-capable hospital for primary PCI were not included in this cohort. The RACE project, described previously,[14–16] is a coordinated statewide system of 119 hospitals and ≈540 EMS agencies in North Carolina that aims to expedite STEMI diagnosis and reperfusion. The key elements of the system include regional organization and coordination, institution of the single best plan for treatment at every point of care, ongoing process measurement, prompt feedback, and establishment of teams of healthcare professionals that span all aspects of STEMI care. Data were obtained using standard data collection from the ACTION (Acute Coronary Treatment and Intervention Outcomes Network) Registry—Get With The Guidelines.[17] Data elements include comprehensive description of medical history, clinical presentation, key process times for reperfusion, and subsequent course of hospitalization. All participating institutions were required to comply with local regulatory and privacy guidelines and, if required, to secure institutional review board approval. Because data were used primarily at the local site for quality improvement, sites were granted a waiver of informed consent under the common rule.

Among the 3908 patients presenting directly to a PCI-capable hospital, we excluded the following from our analyses: patients with rescue PCI (n=7), PCI for non-STEMI (n=6), PCI after successful reperfusion/completed infarct (n=63), other indication for PCI (n=14), and missing indication for PCI (n=523). In the remaining 3295 patients, the indication for PCI was primary PCI for STEMI. To focus our analysis on patients presenting via ground-based EMS, we then excluded 861 self-presenters, 22 mobile intensive care unit transfer patients, and 59 air transfer patients. Among the remaining 2353 patients brought to the hospital by EMS, 1907 had a prehospital ECG, of which STEMI was noted on the first ECG in 1691 patients. An additional 3 patients were excluded as the hospital door to catheterization laboratory arrival time was >24 hours indicating these patients may have been incorrectly coded and were not receiving primary PCI for STEMI. Of the remaining 1688 patients, the location of first evaluation was missing for 1 patient, yielding a final cohort of 1687 patients identified prehospital with STEMI transported directly via EMS to a PCI-capable hospital for primary PCI. Patients transported directly from the field to the catheterization laboratory (ED bypass) were compared with patients triaged and evaluated in the ED before transport to the catheterization laboratory (ED evaluation).

Outcomes of Interest

Time from first medical contact to device activation and in-hospital mortality rates were determined. Processes of STEMI care at the 21 PCI hospitals were also evaluated to identify factors that may be associated with delay in reperfusion.

Statistical Analysis

Descriptive statistics were summarized as medians with 25th and 75th percentiles for continuous variables and number with percentages for categorical variables. Patient characteristics, process measures, and outcomes were compared between groups using Wilcoxon rank-sum test for continuous variables and Fisher exact test and χ^2 test (as appropriate) for categorical variables.

Timing of Reperfusion Therapy

The time from first medical contact to device activation, and the proportion of patients with first medical contact to device activation within 90 minutes were compared between the ED bypass and ED evaluation groups. Time of device activation was defined as the time the first device is activated, regardless of the type of device used. These included time of first balloon inflation, time of first stent deployment, or the time the lesion is first treated with angioJet or other thrombectomy/aspiration, laser or rotational atherectomy. If the lesion could not be crossed with a guidewire or device (and thus none of the above apply), time of device activation was defined as the time of guidewire introduction.[17] In addition, time interval from ED arrival to catheterization laboratory arrival was determined for patients evaluated in the ED.

Scenario Analysis

Imbalance among comparison groups in proportion of sicker patients requiring resuscitation, specifically those with cardiac arrest and requirement for intubation before PCI, may increase treatment times that are not modifiable in the group evaluated in the ED. Therefore, treatment time intervals were compared between groups in a scenario of stable STEMI patients by excluding higher risk patients with cardiac arrest or requiring intubation before PCI.

In a second scenario, we evaluated the effect of the time of day on treatment time intervals for the 2 groups. The decision to transport the patient directly to the catheterization laboratory, thereby bypassing the ED, versus transporting to the ED for evaluation may be influenced by the time of day and catheterization laboratory readiness. Therefore, we stratified patients by hospital time arrival into those presenting during working hours (0701–1800 hours from Monday to Friday) and those presenting during off-hours (1801–0700 hours Monday to Friday, and Saturday and Sunday). Treatment time intervals were compared between the 2 groups separately during working and off-hours.

In-Hospital Mortality

All-cause in-hospital mortality was compared between the 2 groups. The analysis was repeated after excluding patients with cardiac arrest and intubation before PCI. Because patients in this study were not randomly assigned to ED bypass or ED evaluation, we also compared in-hospital mortality after adjusting for patient's propensity to bypass the ED. For this analysis, only patients from hospitals with ≥10% ED bypass were included (11 hospitals; n=989). A propensity score was calculated for each patient using binary logistic regression including all patient characteristics listed in Table 1, and the time of presentation (working versus off-hours). Logistic regression analysis was used to compare in-hospital mortality between ED bypass and ED evaluation after adjusting for propensity score as a continuous covariate. Results are presented as odds ratio with 95% confidence intervals.

Hospital Level Analysis

The proportion of ED bypass patients was determined for each of the 21 PCI-capable hospitals. In addition, median time spent in the ED before catheterization laboratory arrival and proportion of patients achieving first medical contact to device activation within 90 minutes was also determined for each of the hospitals. We explored the correlation between proportion of ED bypass at the hospital level and proportion of patients at the hospital achieving first medical contact to device activation within 90 minutes. We also explored for consistency across hospitals in the achievement of first medical to contact to device activation within 90 minutes with ED bypass compared with ED evaluation. Hospitals that frequently performed ED bypass (ED bypass rate ≥25%) were considered for this analysis.

We also conducted a survey of the hospitals to determine EMS, ED, and catheterization laboratory practices used in the care of patients identified prehospital with STEMI. Treatment time intervals were examined among patients from hospitals that endorsed practices potentially associated with nonessential delays in the ED (routine repetition of ECGs in the ED even when prehospital ECG suggests a STEMI, transferring patients off the EMS stretcher onto an ED bed).

A 2-sided nominal P value <0.05 was considered statistically significant. All statistical analyses were performed using SAS version 9.2 (SAS Institute, Inc, Cary, NC).

Results

Among the 1687 patients identified by EMS with STEMI, 1401 (83.0%) were triaged and evaluated in the ED (ED evaluation), whereas 286 (17.0%) were transported directly to the catheterization laboratory (ED bypass). Demographic and clinical characteristics of the patients in the 2 groups are

Table 1. Demographic and Clinical Characteristics of the Study Population

Characteristics, %	ED Evaluation (n=1401)	ED Bypass (n=286)	*P* Value
Demographics			
Age, y	59 (51–69)	60 (51–69)	0.54
Women	29.1	22.0	0.02
Race (white)	84.1	90.2	0.01
Height, cm	175 (167–180)	175 (168–182)	0.22
Weight, kg	85 (73–98)	84 (75–96)	0.95
Medical history			
Diabetes mellitus	19.2	22.0	0.29
Hypertension	60.5	55.9	0.17
Dyslipidemia	50.7	60.8	0.002
Current smoker	51.7	48.3	0.30
Currently on dialysis	1.0	0.7	1.00
Prior myocardial infarction	23.4	16.8	0.02
Prior heart failure	4.8	2.8	0.16
Prior PCI	23.9	20.6	0.25
Prior CABG	6.1	8.4	0.15
Prior stroke	5.7	4.2	0.39
Peripheral arterial disease	4.2	3.2	0.51
Presentation characteristics			
ECG findings			0.80
ST-elevation	99.4	99.7	
Left bundle-branch block	0.4	0.4	
Isolated posterior MI	0.1	0.0	
Heart rate, bpm	75 (62–89)	76 (63–88)	0.93
Systolic blood pressure, mm Hg	133 (112–155)	136 (119–149)	0.62
Heart failure on presentation	5.6	5.2	0.89
Cardiogenic shock on presentation	11.0	7.7	0.11
Cardiac arrest or intubation before PCI	7.4	1.5	<0.001

Continuous variables are presented as medians (25th–75th percentiles). CABG indicates coronary artery bypass grafting; ED, emergency department; MI, myocardial infarction; and PCI, percutaneous coronary intervention.

Table 2. Timing of Reperfusion Therapy

Time Intervals, min	ED Evaluation (n=1401)	ED Bypass (n=286)	*P* Value
First medical contact to hospital arrival*	33 (25–44)	42 (30–60)	<0.001
Catheterization laboratory arrival to device activation	24 (18–31)	24.5 (18–35)	0.17
Hospital arrival to device activation*	55 (43–69)	28 (20–38)	<0.001
First medical contact to device activation	90 (76–109)	75 (59–93)	<0.001
First medical contact to device activation ≤90 min†	50.1	74.1	<0.001

Time intervals reported as medians (25th–75th percentiles). ED indicates emergency department.
*Hospital arrival refers to ED arrival in the ED evaluation group and catheterization laboratory arrival in the ED bypass group.
†Reported as percentage.

presented in Table 1. Patients evaluated in the ED were more likely to be women, less likely to be white, and more likely to have a history of prior myocardial infarction. The proportion of higher risk patients with cardiac arrest or intubation before PCI was greater among patients evaluated in the ED. There was no difference in proportion of heart failure or shock on presentation between the 2 groups.

Timing of Reperfusion Therapy

Duration from first medical contact to hospital arrival was longer among ED bypass patients (Table 2). Overall, 913 (54.1%) patients achieved first medical contact to device activation within 90 minutes. First medical contact to device activation was faster (75 [59–93] versus 90 [76–109] minutes; *P*<0.001) and achieved more frequently within 90 minutes (74.1% versus 50.1%; *P*<0.001) among ED bypass patients compared with ED evaluation patients. In the ED evaluation group, median time spent in the ED before arrival in the catheterization laboratory was 30 (20–41) minutes.

Excluding Cardiac Arrest or Intubation

When we excluded 103 patients (4 ED bypass, 99 ED evaluation) with cardiac arrest or requirement for intubation before PCI, among patients in the ED evaluation group, the median time in the ED before arrival in the catheterization laboratory remained at 30 (20–40) minutes. First medical contact to device activation remained faster (76 [59–92] versus 89 [75–108] minutes; *P*<0.001) and achieved more frequently within 90 minutes (74.5% versus 51.7%; *P*<0.001) in the ED bypass group.

Working Versus Off-hours

Overall, 766 (45.5%) patients arrived at the hospital during working hours, whereas 918 (54.5%) patients arrived off-hours. The ED was bypassed more frequently during working hours compared with off-hours (28.2% versus 7.6%). Treatment time intervals during working and off-hours are presented in Table 3. Among patients evaluated in the ED, the median time spent in the ED before catheterization laboratory arrival was 24 (16–34) minutes during working hours compared with 34 (24–45) minutes during off-hours. Regardless of the time of day, bypassing the ED was associated with faster first medical contact to device activation, with more frequent achievement within 90 minutes compared with evaluation in the ED.

In-Hospital Mortality

In-hospital mortality was lower among patients bypassing the ED compared with patients evaluated in the ED (1.8% versus 4.6%; *P*=0.02), however, after excluding patients with cardiac arrest or intubation before PCI, in-hospital mortality rates were similar between the 2 groups (ED bypass, 1.8% versus ED evaluation, 3.4%; *P*=0.19). Similarly, after adjustment for propensity score, there was no difference in in-hospital mortality between the 2 groups (adjusted odds ratio, 0.58; 95% confidence interval, 0.21–1.6; *P*=0.29).

Table 3. Timing of Reperfusion Therapy: Working vs Off-Hours

	Working Hours			Off-Hours		
Time Intervals, min	ED Evaluation (n=550)	ED Bypass (n=216)	*P* Value	ED Evaluation (n=848)	ED Bypass (n=70)	*P* Value
First medical contact to hospital arrival	32 (25–43)	39 (28–53)	<0.001	33 (25–44)	55 (41–70)	<0.001
Catheterization laboratory arrival to device activation	23 (18–30)	24 (18.5–32.5)	0.09	24 (18–31)	25 (17–37)	0.31
Hospital arrival to device activation	47 (38–62)	27.5 (20–38)	<0.001	59 (49–73)	33 (22–43)	<0.001
First medical contact to device activation	83 (68–102)	71 (57–85)	<0.001	94 (81–112)	86.5 (73–107)	0.01
First medical contact to device ≤90 min*	61.1	80.1	<0.001	43.0	55.7	0.045

Time intervals reported as medians (25th–75th percentiles). ED indicates emergency department.
*Reported as percentage.

Hospital Level Analysis

There was significant variation across hospitals in the proportion of ED bypass, ranging from 0% to 68% (median, 12.2%; Figure). The proportion of patients achieving first medical contact to device activation within 90 minutes also varied significantly across the hospitals, ranging from 27.8% to 79.8% (median, 52.1%). The correlation between proportion of ED bypass at the hospital level and the proportion of patients achieving first medical contact to device activation within 90 minutes was modest (Spearman correlation coefficient, 0.31). ED bypass rate was ≥25% in 7 of the 21 hospitals. In each of these 7 hospitals, first medical contact to device activation within 90 minutes was achieved more frequently with ED bypass compared with ED evaluation.

All 21 hospitals completed the survey questionnaire. On-site coronary artery bypass grafting was available in all 21 hospitals, but only 1 hospital had 24/7 in-house PCI team. As standard practice, the EDs were informed by EMS of a STEMI patient en route to the hospital in all 21 hospitals, and EMS was capable of transmitting ECGs to the ED in 15 hospitals and directly to catheterization laboratory team in 8 hospitals. Despite universal prenotification, there was significant variation across hospitals in the median time patients spent in the ED, ranging from 14 to 40 minutes ($P<0.001$). ECGs were routinely repeated in the ED in 12 hospitals, and patients were routinely transferred off the EMS stretcher/monitor onto the ED bed/monitor in 12 hospitals. Patients from hospitals that endorsed the practice of routine ECG repetition in the ED and transferring patients off the EMS stretcher onto the ED bed had longer median times in the ED compared with patients from hospitals that did not endorse these practices (32 [25th, 75th percentiles, 22–43] versus 28 [25th, 75th percentiles, 18–38] minutes; $P<0.001$). There was variability across hospitals in who activated the catheterization laboratory (ED physician/charge nurse, 14 hospitals; cardiology fellow, 1 hospital; cardiologist, 1 hospital; and EMS directly, 5 hospitals).

Discussion

Our analysis reveals that among patients identified prehospital with STEMI and transported directly to a North Carolina PCI center, only 54.1% achieve device activation within 90 minutes. A median of 30 minutes is spent in the ED of the PCI hospital contributing significantly to the failure to achieve timely reperfusion. Although used infrequently, the ED bypass strategy is associated with faster reperfusion with a 24% absolute increase in achievement of guideline-based targets. These findings motivate reevaluation of the advantages and disadvantages of ED-based assessments in patients identified prehospital with STEMI, and foster support for the development of STEMI systems with ED bypass protocols for appropriate patients.

The 30-30-30 rule[18] was suggested to aid in achieving the ACC/AHA recommended goal by trisecting the 90-minute benchmark time interval into segments, each dependent on 1 of the 3 STEMI care providers (EMS, ED, and catheterization laboratory). In our study, even after excluding patients requiring resuscitation before PCI, 50% of patients still spent >30 minutes in the ED. Studnek et al[19] found that the ability to transport the patient from the scene to the catheterization laboratory table within 30 minutes was the variable most strongly associated with achieving PCI within 90 minutes. Delays occurred in the ED, despite a universal strategy among all 21 hospitals for prearrival notification of the ED by EMS. Reasons for prolonged ED stay are likely multifactorial, including delays in catheterization laboratory team readiness, ECG repetition, phlebotomy, patient transfer from the EMS stretcher onto the ED bed, and catheterization laboratory activation only after ED evaluation.

Results of our statewide analysis are consistent with smaller single center experiences. In a prospective cohort of 74 consecutive patients compared against a matched historic control, van de Loo et al[20] report a reduction of 27 minutes in door-to-balloon time using an ED bypass strategy. In a single center experience reported by Amit et al,[21] ED bypass was associated with a 24-minute reduction in door-to-balloon time compared

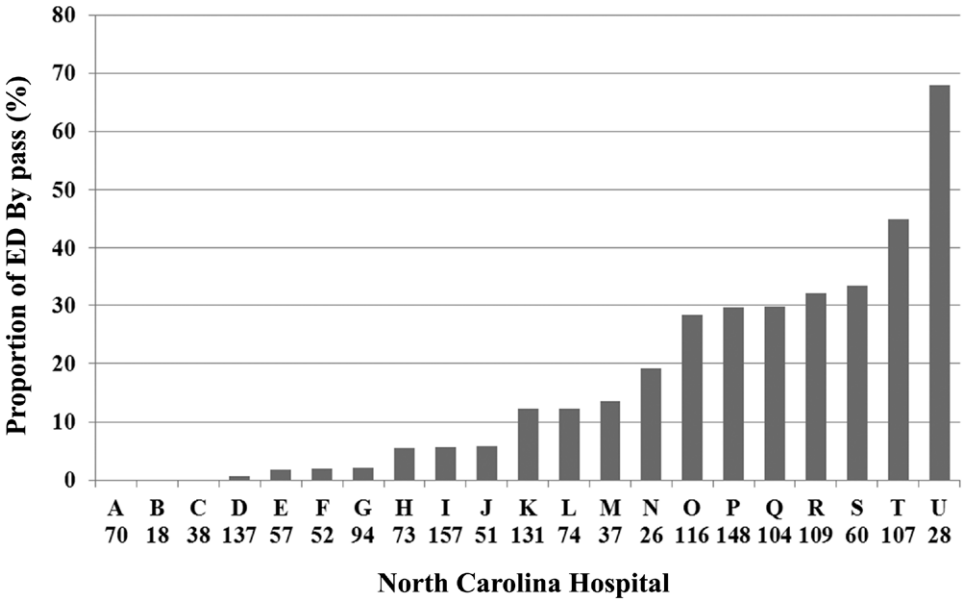

Figure. Proportion of emergency department (ED) bypass per hospital. Proportion of ED bypass varies significantly across hospitals, ranging from 0% to 68%. The total number of patients at each hospital is listed on the horizontal axis.

with admission via the ED. Cheskes et al[22] showed that a paramedic-activated STEMI bypass protocol with direct transport to the catheterization laboratory was associated with a higher proportion of patients meeting the 90-minute ACC/AHA benchmark (91.3%) as compared with the strategy of the paramedic-provided advanced notification of the ED coupled with ED evaluation before the catheterization laboratory (28.4%). The authors proposed a modification of the 30-30-30 rule by combining the EMS and ED care of STEMI patients into a 60-minute EMS time interval. This modification potentially permits a longer paramedic assessment and travel time with subsequent time gains via bypassing the ED of the PCI center.

In our study, the duration from first medical contact to hospital arrival was longer in the ED bypass group compared with ED evaluation. This difference between the 2 groups was even greater during off-hours. We speculate that longer travel distances (ie, longer travel times) may allow sufficient time for the catheterization laboratory to be ready to perform ED bypass, thus selecting such patients into the ED bypass group. This effect is potentially magnified during off-hours, when the catheterization laboratory is usually not in the hospital, resulting in patients with shorter transport distances/times to be taken to the ED, while only patients with longer transport distances/times bypassing the ED. Despite longer duration from first medical contact to hospital arrival, ED bypass was associated with a 15-minute reduction in first medical contact to device activation compared with evaluation in the ED, corresponding to a 24% absolute increase in achievement of guideline-based targets. Previous studies have shown that a 15-minute delay in reperfusion is clinically important and associated with worse clinical outcomes.[2,23] In our study, lower in-hospital mortality among patients bypassing the ED was at least partially explained by the disparity in proportion of higher risk patients between the 2 groups. It is reassuring, however, that even after adjusting for differences in patient characteristics or excluding higher risk patients, the mortality rate was lower among ED bypass patients, albeit statistically insignificantly, with no signal toward worse clinical outcomes with this strategy.

Rational arguments exist in support of a role for the ED before transport to the catheterization laboratory, including (1) to confirm the diagnosis and minimize false activations, (2) to serve as a holding area while awaiting catheterization laboratory readiness, and (3) to resuscitate unstable patients. Given findings from this and other studies[12,13] that time spent in the ED seems longer than desirable and contributes significantly to unacceptably long reperfusion times, reevaluation of the traditional role of the ED is warranted. Rates of false activation can potentially be minimized with comprehensive paramedic training, use of computer ECG interpretation software, and when necessary, wireless transmission of the prehospital ECG for interpretation and consultation. Cheskes et al[22] report <5% rate of catheterization laboratory cancelation after activation by EMS. We previously reported[24] the rate of inappropriate activation by EMS was 25% compared with <15% by emergency physicians. However, the rate of catheterization laboratory cancellations because of reinterpretation of ECGs was only 6% for emergency medical technicians' ECG, compared with 4.6% for emergency physicians' ECG. These low rates of inappropriate activation by EMS personnel support activation of the catheterization laboratory directly by EMS. Importantly, the decision to activate the laboratory and the decision to perform catheterization and intervention are distinct, and the final decision to perform cardiac catheterization remains with the interventionalist. Care pathways are required to be instituted at each hospital for patients with false activation, either returning them to the ED for further work up or transfer to a unit in the hospital, as appropriate.

Shorter time in the ED during working hours compared with off-hours is likely a function of temporal variability in catheterization laboratory readiness. Uncertainty about catheterization laboratory readiness is a significant impediment to adopting a systematic ED bypass strategy. It has been suggested that PCI hospitals have catheterization laboratory staff on-site 24/7 to ensure timely revascularization.[25] However, even in high-volume centers, 24-hour coverage may be prohibitively expensive. Without a 24-hour in-house catheterization laboratory team, there is always the risk of a patient arriving in the laboratory before the catheterization laboratory team, an unsavory scenario because any STEMI patient requires vigilant monitoring and management to avoid and deal with acute clinical decompensation. Variations in the theme of assembling teams comprised critical care nurses, and in-house cardiologists have been proposed to mitigate the risk of the gap between patient arrival and catheterization team arrival to the catheterization laboratory. The care team has standing management orders for events such as hypotension and unstable cardiac rhythms. With implementation an in-house team consisting of an ED nurse, critical care nurse, and chest pain unit nurse, Khot et al[13] demonstrated reductions in door-to-balloon times, particularly during off-hours. For such a strategy to work effectively, it is essential that catheterization laboratory staff arrive within a specific time frame after being paged. In a national study[5] of surveyed hospitals, hospitals that expected staff would be ready to perform PCI within 20 minutes of being paged had shorter door-to-balloon times by 18.8±13.3 minutes, compared with those with a >30-minute expectation.

Implementation of ED bypass requires prehospital identification of STEMI. However, widespread adoption of prehospital ECGs has not yet occurred in the United States, with only a quarter of STEMI patients transported by EMS receiving a prehospital ECG.[6] Factors limiting the use of prehospital ECGs, such as the cost of equipment, training EMS providers in ECG interpretation, and technical limitations on ECG transmission need to be addressed to increase adoption of this strategy. It is important to recognize, however, that even with prehospital identification, not all STEMI care systems will be able to safely implement ED bypass protocols and that many patients with prehospital diagnosis of STEMI will still be evaluated in the ED before transport to the catheterization laboratory. However, a median time of 30 minutes in the ED is unacceptable, and systematic strategies to reduce time spent in the ED need to be implemented to improve reperfusion times. It is possible that ED personnel are not aware of the amount of delay that often occurs. Although some may accept the concept of a 5-minute pit stop in the ED, our study shows that the actual times are far longer. Even during working hours when the catheterization laboratory is often immediately available,

only 1 in 4 times was the interval from ED arrival to catheterization laboratory arrival shorter than 16 minutes, and only 1 in 2 times was it shorter than 24 minutes. Thus, systematic measurement of the time in the ED and regular (monthly) feedback and review with the interdisciplinary STEMI team are important elements for system improvement.

Limitations

Our study has several limitations. The data are observational, registry based, and therefore, subject to unmeasured confounding and bias. Information on the decision to bypass the ED, timing of activation of the catheterization laboratory, immediate availability of the catheterization laboratory, EMS driving distance and times, and other reasons for delays in the ED were not collected, limiting the ability to determine patient and system factors independently associated with time to device activation after first medical contact. Because there were a greater proportion of patients requiring resuscitation before PCI in the group evaluated in the ED, it seems that EMS preferentially directed sicker patients toward the ED. However, longer treatment times associated with evaluation in the ED, even after excluding these higher risk patients, is consistent with the overall results of the study. The decision to bypass the ED was strongly associated with the time of day and the hospital to which the patient was triaged. Although treatment times were shorter both during working and off-hours among patients bypassing the ED, we are unable to ascertain the impact of catheterization laboratory readiness as the reason for the decision to evaluate in the ED or the resulting delay in the ED. In addition, given the variability in proportion of ED bypass across hospitals, the difference in treatment times between the 2 strategies may, in part, reflect unmeasured differences in care processes between hospitals rather than between the 2 strategies alone. However, it is reassuring that timely reperfusion was consistently achieved more frequently with ED bypass compared with ED evaluation in each of the 7 hospitals that frequently performed ED bypass. Our dataset did not permit measurement of whether ED bypass was associated with a greater rate of missed alternative diagnoses or greater rate of false-positive activation of the catheterization laboratory. The study was conducted in North Carolina hospitals, and generalizability of the results to other regions requires further study. Results of this study do not apply to patients who do not have evidence of STEMI on a prehospital ECG or those with STEMI who are transferred from a non-PCI capable center.

Conclusions

Even with prehospital identification of STEMI, and direct transport to a PCI center, only 1 in 2 patients achieved device activation within the guideline-based target time. For patients brought to the ED, a median of 30 minutes is spent in the ED before arrival in the catheterization laboratory, contributing significantly to the failure to achieve timely reperfusion. The strategy to transport patients from the field directly to the catheterization laboratory, thereby bypassing the ED, is used infrequently and represents a potential opportunity to achieve faster reperfusion. Further studies are necessary to develop and test efficient and safe ED bypass protocols for appropriate patients.

Acknowledgments

We acknowledge survey questionnaire participation and response from all 21 North Carolina percutaneous coronary intervention hospitals.

Sources of Funding

This work was supported by an award from the American Heart Association Pharmaceutical Roundtable (0875142 N) and David and Stevie Spina.

Disclosures

Dr Garvey has a working relationship (ie, consulting) with Philips Healthcare. Dr Wilson has a working relationship (ie, consulting) with Abiomed and Boston Scientific. Dr Granger has a working relationship (ie, consulting, research, and educational services) with the following companies: American College of Cardiology Foundation, Astellas Pharma Inc, AstraZeneca, Boehringer Ingelheim, Bristol-Myers Squibb, Elsevier, GlaxoSmithKline, Hoffman LaRoche (Roche Holding), McGraw-Hill Publishing, Medtronic Inc, Merck Sharpe & Dohme (Merck & Co, NJ), Otsuka, Pfizer Inc, Sanofi-Aventis, UpToDate, Inc, and WebMD. Dr Jollis has a working relationship (ie, consulting, research, and educational services) with the following companies: Blue Cross Blue Shield North Carolina, Medtronic Foundation, Sanofi-Aventis, and United Healthcare. The other authors report no conflict.

References

1. Antman EM. Time is muscle: translation into practice. *J Am Coll Cardiol*. 2008;52:1216–1221.
2. 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.
3. O'Gara PT, Kushner FG, Ascheim DD, Casey DE Jr, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB, Krumholz HM, Linderbaum JA, Morrow DA, Newby LK, Ornato JP, Ou N, Radford MJ, Tamis-Holland JE, Tommaso CL, Tracy CM, Woo YJ, Zhao DX, Anderson JL, Jacobs AK, Halperin JL, Albert NM, Brindis RG, Creager MA, DeMets D, Guyton RA, Hochman JS, Kovacs RJ, Kushner FG, Ohman EM, Stevenson WG, Yancy CW; American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2013;127:e362–e425.
4. Bradley EH, Roumanis SA, Radford MJ, Webster TR, McNamara RL, Mattera JA, Barton BA, Berg DN, Portnay EL, Moscovitz H, Parkosewich J, Holmboe ES, Blaney M, Krumholz HM. Achieving door-to-balloon times that meet quality guidelines: how do successful hospitals do it? *J Am Coll Cardiol*. 2005;46:1236–1241.
5. Bradley EH, Herrin J, Wang Y, Barton BA, Webster TR, Mattera JA, Roumanis SA, Curtis JP, Nallamothu BK, Magid DJ, McNamara RL, Parkosewich J, Loeb JM, Krumholz HM. Strategies for reducing the door-to-balloon time in acute myocardial infarction. *N Engl J Med*. 2006;355:2308–2320.
6. Diercks DB, Kontos MC, Chen AY, Pollack CV Jr, Wiviott SD, Rumsfeld JS, Magid DJ, Gibler WB, Cannon CP, Peterson ED, Roe MT. Utilization and impact of pre-hospital electrocardiograms for patients with acute ST-segment elevation myocardial infarction: data from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) Registry. *J Am Coll Cardiol*. 2009;53:161–166.
7. Ortolani P, Marzocchi A, Marrozzini C, Palmerini T, Saia F, Serantoni C, Aquilina M, Silenzi S, Baldazzi F, Grosseto D, Taglieri N, Cooke RM, Bacchi-Reggiani ML, Branzi A. Clinical impact of direct referral to primary percutaneous coronary intervention following pre-hospital diagnosis of ST-elevation myocardial infarction. *Eur Heart J*. 2006;27:1550–1557.

8. Terkelsen CJ, Lassen JF, Nørgaard BL, Gerdes JC, Poulsen SH, Bendix K, Ankersen JP, Gøtzsche LB, Rømer FK, Nielsen TT, Andersen HR. Reduction of treatment delay in patients with ST-elevation myocardial infarction: impact of pre-hospital diagnosis and direct referral to primary percutaneous coronary intervention. *Eur Heart J*. 2005;26:770–777.
9. Bradley EH, Nallamothu BK, Herrin J, Ting HH, Stern AF, Nembhard IM, Yuan CT, Green JC, Kline-Rogers E, Wang Y, Curtis JP, Webster TR, Masoudi FA, Fonarow GC, Brush JE Jr, Krumholz HM. National efforts to improve door-to-balloon time results from the Door-to-Balloon Alliance. *J Am Coll Cardiol*. 2009;54:2423–2429.
10. Jollis JG, Granger CB, Henry TD, Antman EM, Berger PB, Moyer PH, Pratt FD, Rokos IC, Acuña AR, Roettig ML, Jacobs AK. Systems of care for ST-segment-elevation myocardial infarction: a report from the American Heart Association's Mission: Lifeline. *Circ Cardiovasc Qual Outcomes*. 2012;5:423–428.
11. 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.
12. Caputo RP, Kosinski R, Walford G, Giambartolomei A, Grant W, Reger MJ, Simons A, Esente P. Effect of continuous quality improvement analysis on the delivery of primary percutaneous revascularization for acute myocardial infarction: a community hospital experience. *Catheter Cardiovasc Interv*. 2005;64:428–433, discussion 434.
13. Khot UN, Johnson ML, Ramsey C, Khot MB, Todd R, Shaikh SR, Berg WJ. Emergency department physician activation of the catheterization laboratory and immediate transfer to an immediately available catheterization laboratory reduce door-to-balloon time in ST-elevation myocardial infarction. *Circulation*. 2007;116:67–76.
14. 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.
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.e1–851.11.
16. Jollis JG, Al-Khalidi HR, Monk L, Roettig ML, Garvey JL, Aluko AO, Wilson BH, Applegate RJ, Mears G, Corbett CC, Granger CB. Expansion of a regional st-segment elevation myocardial infarction system to an entire state. *Circulation*. 2012;126:189–95.
17. NCDR Elements and Definitions. Action registry—get with the guidelines. https://www.ncdr.com/WebNCDR/docs/default-source/action-v2.3-documents/v2-3-coders-dictionary.pdf. Accessed October 10, 2012.
18. Henry TD, Atkins JM, Cunningham MS, Francis GS, Groh WJ, Hong RA, Kern KB, Larson DM, Ohman EM, Ornato JP, Peberdy MA, Rosenberg MJ, Weaver WD. ST-segment elevation myocardial infarction: recommendations on triage of patients to heart attack centers: is it time for a national policy for the treatment of ST-segment elevation myocardial infarction? *J Am Coll Cardiol*. 2006;47:1339–1345.
19. 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.
20. van de Loo A, Saurbier B, Kalbhenn J, Koberne F, Zehender M. Primary percutaneous coronary intervention in acute myocardial infarction: direct transportation to catheterization laboratory by emergency teams reduces door-to-balloon time. *Clin Cardiol*. 2006;29:112–116.
21. Amit G, Cafri C, Gilutz H, Ilia R, Zahger D. Benefit of direct ambulance to coronary care unit admission of acute myocardial infarction patients undergoing primary percutaneous intervention. *Int J Cardiol*. 2007;119:355–358.
22. Cheskes S, Turner L, Foggett R, Huiskamp M, Popov D, Thomson S, Sage G, Watson R, Verbeek R. Paramedic contact to balloon in less than 90 minutes: a successful strategy for st-segment elevation myocardial infarction bypass to primary percutaneous coronary intervention in a Canadian emergency medical system. *Prehosp Emerg Care*. 2011;15:490–498.
23. 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.
24. Garvey JL, Monk L, Granger CB, Studnek JR, Roettig ML, Corbett CC, Jollis JG. Rates of cardiac catheterization cancelation for ST-segment elevation myocardial infarction after activation by emergency medical services or emergency physicians: results from the North Carolina Catheterization Laboratory Activation Registry. *Circulation*. 2012;125:308–313.
25. Magid DJ, Wang Y, Herrin J, McNamara RL, Bradley EH, Curtis JP, Pollack CV, Jr, French WJ, Blaney ME, Krumholz HM. Relationship between time of day, day of week, timeliness of reperfusion, and in-hospital mortality for patients with acute ST-segment elevation myocardial infarction. *JAMA*. 2005;294:803–812.