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Delays in Primary Percutaneous Coronary Intervention in ST-Segment Elevation Myocardial Infarction Patients Presenting With Cardiogenic Shock

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ABSTRACT

OBJECTIVES This study sought to examine whether quality improvement initiatives across multiple ST-segment elevation myocardial infarction (STEMI) systems translated to faster first medical contact (FMC)-to-device times for patients presenting with cardiogenic shock (CS).

BACKGROUND There are limited data describing contemporary rates of achieving guideline-directed FMC-to-device times for STEMI patients with CS.

METHODS From 2012 to 2014, the American Heart Association Mission: Lifeline STEMI Systems Accelerator project established a protocol-guided approach to STEMI reperfusion systems in 484 U.S. hospitals. The study was stratified by CS versus no CS at presentation and performed Cochrane-Armitage tests to evaluate trends of achieving FMC-to-device time targets. A multivariable logistic regression model assessed the association between achieving guideline-directed FMC-to-device times and mortality.

RESULTS Among 23,785 STEMI patients, 1,993 (8.4%) experienced CS at presentation. For direct presenters, patients with CS were less likely to achieve the 90-min FMC-to-device time compared with no-CS patients (37% vs. 54%; $p < 0.001$). For transferred patients, CS patients were even less likely to reach the 120-min FMC-to-device time compared with no-CS patients (34% vs. 47%; $p < 0.0001$). The Accelerator intervention did not result in improvements in the FMC-to-device times for direct-presenting CS patients (p for trend = 0.53), although there was an improvement for transferred patients (p for trend = 0.04). Direct-presenting patients arriving within 90 min had lower mortality rates compared with patients who reached after 90 min (20.49% vs. 39.12%; $p < 0.001$).

CONCLUSIONS Fewer than 40% of STEMI patients presenting with CS achieved guideline-directed FMC-to-device targets; delays in reperfusion for direct-presenting patients were associated with higher mortality. (J Am Coll Cardiol Intv 2018;11:1824–33) © 2018 by the American College of Cardiology Foundation.

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In-hospital mortality rates following ST-segment elevation myocardial infarction (STEMI) events are declining and are 3% to 4% (1). In contrast, mortality from STEMI-associated cardiogenic shock (CS) remains much higher, at 40% to 50% (2,3). The SHOCK (SHould we emergently revascularize Occluded Coronaries for Cardiogenic shocK) trial established early revascularization as a key component of STEMI-related CS management (4). Early revascularization was characterized in the 2013 American College of Cardiology Foundation/American Heart Association (AHA) STEMI guidelines as a first medical contact (FMC)-to-device time of ≤90 min for patients presenting to a percutaneous coronary intervention (PCI)-capable hospital and ≤120 min for transferred patients, who initially presented to non-PCI-capable hospitals (5). The Regional Approach to Cardiovascular Emergencies initiative and the AHA Mission: Lifeline System Accelerator endeavor are examples of regional systems of care programs that reduced the median time to treatment (6,7). Due to the central importance of early revascularization in STEMI complicated by CS, we sought to examine contemporary rates of achieving early revascularization in CS.

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We explored the rates of early revascularization among STEMI patients presenting with CS in the AHA Mission: Lifeline STEMI Systems Accelerator dataset. The Accelerator initiative was a regional system of care intervention that aimed to increase the percentage of STEMI patients achieving guideline recommended FMC-to-device times (7). We hypothesized that patients presenting with CS have longer delays, thus fewer patients would reach the prespecified FMC-to-device time targets. Furthermore, we postulated that better-organized regional systems of care would improve FMC-to-device times and clinical outcomes for patients with CS.

METHODS

This study is a subgroup analysis from the AHA Mission: Lifeline STEMI Systems Accelerator initiative. The Accelerator program methods were previously described (7,8). Briefly, Accelerator was a national educational outcome research study conducted over 7 study quarters from July 2012 to March 2014. The program attempted to boost the implementation of standardized STEMI care systems across the United States. It included 16 regions, 484 hospitals, and 1,253 emergency medical services (EMS) agencies. The Accelerator project was reviewed by the coordinating center's Institutional Review Boards and classified as exempt.

The study intervention involved training leadership, establishing and implementing common regional protocols, and ongoing performance measurement. National leadership also provided consistent feedback to regional teams regarding their process benchmarks. The regional protocol development was led by local experts and centered on core concepts of rapidly establishing the diagnosis of STEMI, activating the catheterization laboratory with a single phone or radio call, and treating the patient with simple standardized and guideline-based initial regimens (7). To assess the intervention's efficacy, comparisons were based on recent historical data for each region. Therefore, each region specified a baseline quarter to assess temporal trends in outcomes.

DEFINITIONS. Cardiogenic shock. This analysis specifically evaluated patients with CS at FMC; we did not include patients who developed CS as an in-hospital complication. The definition of CS at FMC was obtained from the AR-G (Acute Coronary Treatment and Intervention Outcomes Network Registry-Get With The Guidelines) registry data collection form version 2.2. CS is defined as any 1 of 3 possible scenarios that are determined to be secondary to cardiac dysfunction for >30 min: 1) an episode of systolic blood pressure <90 mm Hg; 2) an episode in which the cardiac index is measured as <2.2 l/min/m^2; or 3) the use of parenteral inotropic or vasopressor agents or mechanical support to maintain a systolic blood pressure ≥90 mm Hg or the cardiac index ≥2.2 l/min/m^2 (9).

CARDIAC ARREST. Cardiac arrest (CA) at FMC was defined by the AR-G registry data collection form as: 1) received attempts at external defibrillation (by lay responders or emergency personnel) or chest compressions by organized EMS or emergency department (ED) personnel; or 2) were pulseless but did not receive attempts to defibrillate or cardiopulmonary resuscitation by EMS personnel.

OUTCOMES. The primary outcome for the Accelerator initiative and this CS-focused analysis was change in percentage of patients meeting guideline goals of FMC-to-device times (≤90 min for direct presenters and ≤120 min for transferred patients) over the 6 quarters post-baseline quarter compared with the baseline quarter. Observed in-hospital outcomes were also presented, including

ABBREVIATIONS AND ACRONYMS

AHA = American Heart Association
CA = cardiac arrest
CS = cardiogenic shock
ED = emergency department
EMS = emergency medical services
FMC = first medical contact
IQR = interquartile range
PCI = percutaneous coronary intervention
STEMI = ST-segment elevation myocardial infarction

TABLE 1 Baseline Characteristics

	No-CS	CS*	p Value
Patients	91.7 (21,792)	8.3 (1,993)	<0.001
Demographics			
Age, yrs	60 (52-70)	63 (55-72)	<0.001
Female	33.1 (660)	28.9 (6,307)	<0.001
White	82.4 (17,959)	81.3 (1,619)	0.12
Comorbidities			
Diabetes mellitus	26.3 (5,727)	29.9 (596)	<0.001
Prior MI	17.5 (2,575)	17.0 (238)	0.67
Prior PCI	19.1 (2,822)	17.1 (240)	0.07
Prior CABG	5.4 (795)	7.1 (100)	0.01
Mode of arrival			
EMS	47.9 (10,441)	65.9 (1,313)	<0.001
Self	28.8 (6,283)	10.8 (215)	<0.001
Transferred	23.3 (5,068)	23.3 (465)	<0.001
Presenting features on FMC			
Symptom onset to FMC, min	72 (34-179)	40 (17-105)	<0.001
Heart rate, beats/min	80 (67-94)	75 (48-100)	<0.001
Systolic BP, mm Hg	142 (122-163)	95 (71-129)	<0.001
Cardiac arrest	4.4 (960)	48.8 (965)	<0.001
Treatment strategy			
Medically managed	5.9 (1,276)	9.8 (196)	<0.001
PCI	90.2 (19,654)	84.3 (1,679)	<0.001
CABG	4.1 (901)	5.4 (107)	0.01

Values are % (n) or median (interquartile range). *There were patients (n = 140)with cardiogenic shock (CS) who were deemed not to be candidates for reperfusion. The most common reason was "other" (70 cases) and "missing" (40 cases). There were patients (n = 236) who were reperfusion candidates but percutaneous coronary intervention (PCI) was not performed. The primary reasons given for PCI not being performed were anatomy not suitable to primary PCI (n = 93), other (n = 53), missing (n = 30), and quality-of-life decision (n = 28).

BP = blood pressure; CABG = coronary artery bypass grafting; EMS = emergency medical services; FMC = first medical contact; MI = myocardial infarction.

reinfarction, heart failure, bleeding events, stroke, and mortality.

STATISTICAL METHODS. The STEMI Systems Accelerator cohort was stratified into 2 cohorts: CS and no CS. Descriptive statistics were described as median (interquartile range [IQR]) for continuous variables and number (percentage) for categorical variables. The statistical tools to compare continuous variables for patient characteristics were Wilcoxon rank-sum test for 2-group comparisons and Kruskal-Wallis test for >2 group comparisons. The Pearson chi-square test or the Fisher exact test were employed for categorical variables. The Cochran-Armitage test for trend was used to portray temporal trends. We created multivariable logistic regression models to determine the association between in-hospital mortality and achieving guideline-directed FMC-to-device times of ≤90 min for direct presenters and ≤120 min for transfer patients. The variables included in this model were obtained from the ACTION (Acute Coronary Treatment and Intervention Outcomes Network) registry in-hospital mortality model (10). We excluded CS from the variable list but included CA and FMC-to-device time; all included variables are presented in Online Appendix. Generalized estimating equations were employed to account for possible in-hospital clustering. To examine the role of CA as an effect modifier for the association between FMC-to-device time and mortality among patients with CS, we performed interaction testing for both adjusted models of direct-presenting patients and transferred patients. All statistical tests were performed at the 0.05 significance level, and the statistical analyses were performed with SAS version 9.4 (SAS Institute, Cary, North Carolina).

RESULTS

BASELINE CHARACTERISTICS. There were 23,785 patients included in the STEMI Systems Accelerator program; 1,993 (8.3%) had CS at presentation. The baseline characteristics are presented in Table 1. CS patients, in comparison with no-CS patients, were older (median age was 63 years vs. 60 years) and had higher rates of diabetes (29.9% vs. 26.3%) and prior coronary artery bypass grafting (7.1% vs. 5.4%). The presenting features at FMC for patients with CS as opposed to no CS included shorter symptom onset-FMC times (40 min vs. 72 min), lower blood pressures (95 mm Hg vs. 142 mm Hg), and higher rates of CA (48.8% vs. 4.4%).

Patients with CS, in comparison with patients with no CS, were less likely to present as self-transport (10.8% vs. 28.8%) and more likely to arrive via EMS (65.9% vs. 47.9%). A similar proportion of CS (23.3%) and no-CS (23.3%) patients were transferred from a non-PCI-capable institution to a PCI-capable center (Table 1). Transferred patients with CS presented to the index hospital less often by self-transport versus EMS (44.5% vs. 55.2%).

IN-HOSPITAL OBSERVED OUTCOMES. The rates of revascularization for patients with CS versus patients with no CS were the following: PCI, 84.3% versus 90.2%; coronary artery bypass grafting, 5.4% versus 4.1%; and none, 10.3% versus 5.7%. The median in-hospital length of stay in days for patients with CS was 4 days (IQR: 2 to 9 days). Patients without CS had a median in-hospital length of stay was 3 days (IQR: 2 to 4 days). CS patients, compared with no-CS patients, had higher unadjusted rates of in-hospital events (Table 2), including heart failure at discharge (15.3% vs. 5.4%), bleeding (11.0% vs. 3.7%), and stroke (2.5% vs. 0.6%). Observed in-hospital mortality among CS patients (34.4%) was higher than that of no-CS patients (3.5%). Figure 1 demonstrates the mortality trend for both CS and no-CS cohorts; there is no significant trend for a change in mortality over

TABLE 2 In-Hospital Outcomes Stratified by CS

	No-CS	CS	p Value
Post-admission reinfarction	0.9 (184)	1.3 (25)	<0.001
Heart failure at discharge	5.4 (1,184)	15.3 (303)	<0.001
Bleeding event	3.7 (802)	11.0 (218)	<0.001
Stroke	0.6 (137)	2.5 (49)	<0.001
Mortality	3.5 (754)	34.4 (686)	<0.001

Values are % (n).
CS = cardiogenic shock.

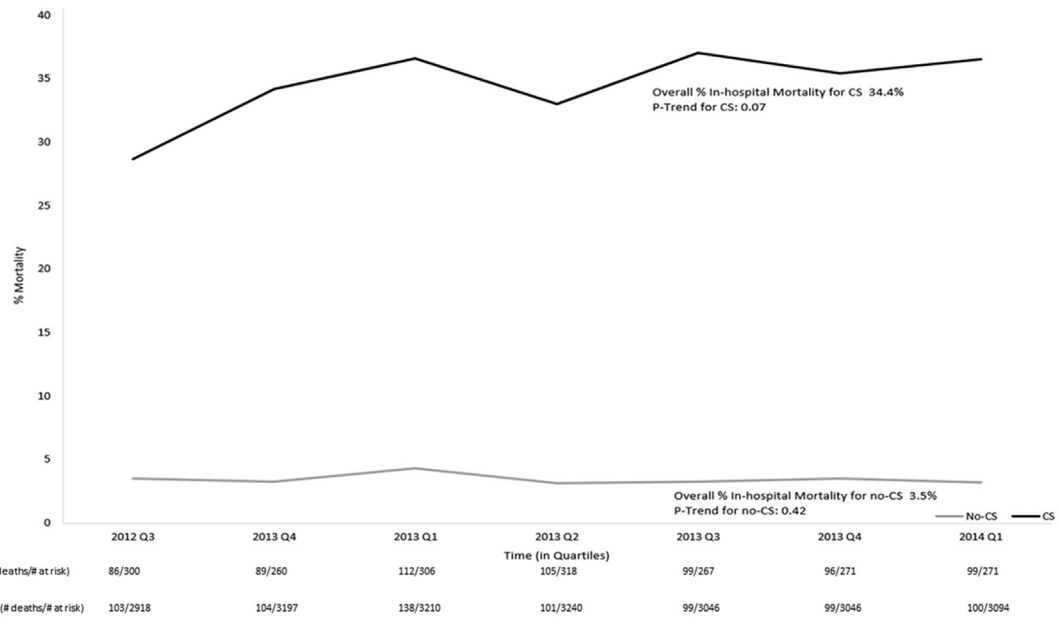
the 7 quarters for either the no-CS (p for trend = 0.42) or CS (p for trend = 0.07) groups.

ED DWELL TIME. The mean ED dwell time for all CS patients was 40 min (IQR: 25 to 59 min) compared with 38 min (IQR: 24 to 54 min) for no-CS patients. The mean ED dwell time exceeded 30 min in 67.9% of CS patients and 65.0% of no-CS patients.

FMC-TO-DEVICE TIMES. Direct-presenting patients. The median FMC-to-device was longer for patients with CS. The median FMC-to-device times for patients with CS was 101.0 min (IQR: 109.0 to 125.5 min), whereas it was 88.0 min (IQR: 71.0 to 109.0 min) for no-CS patients. Fewer direct-presenting CS patients achieved a FMC-to-device time ≤90 min compared with no-CS patients (36.7% vs. 54.5%; p < 0.001). Figure 2A graphically depicts the proportion of direct-presenting patients who achieved a FMC-to-device time ≤90 min. Over the course of the study, there was no significant change in the percentage of patients with CS achieving goal FMC-to-device times (quarter 1: 38.6%, quarter 7: 35.8%; p for trend = 0.53). A sensitivity analysis of direct-presenting patients with CS but no CA did not reveal a statistically significant trend in improvement of FMC-to-device times (p = 0.98). Alternatively, there was a statistically significant increase in the proportion of no-CS patients reaching an FMC-to-device time ≤90 min (quarter 1: 50.9%, quarter 7: 57.0%; p for trend < 0.001).

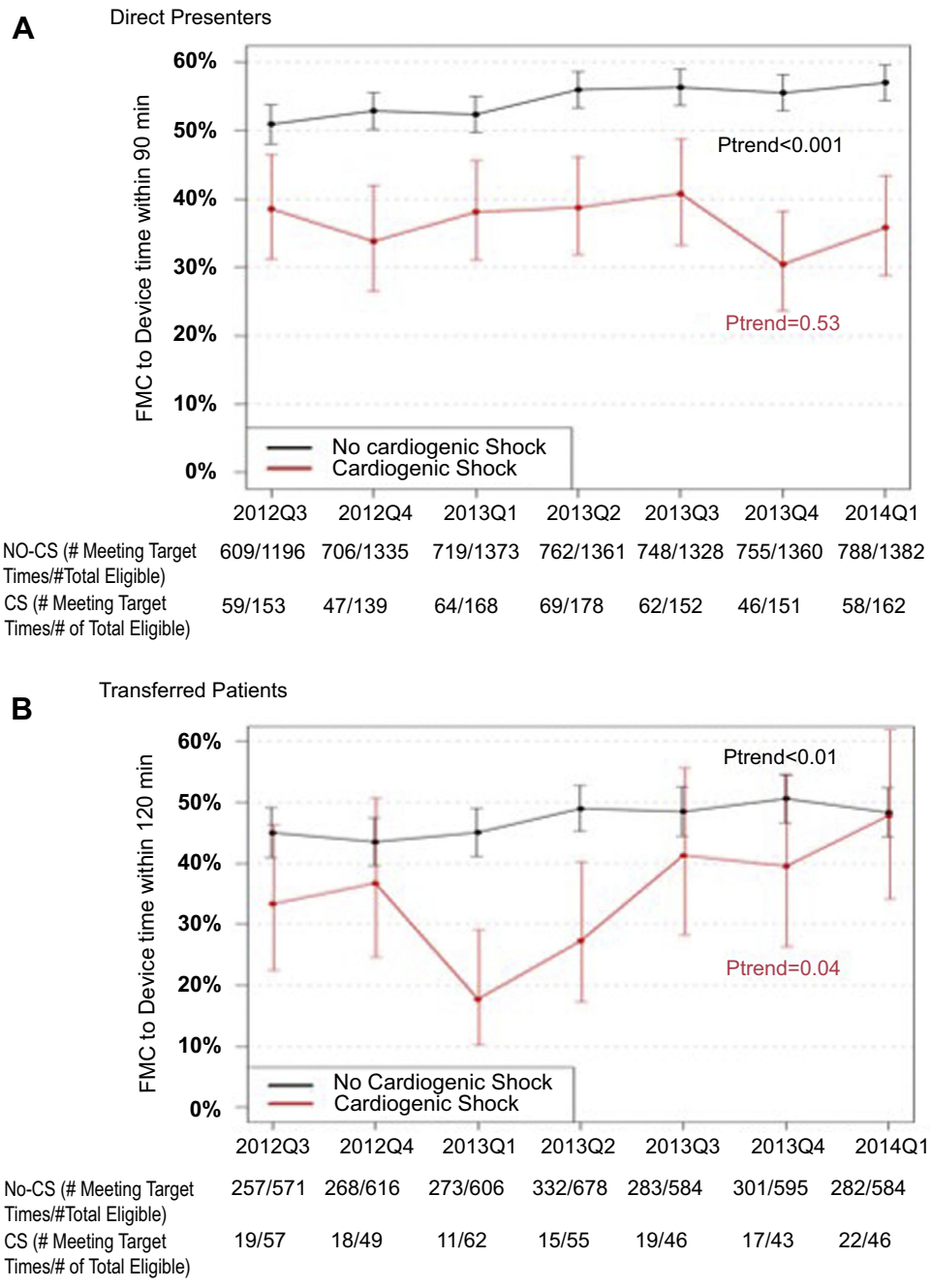
Transferred patients. The median FMC-to-device times for transferred patients with CS was 148 min (IQR: 109 to 216 min), and for patients without CS it was 126 min (IQR: 99 to 182 min). The door-in–door-out times were 67.5 min (IQR: 45 to 111 min) for patients with CS compared with 58 min (IQR: 40 to 91 min) for patients with no CS. Transferred patients with CS reached their guideline-directed FMC-to-device goal of ≤120 min less frequently compared with transferred patients without CS (33.8% vs. 47.1%; p < 0.0001). Figure 2B reflects the temporal trend of the proportion of patients achieving FMC-to-device targets for transferred patients. Among transferred patients, there is a statistically significant trend toward a higher

FIGURE 1 In-Hospital Mortality



In-hospital mortality trend over time stratified by presence of cardiogenic shock (CS). Q = quartile.

FIGURE 2 Proportion of ST-Segment Elevation Myocardial Infarction Patients Achieving Target FMC-to-Device Times

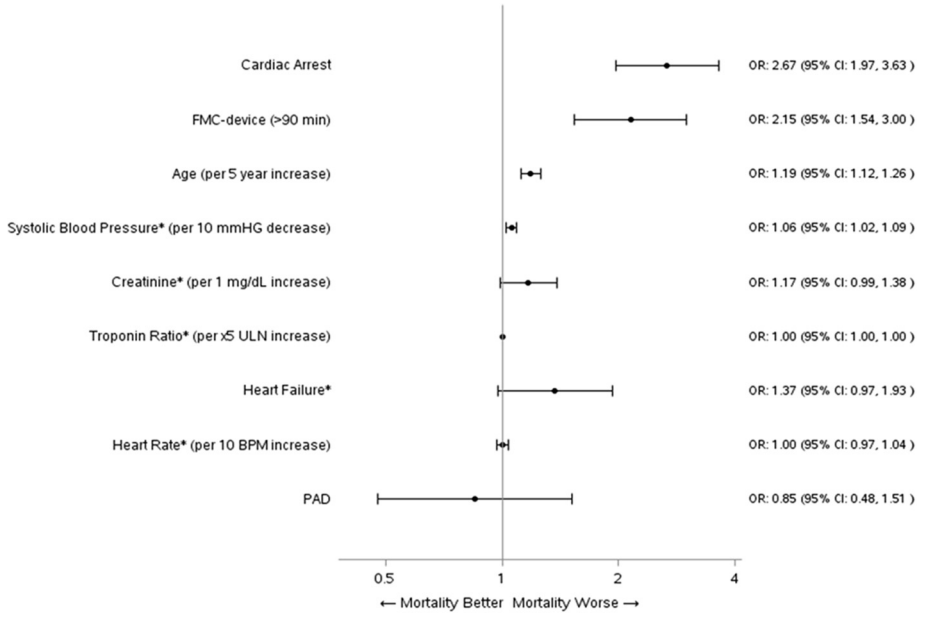


Temporal trend of the proportion of ST-segment elevation myocardial infarction patients achieving a first medical contact (FMC)-to-device time of **(A)** <90 min for direct presenters or **(B)** <120 min for transferred patients stratified by presence of CS. Abbreviations as in Figure 1.

proportion of patients reaching their guideline-directed goal of FMC-to-device time ≤120 min for both cohorts: CS (quarter 1: 33.3%, quarter 7: 47.8%; p for trend = 0.04) and no CS (quarter 1: 45.0%, quarter 7: 48.3%; p for trend = 0.01).

ADJUSTED ASSOCIATIONS OF FMC-TO-DEVICE TIME AND MORTALITY AMONG CS PATIENTS. For direct-presenting CS patients there is an association between achieving a FMC-to-device time ≤90 min and a reduced risk of mortality. Patients with CS who

FIGURE 3 Factors Associated With Mortality for Direct-Presenting CS Patients



Forest plot of factors associated with mortality for direct-presenting CS patients. BPM = beats per minute; CI = confidence interval; OR = odds ratio; PAD = peripheral artery disease; ULN = upper limit of normal; other abbreviations as in Figures 1 and 2.

arrived within 90 min had a 20.49% mortality rate compared with 39.12% among patients who reached >90 min. After adjustment, the odds ratio with respect to mortality for patients with FMC-to-device time >90 min compared with ≤90 min was 2.15 (95% confidence interval: 1.54 to 3.00; $p < 0.001$). Other factors significantly associated with increased risk of mortality include age (per 5-year increase), systolic blood pressure (per 10-mm Hg decrease), and CA (Figure 3). This model had a C statistic of 87.9%.

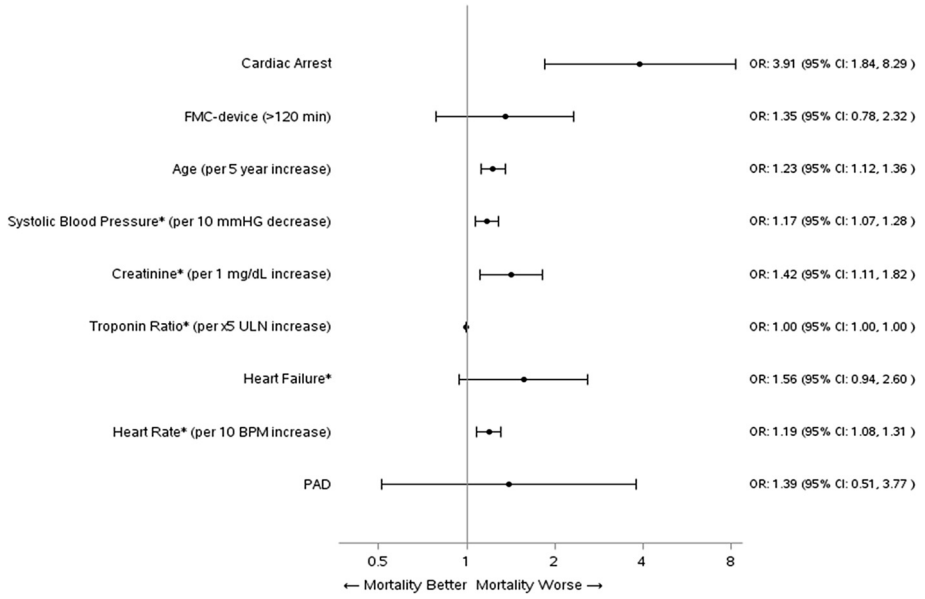
Among transferred patients with CS, there was a lower rate of mortality among patients who met the guideline-directed FMC-to-device time of ≤120 min (19.83% vs. 35.10%). However, this relationship was not statistically significant after multivariable modeling; the odds ratio for FMC-to-device time of >120 min versus ≤120 min, and mortality was 1.35 (95% confidence interval: 0.78 to 2.32; $p = 0.28$). For transferred patients with CS, the factors that were significantly associated with mortality included age (per 5-year increase), baseline creatinine (per 1-mg/dl increase), systolic blood pressure (per 10-mm Hg decrease), heart rate at presentation (per 10-beats/min increase), and CA (Figure 4). This model had a C-statistic of 91.5%.

INTERSECTION OF CS AND CA. Almost one-half of the patients presenting with CS also had CA (n = 965, 48.8%), these patients had the highest mortality, at 46.1%. The mortality rates for patients: without CS or CA was 2.8%, no CS but CA was 17.4%, and CS but no CA was 23.4% (Online Figure 1). There was no change in the proportion of patients presenting with CA among either the CS or no-CS cohorts during the course of the Accelerator intervention (Online Figure 2).

To further characterize patients who successfully achieved goal FMC-to-device times, the Accelerator cohort was stratified into 4 groups: no CS and no CA, no CS and CA, CS and no CA, CS and CA (Online Figure 3). Patients with both CS and CA had the lowest level of achieving FMC-to-device times, at 29.2%. Patients with either CS or CA achieved FMC-to-device times approximately 42% of the time, and patients with neither CS nor CA met the target 51.9%.

These data are further characterized by route of presentation to the coordinating hospital (Online Table 1). The majority of patients with both CS and CA (72.5%) reached the hospital as direct presenters, while 27.5% of patients with both CS and CA presented as transfers. Direct-presenting patients with

FIGURE 4 Factors Associated With Mortality for Transferred CS Patients



Forest plot of factors associated with mortality for transferred CS patients. Abbreviations as in Figures 1 to 3.

CS but without CA reached the 90-min FMC-to-device time at a rate of 44.0%; however, patients with both CS and CA had a successful 90-min FMC-to-device time in only 28.4% of cases. Transferred patients with CS but without CA achieved a 120-min FMC-to-device time in 34.8% of cases; alternatively, patients with both CS and CA met the target goal at rate of 31.5%. The interaction of CS and CA, within the adjusted models for the relationship of FMC-to-device time and mortality, resulted in a p value of 0.009 for direct presenters and 0.009 for transferred patients.

DISCUSSION

Early revascularization is the only proven therapy to reduce the high mortality levels in STEMI complicated by CS (4,5). Using data from the AHA Mission: Lifeline STEMI Systems Accelerator project, we sought to examine contemporary rates of early revascularization in CS patients. Our study had 3 key findings. First, fewer than 40% of patients with CS achieved their guideline-recommended FMC-to-device targets. Second, over the course of 7 quarters, the Accelerator regional system of care intervention did not result in a statistically significant improvement in the FMC-to-device target times for direct-presenting CS patients but did demonstrate an improvement in FMC-to-device times for transferred patients with CS. Third, direct-presenting CS patients who did not achieve their guideline-directed FMC-to-device times had higher mortality rates compared with patients who successfully met FMC-to-device targets, including after accounting for the presence of CA. These findings are novel and in a contemporary dataset underscore the high rate of STEMI patients with CS who do not achieve guideline recommended FMC-to-device times. Future STEMI regional system of care initiatives should incorporate protocols targeted toward patients with CS.

Our findings that fewer than 40% of STEMI patients presenting with CS met their guideline-directed FMC-to-device times are sobering. There are numerous reasons that might influence the long FMC-to-device times for patients presenting with CS. CS patients are critically ill, and CA occurred in almost one-half of CS patients. To facilitate safe transportation, EMS personnel may be required to perform additional time-consuming interventions (obtain intravenous access, securing airways, and performing cardiopulmonary resuscitation) that lead to delays. Similar challenges may affect ED providers; moreover, clinicians may need to rule out pathologies such as aortic dissections that need surgical treatment. Interventional cardiologists may be

compelled to first stabilize patients by deploying mechanical circulatory support devices before addressing the infarct-related artery. Although managing critical illness may create some unavoidable delays, we postulate some delays may be unrelated to CS and are potentially avoidable; moreover, these delays may be minimized through STEMI systems of care that focus on critically ill patients.

The primary outcome of our analysis was the change in the proportion of patients with CS achieving their FMC-to-device times over the duration of the Accelerator program. For direct-presenting patients with CS, there was no improvement in the rate of patients achieving FMC-to-device times. For transferred CS patients, there was a statistically significant improvement in the proportion of patients reaching goal FMC-to-device times, although the degree of improvement was small. These results may be explained by the lack of specialized focus on high-risk STEMI patients with CS or CA in the Accelerator program. Our findings suggest that to improve the FMC-to-device times among these high-risk patients, it is insufficient only to implement a STEMI regional system of care. Rather, specific protocols devised for patients with CS and CA are also needed. These protocols may include approaches to hemodynamic support devices that are required for some patients with CS (11). To optimally deploy and manage these hemodynamic devices, thoughtful systems-based work is needed to coordinate the various team members. Accordingly, several institutions are adopting a multidisciplinary team-based approach to CS management (12). The management of mechanical circulatory support requires advanced training, thus patients with CS may be best cared for at high-volume centers (13). A recent AHA scientific statement on the contemporary management of CS advocated for a model of high-volume hospitals used as hubs for regional systems of care dedicated to CS care (14). An example of a coordinated effort focused on myocardial infarction patients with CS care is the Detroit Cardiogenic Shock Initiative. This initiative started with 5 regional centers that agreed upon utilizing a common protocol for patients with myocardial infarction and CS (15). As additional CS-based systems develop, an important focus area is the creation of protocols dedicated to managing complications that commonly accompany STEMI patients presenting with CS, such as CA, heart failure, and respiratory failure.

Prior studies have demonstrated that systems-related delays to timely reperfusion are associated with higher rates of morbidity and mortality, our work supports these findings in STEMI patients with CS (16,17). We found that in comparison with CS patients who did not achieve their guideline-directed FMC-to-device time, patients reaching their target times had lower mortality rates. Importantly, our analysis was not designed to establish causality; the lower rate of mortality may suggest that patients without delayed FMC device times have less severe disease. Moreover, the delays in achieving target FMC device times may have resulted due to appropriate measures required to first stabilize a critically ill patient. Due to the need to stabilize critically ill patients, perhaps STEMI patients with CS should have different FMC-to-device target times. Additional work needs to be done to establish the optimal reperfusion time targets for patients with CS.

Through the 6 quarters of the Accelerator project, there was no significant change in mortality for patients with or without CS. There are several possible reasons for the lack of a decline in mortality rates among CS patients in our study. First, it is possible that the study duration was not long enough to demonstrate an effect on mortality. Second, as systems mature, there may be an increase of patients who were previously dying in the field surviving until hospital admission (18). Notably, the proportion of CA patients through the duration of Accelerator did not change (Online Appendix). Third, the pathophysiology of CS is multifactorial and complex; Kapur and Esposito (19) have proposed 3 key pillars to address in CS: augmenting coronary perfusion, reducing left ventricular pressure and volume, and providing sufficient perfusion to end organs. Therefore, it is conceivable that for CS patients, solely improving FMC-to-device times is not sufficient to stem the spiral of mortality.

We found a large overlap between patients presenting with CS and CA; these patients had the lowest rates of achieving goal FMC-to-device times and the highest rates of mortality. Our findings illuminating the increasingly large overlap between CS and CA build on data from the National Inpatient Survey and the ACTION (Acute Coronary Treatment and Intervention Outcomes Network) registry (20,21). There is limited information guiding management of these particularly high-risk patients. For example, should there be different temperature targets for CA patients who have concurrent CS? A small 14-patient study suggests that the hemodynamics of cooled post-arrest patients with shock physiology may differ from similar normothermic patients (22). The combination of CS and CA may have important clinical

implications and should be the focus of further investigations.

STUDY LIMITATIONS. First, CS was not a prespecified subgroup in Accelerator, a large national educational outcome research initiative. Hence results must be interpreted with caution (23). Second, the study data were collected from the AR-G registry data collection form version 2.2, which does not contain some important CS-related variables or critical care-pertinent factors. For example, the definition of CS assumes cardiac dysfunction, but our dataset lacks the granularity to describe hypotension due to the Bezold-Jarisch reflex. Furthermore, we did not have data regarding inotropes, mechanical support devices, mechanical ventilation, or right heart catheterization values. Therefore, our findings may be influenced by unmeasured confounding. Third, the effect estimates may have been affected by cointervention bias, as participating hospitals could have instituted changes during our study intervention. Fourth, the Hawthorne effect may have altered the treatment effect, as individuals and hospital systems may behave differently during a regional system-of-care initiative as opposed to during routine clinical practice. Fifth, there was variation in the level of implementation of recommended changes across the different regions included in the Accelerator program (18). Sixth, hospitals participated in this study voluntarily, which may limit generalizability, as it is possible that not all hospital systems have an equal interest in quality improvement.

CONCLUSIONS

Timely reperfusion is a central component of STEMI-related CS management; however, <40% of patients with CS reached their guideline-directed FMC-to-device time targets. Patients with CS who achieved FMC-to-device time goals had lower mortality rates. These findings suggest the need for regional systems-of-care endeavors focused on management specific to high-risk STEMI patients with CS.

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PERSPECTIVES

WHAT IS KNOWN? Mortality rates of STEMI patients complicated by CS remain very high, at 40% to 50%, and the only therapy shown to reduce mortality is early revascularization.

WHAT IS NEW? Our findings reveal that only 37% of direct-presenting and 33% of transferred STEMI patients with CS achieved their guideline-directed FMC-to-device time targets. Patients who achieved their FMC-to-device goals had lower mortality rates when compared with patients who did not reach these targets. The STEMI regional system-of-care intervention did not improve FMC-to-device times for patients with CS.

WHAT IS NEXT? These data should spur additional work to identify modifiable causes for delays in treatment and inform the development of regional systems of care that are targeted toward high-risk patients with CS.

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KEY WORDS cardiac arrest, cardiogenic shock, first-medical-contact to device, mortality, regional systems of care, STEMI, treatment delays

APPENDIX For an expanded list of covariates that were used in the ACTION Mortality model as well as supplemental figures and a table, please see the online version of this paper.