Improvement in Care and Outcomes for Emergency Medical Service–Transported Patients With ST-Elevation Myocardial Infarction (STEMI) With and Without Prehospital Cardiac Arrest: A Mission: Lifeline STEMI Accelerator Study

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Background—Patients with ST-elevation myocardial infarction (STEMI) with out-of-hospital cardiac arrest (OHCA) may benefit from direct transport to a percutaneous cardiac intervention (PCI) hospital but have previously been less likely to bypass local non-PCI hospitals to go to a PCI center.

Methods and Results—We reported time trends in emergency medical service transport and care of patients with STEMI with and without OHCA included from 171 PCI-capable hospitals in 16 US regions with participation in the Mission: Lifeline STEMI Accelerator program between July 1, 2012, and March 31, 2014. Time trends by quarter were assessed using logistic regression with generalized estimating equations to account for hospital clustering. Of 13 189 emergency medical service–transported patients, 88.7% (N=11 703; 10.5% OHCA) were taken directly to PCI hospitals. Among 1486 transfer-in patients, 21.7% had OHCA. Direct transport to a PCI center for OHCA increased from 74.7% (July 1, 2012) to 83.6% (March 31, 2014) (odds ratio per quarter, 1.07; 95% confidence interval, 1.02–1.14), versus 89.0% to 91.0% for patients without OHCA (odds ratio, 1.03; 95% confidence interval, 0.99–1.07; interaction P=0.23). The proportion with prehospital ECGs increased for patients taken directly to PCI centers (53.9%–61.9% for those with OHCA versus 73.9%–81.9% for those without OHCA; interaction P=0.12). Of 997 patients with OHCA taken directly to PCI hospitals and treated with primary PCI, first medical contact-to-device times within the guideline-recommended goal of ≤90 minutes were met for 34.5% on July 1, 2012, versus 41.8% on March 31, 2014 (51.6% and 56.1%, respectively, for 9352 counterparts without OHCA; interaction P=0.72).

Conclusions—Direct transport to PCI hospitals increased for patients with STEMI with and without OHCA during the 2012 to 2014 Mission: Lifeline STEMI Accelerator program. Proportions with prehospital ECGs and timely reperfusion increased for patients taken directly to PCI hospitals. **(*J Am Heart Assoc.* 2017;6:e005717. DOI: 10.1161/JAHA.117.005717.)**

Key Words: acute coronary syndrome • cardiac arrest • percutaneous coronary intervention • quality of care • systems of care

Patients with ST-elevation myocardial infarction (STEMI) with out-of-hospital cardiac arrest (OHCA) constitute an important patient population, with significantly higher rates of system delay and mortality relative to patients with STEMI without OHCA.[1] Because STEMI is a common cause of cardiac arrest, obtainment of a 12-lead ECG as soon as possible after return of spontaneous circulation to determine whether acute ST elevation is present is a class 1 recommendation in current OHCA guidelines.[2,3] Because it is impossible to determine the likelihood of neurological recovery of patients with OHCA in the first hours after return of spontaneous circulation, immediate reperfusion of patients with STEMI with OHCA is recommended, regardless of coma or induced temperature management.[2]

Nonetheless, OHCA is a frequently reported reason for failure to meet guideline-recommended goals of timely reperfusion in patients with STEMI.[1,4] Moreover, patients with STEMI with OHCA have previously been less likely to bypass the nearest non–percutaneous cardiac intervention (PCI) hospital to reach a cardiac center relative to patients with STEMI without OHCA.[5] Accordingly, a policy statement from the American Heart Association stresses the need for

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Received January 29, 2017; accepted August 23, 2017.

Clinical Perspective

What Is New?

- After a comprehensive regional systems-of-care program, the Mission: Lifeline STEMI (ST-elevation myocardial infarction) Accelerator project represents the largest US national effort to coordinate STEMI care on a regional basis to date. The project involved 484 hospitals (171 percutaneous cardiac intervention [PCI]–capable hospitals) and 1253 emergency medical service agencies in 16 regions, using standard data collection and regional treatment protocols, and was conducted from 2012 to 2014. Direct transport to PCI hospitals increased for patients with STEMI with and without prehospital cardiac arrest, and proportions with prehospital ECGs and timely reperfusion increased for patients taken directly to PCI hospitals.

What Are the Clinical Implications?

- Despite improvements in proportions with prehospital ECGs, direct transport to a PCI hospital, and timely reperfusion after the Mission: Lifeline STEMI Accelerator project, substantial proportions were not taken directly to PCI centers. In particular, this included patients with cardiac arrest, in whom intensive care treatments often are indicated and are more available at these sites. Given that most citizens in the United States live within 60 minutes of the nearest PCI center, continued and further coordination between emergency medical service agencies and hospitals is needed for optimal regionalization of care.

regional systems of care for patients with OHCA with substantial overlap to the regional systems of care that are recommended for patients with STEMI.[6] In addition to timely catheterization, patients with OHCA may also benefit from temperature management and other intensive care. These services are more likely to be available at a PCI center.[2,3]

Patients with cardiac arrest at the time of first medical contact (FMC) were registered in the Mission: Lifeline STEMI Accelerator project, which represents the largest national effort to coordinate regional STEMI care between hospitals and emergency medical service (EMS) agencies in 16 US regions from 2012 to 2014.[7,8] Using data from the Mission: Lifeline STEMI Accelerator project, we evaluated whether changes in care and outcomes after these initiatives equally applied to patients with and without OHCA. We evaluated temporal changes in the following care and process measures: (1) proportions of patients with and without OHCA with a 12-lead ECG obtained in the prehospital setting, (2) proportions taken directly to a PCI center, and (3) proportions meeting guideline-recommended goals of timely reperfusion. Finally, we evaluated patient characteristics and outcomes according to STEMI and OHCA status.

Methods

The Mission: Lifeline STEMI Accelerator Project

This study uses data from the Mission: Lifeline STEMI Accelerator project that was organized and executed between July 1, 2012 (2012Q3), and March 31, 2014 (2014Q1), in 16 US regions.[7,8] The intervention was initiated on the basis that, although the number of PCI-capable hospitals in recent years has increased by almost 50% and 90% of Americans currently live within 60 minutes of a PCI-capable facility, the organization of the healthcare system, including a highly fragmented EMS system, hinders coordination between EMS providers and hospitals.[8] Ultimately, this leads to system delays and a substantial number of patients who do not meet guideline-recommended goals of timely intervention.[8] Moreover, there is competition among hospitals and physician groups that is a barrier to coordinated care.[8] Because this fragmentation and competition among hospitals and physician groups have hindered the establishment of coordinated treatment plans, procedures, and common regional approaches, Mission: Lifeline STEMI Accelerator aimed to improve regional STEMI patient care through the development of leadership teams, coordinated protocols, shared data collection, and feedback systems for US-based hospitals and EMS agencies. Among 21 regions that applied for project participation, 16 US regions, including 484 hospitals (171 PCI-capable hospitals) and 1253 EMS agencies, met the enrollment criteria. Enrollment criteria included that at least 70% of the PCI-capable hospitals in the region that were participating in the National Cardiovascular Data Registry Acute Coronary Treatment and Intervention Outcomes Network (ACTION) Registry-Get With The Guidelines (ACTION-GWTG and ACTION REGISTRY-GWTG) program[9] committed to report data for at least 6 consecutive quarters. These sites were willing to organize regional leadership and to develop and share protocols for the diagnosis and treatment of patients with STEMI presenting to EMS personnel or non-PCI hospitals. Regional protocols were developed that included common criteria for establishing the diagnosis of STEMI, standards to obtain prehospital ECGs, a system to activate a catheterization laboratory with a single telephone or radio call, plans to treat patients with simple initial regimens, and methods to transport patients according to destination protocols. After hospital enrollment in the ACTION REGISTRY-GWTG and training of leadership, the above outlined protocols were shared and implemented in each region, along with ongoing data reporting to the ACTION REGISTRY-GWTG and feedback through quarterly reports. Furthermore, to change the standard of care and to create sustainable systems, local and regional mechanisms for protocol implementation, such as EMS annual training sessions or state-approved treatment protocols, were used to encourage the implementation of the Mission: Lifeline STEMI Accelerator project initiatives.

Study Population

Only EMS-transported patients with STEMI were included. We included patients transported directly to a PCI hospital and transfer-in patients enrolled in the Mission: Lifeline STEMI Accelerator project from 171 PCI-capable hospitals between July 2012 and March 2014. We excluded a few patients with missing information on cardiac arrest at the time of EMS arrival (FMC). This study does not include patients with OHCA without STEMI.

Study Variables

We included the following variables from the ACTION REGISTRY-GWTG: age, sex, calendar time in year quarter, race/ethnicity, insurance status, medical history (prior MI, prior heart failure, prior PCI, prior coronary artery bypass grafting [CABG], and diabetes mellitus), signs and symptoms at presentation (symptom onset to FMC in minutes, cardiogenic shock, heart failure, reperfusion candidacy, heart rate and systolic blood pressure on admission, and whether STEMI was diagnosed on first or subsequent ECG), revascularization procedures during hospitalization (PCI, CABG, or not treated), and in-hospital complications (death, cerebrovascular attack/stroke, hemorrhagic stroke, cardiogenic shock, heart failure, major bleeding, and reinfarction). Some of the medical history data (prior MI, prior heart failure, prior PCI, and prior CABG) were not available on the ACTION REGISTRY-GWTG short form. As such, missing observations were relatively frequent for these variables.

Exposure Variables

We included OHCA status (defined as cardiac arrest at FMC) and calendar time (consisting of 7 calendar quarters, from 2012Q3 to 2014Q1 as variables of interest. In the analyses, when direct transport to a PCI-capable hospital was not analyzed as an outcome, we also stratified patients according to whether they were transported directly to a PCI-capable hospital or whether they were transfer-in patients.

Outcomes

We assessed the following outcomes: (1) use of prehospital ECGs, (2) direct transport to a PCI-capable hospital versus transfer-in patient, (3) achievement of guideline-recommended goals for FMC-to-device (FMC2D) time for patients treated with primary PCI (guideline goals of ≤90 minutes for patients transported directly to a PCI hospital and ≤120 minutes for transfer-in patients), and (4) in-hospital mortality.

Statistical Analysis

Characteristics were described using counts and percentages for categorical variables and medians with 25th to 75th percentiles for continuous variables, and the extent of missing data was reported. The proportion of patients with prehospital ECG and the proportion taken directly to a PCI center were calculated over calendar time (quarter) and reported graphically, along with 95% Wald confidence limits. Logistic regression was used to assess the association between calendar time (quarter) and outcomes, according to OHCA status, and for direct versus transfer-in patients separately. The linearity of the relationship on a logit scale between quarter and outcomes was tested for each model within each group of interest. A model using a flexible spline function of time was fit, and goodness of fit was compared with that of the model using a linear function of time. Relationships were determined to be approximately linear, except in 2 cases (prehospital ECG among direct presenters and among transfer-in patients) where nonlinearity was observed. However, in these cases, the associations were still monotone; for the purpose of a parsimonious presentation of results, these relationships were modeled as linear. Flexible spline transformations of the continuous variables were used. All models included an interaction term between quarter and OHCA, and the interaction *P* value was provided as a test of whether the trends over time in outcomes were similar in patients with and without OHCA. Estimation with generalized estimating equations with an exchangeable working correlation matrix was used to account for clustering within hospitals. This correlation structure assumes that hospitals are independent and patients within hospitals are equally correlated. *P* values and confidence intervals (CIs) were calculated using robust variance estimates to account for possible misspecification of the correlation structure. Odds ratios (ORs) with 95% CIs were determined for each quarter increase in time for patients with and without OHCA. Unadjusted analyses included calendar time and OHCA in the model. Adjusted analyses were performed for the outcomes of FMC2D time within guideline-recommended goals (≤90 minutes for patients transported directly to a PCI hospital and ≤120 minutes for transfer-in patients) and in-hospital mortality, by including the following baseline covariates in models: age, systolic blood pressure, heart rate, heart failure only, heart failure with shock on admission, baseline troponin ratio (upper limit of normal), initial serum creatinine, and peripheral arterial disease. The percentage of missing data for adjustment variables was low (<4%), so missing continuous variables were imputed to sex-specific median values and missing categorical variables were imputed to the mode. Variables that had a high level of missingness, including prior MI, prior heart failure, prior PCI, and prior CABG, were not available on the short version of the ACTION REGISTRY-GWTG data collection form.

These variables were not included in the adjustment models. Continuous adjustment variables were truncated at the 1st and 99th percentiles. For in-hospital mortality, we also assessed the overall association with direct versus transfer-in status for patients with STEMI with and without OHCA using unadjusted and adjusted logistic regression analyses. All analyses were 2 sided and tested at the nominal 0.05 significance level, and no adjustment was made for multiple hypothesis testing. Thus, results should be interpreted as exploratory rather than confirmatory. Data management and statistical analyses were performed using SAS version 9.4.

Ethics

The project was conducted under the approval of the Duke Institutional Review Board, with a waiver for patient informed consent. The study is approved by the Mission: Lifeline Steering Committee.

Results

Patients

Of 13 189 EMS-transported patients, 88.7% (N=11 703) were transported directly to a PCI hospital and 10.5% (N=1227) of these had OHCA. Among 1486 transfer-in patients, 21.7% (N=322) had OHCA (Figure 1).

Characteristics

Characteristics according to OHCA status and direct versus transfer-in status are shown in Table 1. Relative to patients without OHCA, patients with OHCA were slightly younger (in particular, the transfer-in patients) and were more likely to be men. No substantial differences were seen for race and insurance status between patients with and without OHCA, regardless of whether patients were transported directly to a PCI hospital or were transfer-in patients. Patients without OHCA were more likely to have a medical history of MI and prior PCI relative to patients with OHCA. No substantial differences were seen in other medical history components, including prior heart failure, CABG, or diabetes mellitus.

Signs and Symptoms at Presentation

Symptom onset to FMC measures were shorter for directly transported patients with OHCA relative to directly transported patients without OHCA. This was also the case for transfer-in patients with OHCA relative to transfer-in patients without OHCA (Table 1). Regardless of direct or transfer-in

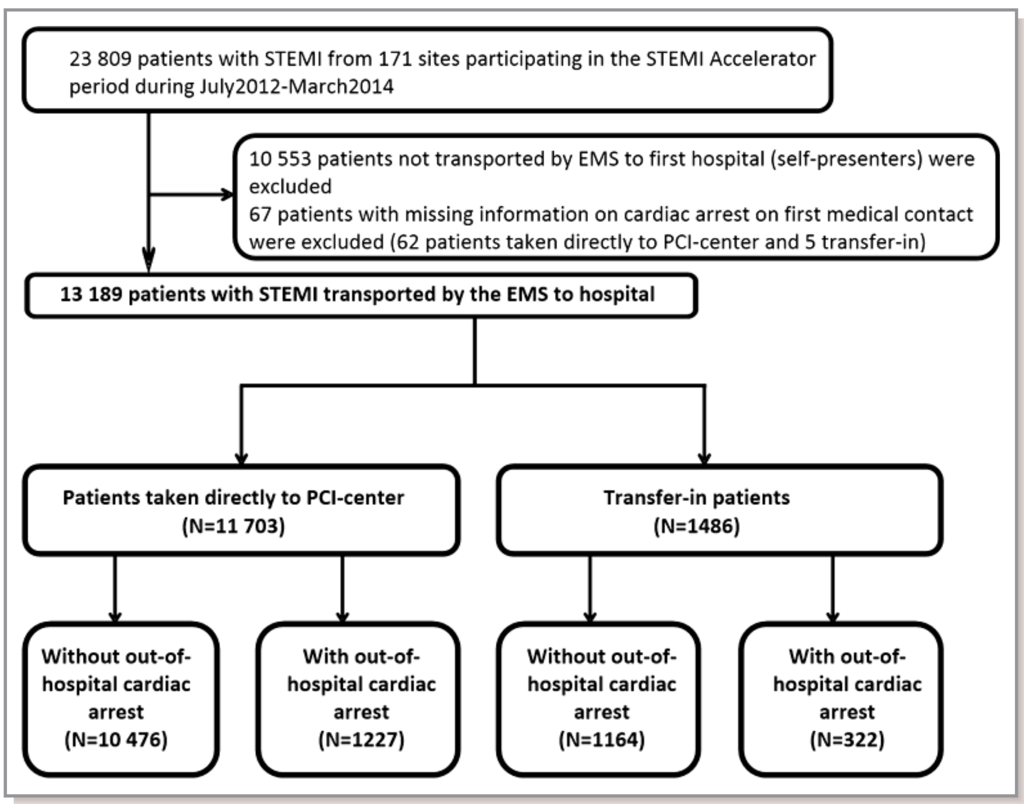

Figure 1. Patient selection process. This figure shows the patient selection process and classification of patients into 4 study groups. EMS indicates emergency medical service; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous cardiac intervention; and STEMI, ST-elevation myocardial infarction.

Table 1. Characteristics and In-Hospital Complications Across the 4 Study Groups

Characteristics	Patients Directly Transported to a PCI Center		Transfer-In Patients	
	Without OHCA (N=10 476)	With OHCA (N=1227)	Without OHCA (N=1164)	With OHCA (N=322)
Demographics				
Age, median (25th–75th percentile), y	62 (53–72)	61 (53–70)	63 (54–73)	59 (52–69)
Male sex, n (%)	7064 (67.4)	897 (73.1)	759 (65.2)	233 (72.4)
Race, n (%)				
Black	1280 (12.2)	174 (14.2)	119 (10.2)	32 (9.9)
White	8498 (81.1)	961 (78.3)	973 (83.6)	268 (83.2)
Other	698 (6.7)	92 (7.5)	72 (6.2)	22 (6.8)
Insurance status, n (%)				
HMO/private	5489 (52.4)	620 (50.5)	606 (52.1)	175 (54.4)
Medicare	2420 (23.1)	297 (24.2)	289 (24.8)	60 (18.6)
Military/VAMC	116 (1.1)	15 (1.2)	16 (1.4)	2 (0.6)
Medicaid	640 (6.1)	66 (5.4)	78 (6.7)	26 (8.1)
Self/none	1667 (15.9)	210 (17.1)	158 (13.6)	58 (18.0)
Other	144 (1.4)	19 (1.6)	17 (1.5)	1 (0.3)
Medical history, n (%)				
Prior myocardial infarction	1404 (13.4)	130 (10.6)	164 (14.1)	38 (11.8)
Missing	3300 (31.5)	399 (32.5)	439 (37.7)	118 (36.7)
Prior heart failure	418 (4.0)	72 (5.9)	60 (5.2)	12 (3.7)
Missing	3304 (31.5)	399 (32.5)	439 (37.7)	117 (36.3)
Prior PCI	1523 (14.5)	109 (8.9)	178 (15.3)	35 (10.9)
Missing	3300 (31.5)	399 (32.5)	439 (37.7)	117 (36.3)
Prior CABG	384 (3.7)	58 (4.7)	50 (4.3)	18 (5.6)
Missing	3304 (31.5)	399 (32.5)	440 (37.8)	117 (36.3)
Diabetes mellitus	2799 (26.7)	341 (27.8)	333 (28.6)	84 (26.1)
Missing	7 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)
Signs and symptoms at presentation				
Symptom onset to FMC, median (25th–75th percentile), min	52 (25–121)	20 (10–48)	90 (55–175)	48 (35–80)
Missing, n (%)	1090 (10.4)	236 (19.2)	139 (11.9)	59 (18.3)
Cardiogenic shock, n (%)	647 (6.2)	660 (53.8)	89 (7.7)	178 (55.3)
Missing, n (%)	9 (0.1)	1 (0.1)	1 (0.1)	1 (0.3)
Heart failure, n (%)	698 (6.7)	203 (16.5)	101 (8.7)	65 (20.2)
Missing, n (%)	7 (0.1)	1 (0.1)	1 (0.1)	0 (0.0)
Reperfusion candidate, n (%)	10 035 (95.8)	1158 (94.4)	1098 (94.3)	299 (92.9)
Missing, n (%)	11 (0.1)	3 (0.2)	1 (0.1)	0 (0.0)
Heart rate on admission, median (25th–75th percentile), bpm	78 (64–92)	82 (46–104)	78 (64–92)	80 (0–100)
Missing, n (%)	19 (0.2)	5 (0.4)	2 (0.2)	3 (0.9)
Systolic BP on admission, median (25th–75th percentile), mm Hg	136 (114–156)	114 (64–143)	136 (114–154)	105 (0–134)
Missing, n (%)	21 (0.2)	6 (0.5)	4 (0.3)	3 (0.9)
STEMI diagnosed on first ECG, n (%)	9090 (86.8)	1054 (85.9)	979 (84.1)	270 (83.9)
Missing, n (%)	12 (0.1)	1 (0.1)	1 (0.1)	1 (0.3)

Continued

Table 1. Continued

Characteristics	Patients Directly Transported to a PCI Center		Transfer-In Patients	
	Without OHCA (N=10 476)	With OHCA (N=1227)	Without OHCA (N=1164)	With OHCA (N=322)
Procedures during hospitalization, n (%)				
PCI	9503 (90.7)	1024 (83.5)	1018 (87.5)	263 (81.7)
Missing	3 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
CABG	388 (3.7)	39 (3.2)	73 (6.3)	13 (4.0)
Missing	11 (0.1)	1 (0.1)	2 (0.2)	0 (0.0)
Complications, n (%)				
In-hospital death	518 (4.9)	440 (35.9)	66 (5.7)	128 (39.8)
CVA/stroke	71 (0.7)	21 (1.7)	14 (1.2)	10 (3.1)
Missing	12 (0.1)	6 (0.5)	1 (0.1)	0 (0.0)
Hemorrhagic stroke (among patients with CVA/stroke)	9 (12.7)	4 (19.0)	2 (14.3)	1 (10.0)
Missing (among patients with CVA/stroke)	1 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)
Cardiogenic shock	835 (8.0)	255 (20.8)	102 (8.8)	64 (19.9)
Missing	12 (0.1)	6 (0.5)	0 (0.0)	0 (0.0)
Heart failure	672 (6.4)	154 (12.6)	89 (7.7)	40 (12.4)
Missing	11 (0.1)	6 (0.5)	0 (0.0)	0 (0.0)
Major bleeding	442 (4.2)	116 (9.5)	55 (4.7)	37 (11.5)
Missing	10 (0.1)	6 (0.5)	0 (0.0)	0 (0.0)
Reinfarction	93 (0.9)	19 (1.6)	11 (1.0)	5 (1.6)
Missing	10 (0.1)	6 (0.5)	0 (0.0)	0 (0.0)

Data show characteristics (demographics, insurance status, medical history, and signs and symptoms at presentation), in-hospital revascularization procedures (PCI and CABG), and in-hospital complications (death, CVA/stroke, proportion with hemorrhagic stroke among patients with CVA/stroke, cardiogenic shock, heart failure, major bleeding, and reinfarction) across the 4 study groups (directly transported vs transfer-in patients with STEMI stratified by prehospital cardiac arrest status). Categorical data are reported as counts (percentages), and missing data are included in analyses of the percentages. Continuous data are reported as medians (25th–75th percentiles). BP indicates blood pressure; bpm, beats per minute; CABG, coronary artery bypass grafting; CVA, cerebrovascular attack; FMC, first medical contact; HMO, health maintenance organization; OHCA, out-of-hospital cardiac arrest; PCI, percutaneous cardiac intervention; STEMI, ST-elevation myocardial infarction; VAMC, Veteran Affairs Medical Center.

status, patients with OHCA were more likely to be seen with cardiogenic shock and heart failure, and correspondingly, patients with OHCA had a lower systolic blood pressure and slightly higher heart rates on admission. More than 90% of all patients were reperfusion candidates, with limited differences between the groups, and ≈95% of the patients without OHCA were subsequently treated with either PCI or CABG relative to ≈90% of the patients with OHCA (Table 1).

Use of Prehospital ECGs

Proportions evaluated with a prehospital ECG increased over time among patients transported directly to a PCI hospital (Figure 2). This increase was seen for both patients with and without OHCA, from 73.9% in 2012Q3 to 81.9% in 2014Q1 for patients without OHCA (trend $P<0.001$) and from 53.9% in 2012Q3 to 61.9% in 2014Q1 for patients with OHCA (trend $P=0.014$; interaction $P=0.12$). Among transfer-in patients, there was a small, but nonstatistically significant, increase over time in the proportion evaluated with a prehospital ECG among patients without OHCA (35.5%–40.0%; trend $P=0.14$). The proportion with a prehospital ECG decreased over time among patients with OHCA (37.1%–15.8%; trend $P=0.14$), with a significantly differing trend (interaction $P=0.033$) between patients with and without OHCA (Figure 2 and Table 2).

Direct Transport to a PCI Center

The proportion with OHCA taken directly to a PCI center increased significantly from 74.7% to 83.6% between 2012Q3 and 2014Q1 (OR per quarter, 1.07; 95% CI, 1.02–1.14; trend $P=0.012$), compared with a more modest increase of 89.0% to 91.0% for patients without OHCA (OR per quarter, 1.03; 95% CI, 0.99–1.07; trend $P=0.11$). The trend in increase was of similar magnitude on the OR scale (interaction $P=0.23$; Figure 3).

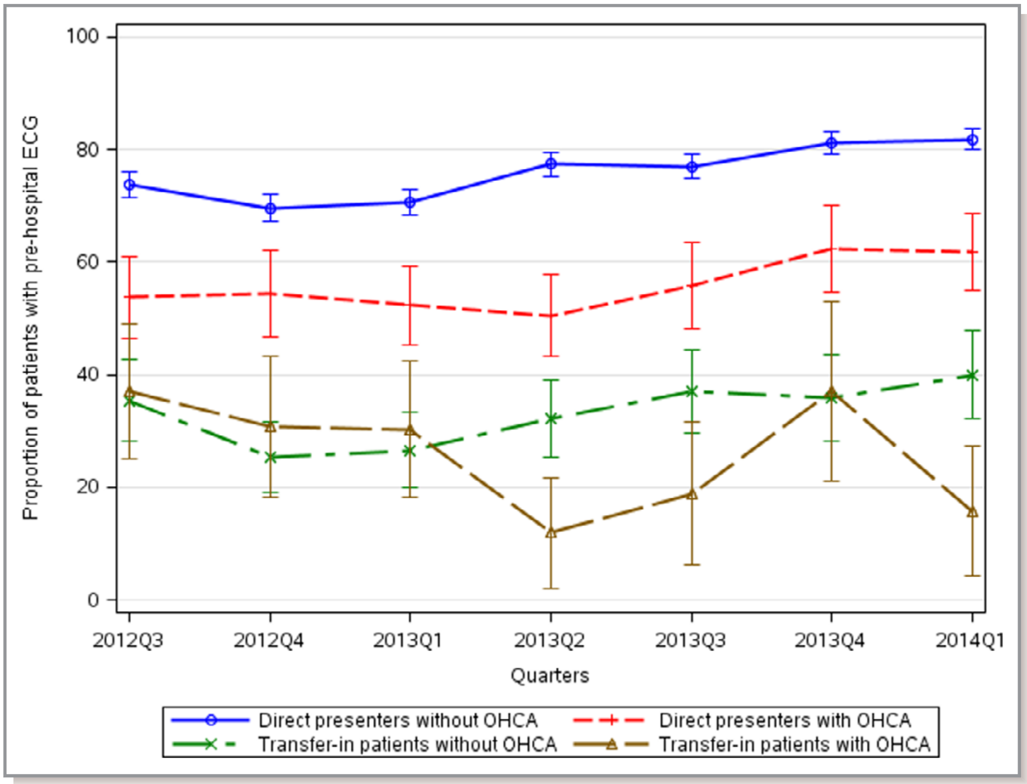

Figure 2. Proportion of patients with prehospital ECG according to the 4 study groups and by quarter. This figure shows temporal changes in proportions evaluated with a prehospital ECG from July 1, 2012 (third quarter 2012 [2012Q3]; from July 1, 2012 to September 30, 2012), to March 31, 2014 (first quarter 2014 [2014Q1]; from January 1, 2014, to March 31, 2014), according to the following study groups: (1) patients without out-of-hospital cardiac arrest (OHCA) taken directly to a percutaneous cardiac intervention (PCI) hospital (blue); (2) patients with OHCA taken directly to a PCI hospital (red); (3) transfer-in patients without OHCA (green); and (4) transfer-in patients with OHCA (brown). 2012Q4 indicates fourth quarter 2012 (from October 1, 2012 to December 31, 2012); 2013Q1, first quarter 2013 (from January 1, 2013, to March 31, 2013); 2013Q2, second quarter 2013 (from April 1, 2013, to June 30, 2013); 2013Q3, third quarter 2013 (from July 1, 2013, to September 30, 2013); and 2013Q4, fourth quarter 2013 (from October 1, 2013, to December 31, 2013).

FMC2D Time

Of 13 189 included patients, 11 586 were treated with primary PCI and were included in analyses of whether guideline-recommended goals of FMC2D times were achieved. Of these 11 586 patients, 10 434 were taken directly to a PCI center (9425 without OHCA and 1009 with OHCA) and 1152 were transfer-in patients (904 without OHCA and 248 with OHCA). FMC2D times were missing for 85 patients (0.8%) who were taken directly to a PCI center (73 of 9425 without OHCA and 12 of 1009 with OHCA) and for 16 patients (1.4%) in the transfer-in group (7 had OHCA and 9 did not have OHCA).

A significantly higher proportion of patients with STEMI without OHCA (N=9352) taken directly to a PCI-capable center were treated with PCI within the guideline-recommended goal of ≤90 minutes in 2014Q1 compared with 2012Q3 (56.1% versus 51.6%; adjusted OR per quarter, 1.04; 95% CI, 1.01–1.06; Table 2). The increase from 34.5% in 2012Q3 to 41.8% in 2014Q1 among patients with OHCA (N=997) taken directly to a PCI center was not statistically significant; however, trends between these patients with and without OHCA were similar (interaction *P*=0.72).

Similarly, among transfer-in patients with OHCA (N=241), a greater proportion met an FMC2D time of ≤120 minutes over time (21.3% in 2012Q3 to 36.7% in 2014Q1; Table 2). Although a small decrease in the proportion treated within guideline-recommended goals was seen among transfer-in patients without OHCA (49.3% in 2012Q3 to 44.4% in 2014Q1), trends did not differ for transfer-in patients with and without OHCA (interaction *P*=0.20).

In-Hospital Complications

In-hospital complications according to OHCA and direct versus transfer-in status are shown in Table 1. Regardless

Table 2. Time Trends in Prehospital ECG Use, FMC2D Time Within Guideline-Recommended Goals, and In-Hospital Mortality for Patients With and Without OHCA Stratified by Direct Versus Transfer-In Status

Outcomes	Unadjusted OR (95% CI)*	*P* Value	Adjusted OR (95% CI) *	*P* Value
Among patients transported directly to a PCI hospital				
Prehospital ECG use				
Overall quarter×OHCA status interaction	···	0.12	···	···
Per-quarter increase among patients with OHCA	1.07 (1.01–1.12)	0.014	···	···
Per-quarter increase among patients without OHCA	1.12 (1.07–1.16)	<0.001	···	···
FMC2D time ≤90 minutes (among PCI-treated patients)				
Overall quarter×OHCA status interaction	···	0.96	···	0.72
Per-quarter increase among patients with OHCA	1.04 (0.98–1.10)	0.23	1.03 (0.97–1.09)	0.37
Per-quarter increase among patients without OHCA	1.04 (1.01–1.06)	0.002	1.04 (1.01–1.06)	0.003
In-hospital mortality (among PCI-treated patients)				
Overall quarter×OHCA status interaction	···	0.16	···	0.18
Per-quarter increase among patients with OHCA	1.04 (0.96–1.12)	0.35	1.05 (0.96–1.15)	0.26
Per-quarter increase among patients without OHCA	0.97 (0.93–1.02)	0.24	0.98 (0.94–1.03)	0.47
Among transfer-in patients				
Prehospital ECG use				
Overall quarter×OHCA status interaction	···	0.033	···	···
Per-quarter increase among patients with OHCA	0.89 (0.77–1.04)	0.14	···	···
Per-quarter increase among patients without OHCA	1.07 (0.98–1.16)	0.14	···	···
FMC2D time ≤120 minutes (among PCI-treated patients)				
Overall quarter×OHCA status interaction	···	0.15	···	0.20
Per-quarter increase among patients with OHCA	1.13 (1.00–1.28)	0.055	1.12 (0.98–1.27)	0.084
Per-quarter increase among patients without OHCA	1.02 (0.96–1.08)	0.53	1.02 (0.96–1.09)	0.52
In-hospital mortality (among PCI-treated patients)				
Overall quarter×OHCA status interaction	···	0.78	···	0.95
Per-quarter increase among patients with OHCA	1.01 (0.88–1.16)	0.89	1.05 (0.90–1.23)	0.51
Per-quarter increase among patients without OHCA	0.99 (0.88–1.10)	0.81	1.05 (0.90–1.22)	0.56

Data show time trends (logistic regression) in prehospital ECG use and proportion meeting guideline-recommended goals of FMC2D time and in-hospital mortality, according to OHCA and direct vs transfer-in status among emergency medical service–transported patients with ST-elevation myocardial infarction. CI indicates confidence interval; FMC2D, first medical contact to device; OHCA, out-of-hospital cardiac arrest; OR, odds ratio; and PCI, percutaneous cardiac intervention.
*Per one quarter increase.

of direct or transfer-in status, patients with OHCA were substantially more likely to experience cardiogenic shock, heart failure, and reinfarction during hospitalization compared with patients without OHCA. Relative to patients without OHCA, those with OHCA were more likely to experience a stroke or major bleeding during hospitalization, in particular transfer-in patients.

In-Hospital Mortality

Overall, in-hospital mortality was 4.9% for patients without OHCA taken directly to a PCI center versus 5.7% for the corresponding transfer-in patients without OHCA. Among patients with OHCA, percentages were 35.9% and 39.8%, respectively (Table 1). For primary PCI-treated patients, in-hospital mortality was 29.8% for patients with OHCA who were transported directly to a PCI hospital versus 35.9% for transfer-in patients with OHCA (OR, 0.76; 95% CI, 0.56–1.02), compared with 4.1% versus 5.3% for directly transported patients without OHCA versus transfer-in patients without OHCA (OR, 0.86; 95% CI, 0.64–1.16; interaction P=0.49). In-hospital mortality rates did not substantially change over time between primary PCI-treated patients with and without OHCA stratified by direct transport versus transfer-in status (interaction P=0.18 for patients transported directly to a PCI hospital, and interaction P=0.95 for transfer-in patients; Table 2).

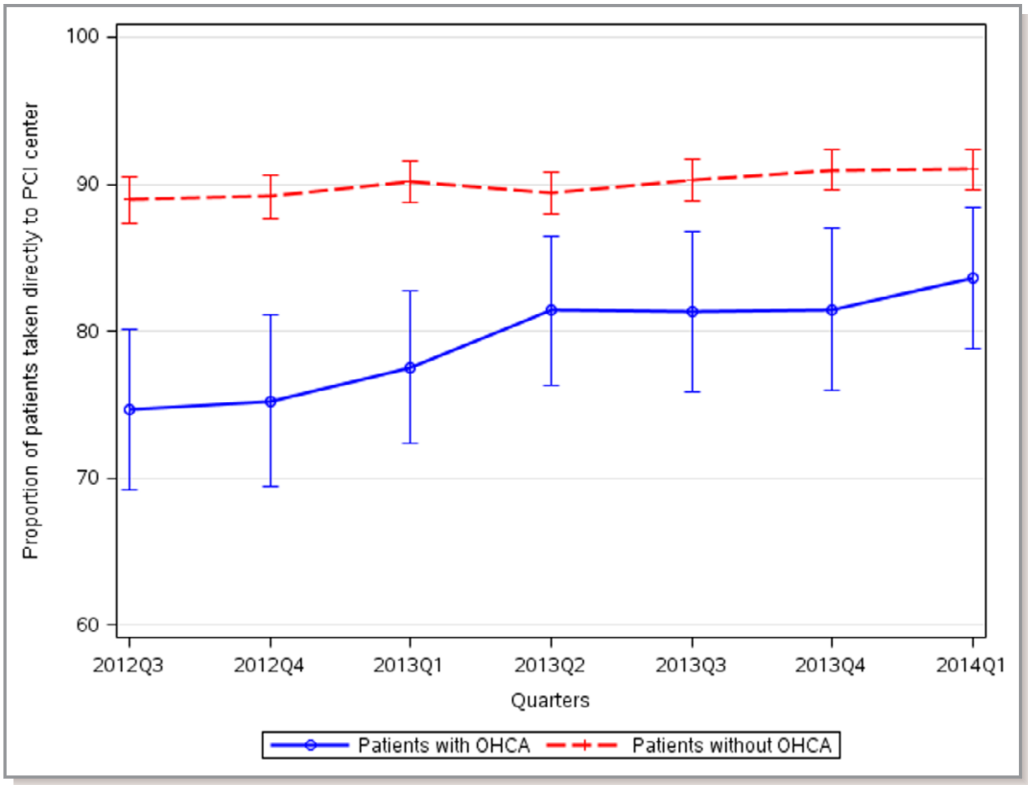

Figure 3. Proportion of patients taken directly to a percutaneous cardiac intervention (PCI) center, according to out-of-hospital cardiac arrest (OHCA) status and quarter. This figure shows temporal changes in proportion of patients with and without OHCA taken directly to a PCI center from July 1, 2012 (third quarter 2012 [2012Q3]; from July 1, 2012 to September 30, 2012), to March 31, 2014 (first quarter 2014 [2014Q1]; from January 1, 2014, to March 31, 2014). 2012Q4 indicates fourth quarter 2012 (from October 1, 2012 to December 31, 2012); 2013Q1, first quarter 2013 (from January 1, 2013, to March 31, 2013); 2013Q2, second quarter 2013 (from April 1, 2013, to June 30, 2013); 2013Q3, third quarter 2013 (from July 1, 2013, to September 30, 2013); and 2013Q4, fourth quarter 2013 (from October 1, 2013, to December 31, 2013).

Discussion

We used data from the Mission: Lifeline STEMI Accelerator project that represents the largest US national effort to organize STEMI care on a regional basis to date. The project involved 484 hospitals (171 PCI-capable hospitals) and 1253 EMS agencies in 16 regions using standard data collection and regional treatment protocols from 2012 to 2014.[7,8] We found that quality of care improved for EMS-transported patients with STEMI with and without OHCA. In both groups, among patients taken directly to a PCI center, we observed significant increases in proportions with prehospital ECGs, and the proportion meeting FMC2D guideline-recommended goals mainly increased for patients without OHCA. Despite these improvements, a substantial proportion did not have prehospital ECGs obtained, were not taken directly to PCI hospitals, and were not treated within guideline-recommended goals. Although in-hospital mortality was significantly higher for patients with OHCA relative to patients without OHCA, mortality only improved slightly over time for both patients with and without OHCA, regardless of direct versus transfer-in status. Thus, significant room for improvement in care and outcomes remains for patients with STEMI with and without OHCA.

Despite decades of evidence, including randomized trial data calling for primary PCI within FMC2D times of ≤90 minutes for direct EMS-transported cases and ≤120 minutes for patients requiring interhospital transfer, up to 30% to 50% of all patients with STEMI are not treated within these guideline-recommended goals for timely reperfusion.[5,10–14] Previous studies have shown that patients with STEMI with OHCA constitute an important subgroup, with significantly higher rates of system delay and mortality relative to patients with STEMI without OHCA.[1] Historically, patients with OHCA with STEMI were less likely to be taken directly to a PCI hospital compared with their counterparts without OHCA.[5] Because STEMI is a common underlying cause of cardiac arrest, guidelines recommend (with a class 1 level of recommendation) that a 12-lead ECG should be obtained as soon as possible after circulation has been restored.[2,3] Also, these guidelines stress that patients with OHCA should be treated with primary PCI just as patients without OHCA, because it is impossible to predict final neurological outcome regardless of coma or temperature management at presentation.[2] For these reasons, this current study was undertaken to investigate whether efforts to improve quality of care for patients with STEMI during the Mission: Lifeline STEMI Accelerator program equally affected populations of patients with and without OHCA.

We reported temporal changes in proportions of EMS-transported cases who had 12-lead ECGs obtained in the prehospital setting, proportions taken directly to PCI centers, and proportions meeting the guideline-recommended FMC2D time goals for patients with STEMI with and without OHCA as measures of changes in quality of care. Although we demonstrate significant increases over the study period in proportions with a prehospital ECG for patients with and without OHCA taken directly to a PCI hospital, substantial differences remained in relation to not only the transfer-in counterparts but also between patients with and without OHCA who were transported directly to a PCI hospital. Despite significantly more patients having prehospital ECGs both over time and in comparison to previous ACTION REGISTRY-GWTG studies, these previous ACTION REGISTRY-GWTG studies demonstrated that prehospital ECGs were associated with greater use of reperfusion therapy, faster reperfusion times, and a trend for lower mortality.[1,15,16] Although use of prehospital ECGs increased for patients taken directly to a PCI-capable facility, the use of prehospital ECGs decreased over time for transfer-in patients, and patients with OHCA were significantly less likely to have a prehospital ECG obtained over time relative to their counterparts without OHCA. Because OHCA is a frequently reported reason for not meeting guideline-recommended goals of FMC2D, it is important to continuously improve the number of patients evaluated with a prehospital ECG and minimize the gaps in quality of care that we show persist between patients with and without OHCA.

We also found significant increases in the proportion of patients transported directly to PCI hospitals, but this increase was only significant among patients with OHCA. This increase is important, because patients with OHCA, in addition to timely catheterization, may benefit from temperature management and other intensive care services that are more available at PCI centers. However, despite the improvement in this quality of care measure for patients with OHCA, patients with STEMI without OHCA were still more likely to be taken directly to a PCI center relative to patients with STEMI without OHCA, in line with previous study findings.[5] Thus, this suggests an opportunity for further improvement in the quality of care for patients with OHCA.

Concurrent with the significant increases in proportions taken directly to PCI hospitals, increases in use of prehospital ECGs were seen for patients taken directly to PCI hospitals. Also, increases in the proportion with FMC2D times within the guideline-recommended goal of ≤90 minutes were seen over time in patients treated with primary PCI, in particular for patients without OHCA. These improvements were not seen for transfer-in patients. Although PCI-capable hospitals in recent years have increased in numbers by almost 50%, and 90% of Americans currently live within 60 minutes of a PCI-capable facility,[17–20] 45% of the patients treated with primary PCI were still not treated within the guideline-recommended goals, in line with previous reports.[5,11,12] Even though improvement may have continued to occur beyond the study measurement period, it is still highly likely that further efforts will be needed to maintain and improve quality of the regional efforts seen in this study. Furthermore, minimal improvements in mortality were seen over time regardless of OHCA and direct versus transfer-in status. Thus, despite substantial efforts to improve care and outcomes and despite significant improvements in quality of care, there remains substantial room for further advances in care and outcomes for both patients with and without OHCA.

Limitations

This study has limitations. First, the observational nature of this study does not allow any conclusions of causal relationships to be made. As such, our study results should be interpreted as associations, as we cannot rule out alternative explanations because of unmeasured confounders. Because the ACTION REGISTRY-GWTG was expanded regionally to institutions and patients who previously would not have been included, treatment times and outcomes had the potential to change over calendar time, independently of the STEMI Accelerator program. Second, we are not able to report data on distance from scene to hospital that is a factor for EMS personnel to consider when having to decide which hospital to transport the patient to. In continuation, the included transfer-in patients in this study may constitute patients with a better prognosis than patients who also initially were taken to a non-PCI hospital but for whom the decision not to transfer the patient was made (ie, because of disease instability [eg, cardiogenic shock]). As such, differences in care and outcomes may be greater than what we reported in this study. Third, data on use of temperature management and other critical care modalities that may benefit patients with OHCA were also not available for reporting in this study. Fourth, we were only able to include patients with OHCA who had a recognized STEMI in this study, which represents a subpopulation of all patients with OHCAs. There is likely a greater potential for improvement of care and outcomes for patients with OHCA who were not identified to have a STEMI on the ECG, yet still had acute coronary disease. Initial ECGs taken just after return of spontaneous circulation are not always reliable and predictable of acute coronary syndrome, suggesting that patients with OHCA without obvious causes of arrest should be transported to a hospital with angiography- and PCI-capable facilities.[21] Moreover, patients with OHCA may also benefit from other guideline-recommended therapies, including target temperature management, that are more available at invasive hospital centers, in line with the American Heart Association policy statement calling for regional systems of care for patients with OHCA.[6] Fifth, hospitals participating in the ACTION REGISTRY-GWTG represent a subset of all hospitals in the United States performing PCI. Hospitals participating in the ACTION REGISTRY-GWTG may possibly have greater focus on quality, timely treatment, and, ultimately, better outcomes compared with other PCI-capable hospitals in the United States. Sixth, measuring quality-of-care indicators over 2 years may be insufficient to detect whether improvement occurred, as improvement may continue to occur beyond the measurement period used in this study. With expanding systems and measurements, patients with greater mortality risks could potentially also have been increasingly included in later quarters relative to the beginning of the Mission: Lifeline STEMI Accelerator project. In addition, there may also be other explanations about why certain outcomes, including mortality, did not substantially change over time (ie, participation and improvements in care and outcomes in the ACTION REGISTRY-GWTG before enrollment in the Mission: Lifeline STEMI Accelerator project). Last, outcomes where minimal changes had occurred over time, or comparisons involving small subgroups, may be subject to false-negative findings.

Conclusions

The Mission: Lifeline STEMI Accelerator program represents the largest US national effort to organize STEMI care on a regional basis to date. The program involved 484 (171 PCI-capable) hospitals and 1253 EMS agencies in 16 regions, with standardized data collection and regional treatment protocols, from 2012 to 2014. Significant increases in care were found in patients with direct transport to a PCI center for those with STEMI with and without OHCA. Proportions with prehospital ECGs and timely reperfusion increased for patients taken directly to PCI hospitals. Despite these improvements, significant differences in these care measures between patients with and without OHCA continued to exist. Substantial proportions of patients with (and without) OHCA did not have prehospital ECGs obtained, were not taken directly to PCI hospitals, and were not treated within guideline-recommended goals of timely reperfusion, which highlight future target areas for quality care improvement.

Sources of Funding

This study is funded by the American Heart Association Mission: Lifeline.

Disclosures

Kragholm reports having received research grants from The Laerdal Foundation and speaker honoraria from Novartis Healthcare Denmark A/S. Roe reports having received research grants from Astra Zeneca, Eli Lilly & Co, Janssen Pharmaceuticals, Sanofi-Aventis, Daiichi-Sankyo, Ferring Pharmaceuticals, and The Familial Hypercholesterolemia Foundation; speaker honoraria from Amgen and Bristol Myers Squibb; and consultant/advisory board fees from Astra Zeneca, Eli Lilly & Co, Daiichi-Sankyo, Amgen, PriMed, Myokardia, Boehringer-Ingelheim, and Merck & Co. Jollis and Granger report having received research grants from The Medtronic Foundation. All remaining authors have no disclosures to report.

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