CORONARY ARTERY DISEASE

Editor’s Choice

A Hospital-Wide System to Ensure Rapid Treatment Time Across the Entire Spectrum of Emergency Percutaneous Intervention

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Objectives: This study's aim was to describe a hospital-wide system to deliver rapid door-to-balloon time across the entire spectrum of emergency percutaneous intervention. Background: Many patients needing emergency PCI are excluded from door-to-balloon public reporting metric; these groups do not achieve door-to-balloon times <90 min and have increased mortality rates. Methods: We prospectively implemented a protocol for patients with STEMI or other emergency indication for catheterization mandating (1) emergency department physician or cardiologist activation of the catheterization lab and (2) immediate patient transfer to an immediately available catheterization lab by an in-house nursing transfer team. Results: From September 1, 2005 to December 31, 2008, 526 consecutive patients underwent emergency PCI. Median door-to-balloon time was 68 min with 85.7% <90 min overall. Important subgroups included primary emergency department (62.5 min), cardiorespiratory arrest (71 min), cardiogenic shock (68 min), need for temporary pacemaker or balloon pump (67 min), initial ECG without ST-elevation (66.5 min), transfer from another ED (84 min), in-hospital (70 min), and activation indications other than STEMI (68 min). Patients presenting to primary ED and in transfer were compared to historical controls. Treatment <90 min increased

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Mean infarct size decreased, as did hospital length-of-stay and admission total hospital costs. Acute myocardial infarction all-cause 30-day unadjusted mortality and risk-standardized mortality ratios were substantially lower than national averages. Conclusion: A hospital-wide systems approach applied across the entire spectrum of emergency PCI leads to rapid door-to-balloon time, reduced infarct size and hospitals costs, and low myocardial infarction 30-day all-cause mortality.

Key words: angioplasty and stenting; quality improvement; percutaneous coronary intervention; stents; healthcare costs; public reporting

INTRODUCTION

The importance of time to reperfusion in primary percutaneous coronary intervention (PCI) for ST-elevation myocardial infarction (STEMI) has been clearly demonstrated with a powerful relationship between delays in door-to-balloon time and increased mortality [1]. Intense focus on door-to-balloon time by cardiologists and hospitals has led to a substantial increase in the proportion of STEMI patients with door-to-balloon times ≤90 min from 44.2% in 2005 to 91.4% in 2010 in a Medicare public reporting database [2]. The Medicare public reporting database, however, only includes a small minority of patients undergoing emergency percutaneous intervention (Fig. 1). In one series, the public reporting measure only included 13% of STEMI patients as STEMI patients with an initial ECG without ST elevation and in-hospital and transfer STEMI patients are all excluded [3]. In addition, public reporting of door-to-balloon time has been associated with an increase in patients excluded due to “acceptable” nonsystem delays from 3.7% in 2005 to 8.1% in 2010 [2]. Finally, many emergency percutaneous intervention patients with indications other than ST-elevation such as refractory unstable angina, NSTEMI, and cardiac arrest are not included within systems to improve door-to-balloon time. In contrast to improvements in the Medicare public reporting database, patients with reported nonsystem delays as well as in-hospital and transfer STEMI fail to achieve a median door-to-balloon time ≤90 min and have a substantially higher mortality [4–7]. A comprehensive hospital-wide system to ensure timely reperfusion within 90 min in all emergency PCI patients is needed and may be a novel strategy to reduce myocardial infarction mortality. Therefore, we present the impact on door-to-balloon time and mortality of a strategy of emergency department physician or cardiologist one-call activation of the catheterization lab combined with immediate physical transfer of the patient to an immediately available catheterization lab by in-house nursing staff prospectively applied across the entire spectrum of emergency PCI.

METHODS

Study Design and Protocol Description

This prospective study was conducted between October 1, 2004 and December 1, 2008 at St. Francis Hospital and Health Center (Beech Grove and Indianapolis, IN), a 591-bed tertiary care community hospital consisting of two campuses 7 miles apart. Details of the hospital system, the protocol during the historical control period (October 1, 2004–August 31, 2005) and characteristics of the enrolled patients during the historical control period have been previously reported [8]. Beginning September 1, 2005, we prospectively enrolled a consecutive series of patients with emergency catheterization lab activation irrespective of clinical indication, manner or timing of presentation, activating physician, or location within the hospital. We mandated the ED physicians to activate the catheterization lab for STEMI in the emergency department; cardiologists could activate the catheterization lab for any patient requiring emergent catheterization independent of indication (i.e., STEMI, refractory unstable angina, NSTEMI, unstable angina, NSTEMI, Cardiac Arrest).
cardiogenic shock, or cardiac arrest) or location (i.e., emergency department, inpatient floor, or intensive care unit; Fig. 2). The emergency department physician or cardiologist contacted the hospital operator to activate the catheterization lab. The operator subsequently paged the cardiology physician assistant, catheterization lab coordinator, and a critical care unit nurse during regular hours or the on-call cardiologist, interventional cardiologist, critical care unit nurse, chest pain unit nurse, and the on-call catheterization team during off-hours. Four catheterization staff members take home call during off-hours and are expected to arrive to the hospital within 30 min of laboratory activation.

Following catheterization lab activation, the in-house Emergency Heart Attack Response Team (EHART™), consisting of an emergency department nurse, a critical care unit nurse, and a chest pain unit nurse initiated a policy of immediate transfer of the patient to an immediately available catheterization lab. The critical care unit nurse proceeded to the patient’s location and initiated a standard resuscitation order set with the emergency department or bedside nurse (if patient was not in the emergency department). The nurses then proceeded to immediately transfer the patient to the catheterization lab. The only exceptions to immediate transfer by the nursing staff included hemodynamic compromise (requiring vasopressors, temporary pacing, or balloon pump) and ongoing CPR; these patients were prepared for immediate transfer but transferred by the nursing staff with the cardiologist. The critical care unit nurse could administer dopamine or norepinephrine intravenous drips, perform defibrillation, and direct intubation by respiratory therapy all without prior physician approval in case of sustained hypotension or arrest. The Critical Care Unit modified the work requirements for the EHART™ nurse by assigning the nurse one patient instead of two patients.

To make the cath lab immediately available during regular hours, the catheterization lab coordinator identified a room and staff for the patient. The lab coordinator could remove an elective patient from the lab if the case had not started (defined as cardiologist fully scrubbed at bedside obtaining access). If all rooms were occupied with cases in progress, then the STEMI patient went to the first available room. Upon patient placement on the catheterization lab table, the Emergency Heart Attack Response Team members transferred the patient’s nursing care to the catheterization team.

To make the cath lab immediately available during off-hours, the chest pain unit nurse proceeded to the catheterization lab, activated the catheterization lab imaging equipment, and confirmed that the temporary pacemaker, balloon pump, defibrillator, and activated clotting time machine were in working order. This individual subsequently assisted the critical care unit nurse and emergency department nurse in the initial setup of the patient including placement on the catheterization table, monitoring equipment setup, prepping of groins, and assistance with the sterile catheterization lab table. The emergency department nurse and critical care nurse monitored the patient until the third and fourth catheterization staff members arrived and subsequently transferred nursing care to the catheterization team. If the patient was unstable, all staff attended to the patient until safe transfer of care was possible.

For cath lab activations by emergency department (ED) physicians, all activities in the emergency department, during the transfer to the catheterization lab, and during initial setup in the catheterization lab did not require cardiologist presence or input. The cardiologist evaluated the patient and confirmed the appropriateness for emergency catheterization in the emergency department, en route to the catheterization lab, or in the catheterization lab.
Study Endpoints and Statistical Analysis

Median door-to-balloon time was the primary endpoint and was defined as follows: [1] door-to-balloon time for primary emergency department patients, [2] first door-to-balloon time for transfer patients, [3] activating ECG-to-balloon time for patients without ST-elevation on first ECG and in-hospital, and [4] activation-to-balloon time for patients with activating indication other than STEMI. Secondary endpoints included the proportion of door-to-balloon times ≤90 min, infarct size measured by peak creatinine kinase within the first 24 hr [9–11], hospital costs (total, direct, and indirect), and hospital length of stay. Hospital cost data reflect the actual costs involved in the delivery of care to each patient and were determined by the hospital’s cost-accounting software (Alliance for Decision Support, Avega Health Systems, El Segundo, CA). Mortality was determined by hospital medical record review and via query of Social Security Death Index. Using a national mortality database, we analyzed 30-day all-cause unadjusted mortality and 30-day all-cause risk-standardized mortality ratios for patients diagnosed with acute myocardial infarction for our hospital compared to national averages for the time periods.

Fig. 3. Summary of 679 consecutive emergency catheterization lab activations according to indication and origin of patient. ECG = Electrocardiogram, STEMI = ST-Elevation Myocardial Infarction.
| TABLE I. Demographics, Initial Presentation Characteristics, and Treatment Outcomes in STEMI and Emergent Activation Patients Undergoing PCI |
|-------------------------------------------------|-------------------------------------------------|-----------------|-------|
| STEMI activation + PCI (N = 466) | Emergent indication activation + PCI (N = 60) | P value |
| Age, y | 60 ± 13 | 59 ± 13 | 0.449 |
| Female gender | 148 (31.8) | 13 (21.7) | 0.136 |
| **Health insurance** | | | |
| Private | 241 (51.7) | 35 (58.3) | 0.7368 |
| Medicare | 160 (34.3) | 19 (31.7) | ... |
| Medicaid | 15 (3.2) | 1 (1.7) | ... |
| Self-pay | 50 (10.7) | 5 (8.3) | ... |
| **Medical history** | | | |
| Current smoker | 228 (48.9) | 23 (38.3) | 0.132 |
| Diabetes | 85 (18.2) | 11 (18.3) | 1 |
| Hypertension | 273 (58.6) | 32 (53.3) | 0.488 |
| Hypercholesterolemia | 240 (51.5) | 34 (56.7) | 0.494 |
| Family history of CHD | 156 (33.5) | 28 (46.7) | 0.061 |
| Congestive heart failure | 21 (4.5) | 5 (8.3) | 0.203 |
| COPD | 45 (9.7) | 3 (5) | 0.340 |
| Prior carotid disease | 7 (1.5) | 2 (3.3) | 0.274 |
| Prior PCI | 113 (24.2) | 18 (30) | 0.343 |
| Prior CABG | 24 (5.2) | 9 (15) | 0.0076 |
| PVD | 29 (6.2) | 10 (16.7) | 0.0078 |
| Stroke | 15 (3.2) | 1 (1.7) | 1 |
| **Initial presentation** | | | |
| Regular hours | 159 (34.1) | 8 (13.3) | 0.0010 |
| Transferred to PCI | 79 (17) | 5 (8.3) | 0.094 |
| **Symptom onset to arrival** | | | |
| ≤1 h | 183 (46.2) | 16 (38.1) | 0.0240 |
| >1–2 h | 96 (24.2) | 5 (11.9) | ... |
| >2–6 h | 74 (18.7) | 11 (26.2) | ... |
| >6–12 h | 25 (6.3) | 4 (9.5) | ... |
| >12 h | 18 (4.5) | 6 (14.3) | ... |
| Unknown | 70 (15) | 18 (30) | 0.0056 |
| Chest pain at presentation | 423 (90.8) | 56 (93.3) | 0.636 |
| Prehospital ECG | 120 (25.8) | 9 (15) | 0.079 |
| Ambulance arrival | 207 (44.4) | 13 (21.7) | 0.0007 |
| Field defibrillation | 17 (3.6) | 0 (0) | 0.240 |
| Field CPR | 13 (2.8) | 0 (0) | 0.379 |
| Field intubation | 7 (1.5) | 0 (0) | 1 |
| Heart rate, bpm | 78 ± 21 | 81 ± 20 | 0.294 |
| Systolic blood pressure, mm Hg | 139 ± 41 | 139 ± 33 | 0.987 |
| Diastolic blood pressure, mm Hg | 81 ± 22 | 82 ± 19 | 0.761 |
| **Location of infarct** | | | |
| Anterior | 153 (32.8) | N/A | ... |
| Inferior | 278 (59.7) | N/A | ... |
| Lateral (isolated) | 31 (6.7) | N/A | ... |
| LBBB | 4 (0.9) | N/A | ... |
| ECG leads with ST-elevation | | | |
| 2 | 84 (18.1) | N/A | ... |
| ≥4 | 241 (52.1) | N/A | ... |
| ≥5 | 138 (29.8) | N/A | ... |
| Elevated cardiac troponin | 459 (98.5) | 53 (88.3) | <0.0001 |
| Cardiogenic shock | 83 (17.8) | 8 (13.3) | 0.471 |
| Cath lab activation | 378 (81.1) | 7 (11.7) | <0.0001 |
| ED physician | 88 (18.9) | 53 (88.3) | ... |
| Cardiologist | 449 (96.6) | 59 (98.3) | 1 |
| Medical therapy | 382 (82.2) | 53 (88.3) | 0.4597 |
| Heparin | 447 (95.9) | 56 (93.3) | 0.092 |
| Glycoprotein IIb/IIIa inhibitor | 442 (94.8) | 54 (91.5) | 0.357 |
of July 2008 and June 2008 and July 2006 to June 2009. All patients provided informed consent, and our institutional review board approved the study.

Time values are presented as medians with interquartile ranges and were analyzed using one sample Wilcoxon signed rank test against a median value of 90 min. The proportion of patients with door-to-balloon ≤90 min was compared to the goal of 75% by the binomial test. Continuous data are presented as means ± standard deviation and were analyzed by two sample t-tests. Categorical data are presented as proportions and were analyzed by Fisher’s exact test. P < 0.05 was considered statistically significant. Stata Software (version 8.2, College Station, TX) and Prism (version 6.0d, La Jolla, CA) were used for statistical analyses.

**TABLE I. Continued**

| Stem-Related Artery | STEMI activation + PCI | Emergent indication activation + PCI | P value |
|---------------------|------------------------|--------------------------------------|---------|
| Bivalirudin          | 4 (0.9)                | 1 (1.7)                              | 0.456   |
| Thrombolytics       | 14 (3)                 | 0 (0)                                | 0.386   |
| In-hospital cardiopulmonary arrest | 46 (9.9)  | 3 (5)                                | 0.342   |
| In-hospital defibrillation before PCI | 27 (5.8)  | 0 (0)                                | 0.060   |
| In-hospital CPR prior to PCI | 17 (3.6)  | 1 (1.7)                              | 0.708   |
| In-hospital intubation prior to PCI | 29 (6.2)  | 2 (3.3)                              | 0.561   |
| Temporary pacemaker before PCI | 29 (6.2)  | 0 (0)                                | 0.063   |
| IABP before PCI     | 5 (1.1)                | 0 (0)                                | 1       |
| IABP after PCI      | 46 (9.9)               | 6 (10)                               | 1       |
| Catheterization results |                     |                                      |         |
| Infarct-related artery |                     |                                      |         |
| Left main           | 2 (0.4)                | 2 (3.3)                              | 0.0056  |
| Left anterior descending | 170 (36.5) | 17 (28.3)                           | ...     |
| Left circumflex     | 59 (12.7)              | 16 (26.7)                            | ...     |
| Right coronary      | 225 (48.3)             | 25 (48.3)                            | ...     |
| Bypass graft        | 10 (2.1)               | 2 (3.3)                              | ...     |
| Treatment           |                       |                                      |         |
| Balloon angioplasty only | 61 (13.1)  | 15 (25)                              | 0.1085  |
| Balloon angioplasty/stent | 401 (86.1) | 45 (75)                              | ...     |
| Balloon angioplasty/angiogel | 3 (0.6)  | 0 (0)                                | ...     |
| Balloon angioplasty/rotoblation/stent | 1 (0.2)  | 0 (0)                                | ...     |
| Type of stent       |                       |                                      |         |
| Bare metal stent    | 218 (54.2)             | 21 (46.7)                            | 0.080   |
| Drug-eluting stent  | 181 (45)               | 22 (48.9)                            | ...     |
| Bare metal stent and | 3 (0.7)               | 2 (4.4)                              | ...     |
| drug-eluting stent  |                       |                                      |         |
| Interventional cardiologist experience, years | 11 ± 10 | 11 ± 10                              | 0.828   |
| Mean infarct size, peak | 1,683 ± 2,494e | 975 ± 1,656d  | 0.0378  |
| creatine kinase IU/L |                       |                                      |         |
| Mean DRG relative weight | 2,6806 ± 1,605 | 2,8054 ± 2,6235 | 0.603   |
| Mean total hospital costs, $ | 20,408 ± 16,830 | 20,197 ± 13,833 | 0.926   |
| Mean direct hospital costs, $ | 13,853 ± 11,960 | 13,624 ± 9,879 | 0.887   |
| Mean indirect hospital costs, $ | 6,554 ± 4,993 | 6,574 ± 4,066  | 0.977   |
| Mean hospital length of stay, day | 4 ± 4 | 5 ± 4 | 0.412 |
| Mean time in coronary care unit, h | 58 ± 74 | 58 ± 72 | 0.976 |
| All cause in-hospital mortality | 23 (4.9) | 2 (3.3) | 0.756 |
| All cause 30 day mortality | 27 (5.6) | 2 (3.3) | 0.761 |
| All cause 1 year mortality | 36 (7.7) | 3 (5) | 0.785 |
| All cause 1 year mortality | 36 (7.7) | 3 (5) | 0.604 |

Values are expressed as mean ± SD or n (%). ED, emergency department; CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; PCI, percutaneous intervention; CABG, coronary artery bypass grafting; PVD, peripheral vascular disease; ECG, electrocardiogram; CPR, cardiopulmonary resuscitation; LBBB, left bundle branch block; cath lab, catheterization laboratory; IABP, intra-aortic balloon pump; and DRG, diagnosis-related group.

^n = 465.

^b^n = 59.

^c^n = 446.

^d^n = 57.
RESULTS

STEMI accounted for 83.1% of 673 consecutive emergency catheterization lab activations (Fig. 3). The proportion undergoing diagnostic catheterization was slightly higher in the STEMI activation group compared to indications other than STEMI (98.6% vs. 94.7%, P = 0.0194) while the proportion undergoing PCI was markedly higher in the STEMI group (83.4% vs. 52.6%, P < 0.0001).

STEMI patients had lower rates of prior CABG and peripheral vascular disease compared to patients with indications other than STEMI (Table I). Patient with indications other than STEMI were more likely to have off-hours cath lab activations, self-transportation, and left circumflex involvement as the infarct-related artery. Emergency department physicians accounted for 81.1% of cath lab activations for STEMI but only 11.7% of activations for indications other than STEMI.

Compared to historical controls, the clinical profile of STEMI patients undergoing PCI originating from the primary emergency department and in transfer (Groups A1 and A3 from Fig. 3) was similar (Supporting Information, Appendix). The proportion treated within 90 min increased from 28.3% to 85.3% (P < 0.0001; Table II). There was a 10-fold increase in the treatment within 45 min and a nearly 10-fold reduction in treatment requiring >120 min (P < 0.0001). Mean infarct size, hospital length of stay, total and direct hospital costs all decreased. PCI unadjusted all-cause in-hospital, 30-day, and 1 year mortality were unchanged.

For all patient types, median door-to-balloon time was 68 min with 85.7% of patients treated within 90 min (Table III). For STEMI patients presenting to the primary emergency department (Fig. 3, Group A1), a median door-to-balloon time less than 90 min was achieved overall and in every subgroup. Similarly, the goal of 75% of patients to be treated within 90 min was achieved except in patients with prior CABG and patients presenting without chest pain. Furthermore, all emergency PCI patient subgroups achieved a median door-to-balloon time < 90 minute; nearly all achieved the goal of 75% of patients within 90 min except for STEMI transfer patients and those with STEMI in-hospital.

Compared to national averages, there were substantially lower unadjusted 30-day all-cause mortality for acute myocardial infarction and 30-day all-cause risk-standardized mortality ratios for the time periods of July 2008 and June 2008 and July 2006 to June 2009 (Fig. 4).

DISCUSSION

Our study is the first description of a hospital-wide systems approach to achieve rapid door-to-balloon time by implementing a uniform strategy across the entire spectrum of emergency PCI. This consistent

### Table II. Door-to-Balloon Time, Infarct Size, Hospital Length of Stay, Costs, and All-Cause Mortality Before and After Process Change in Primary and Transfer ED Patients

|                  | Cardiology only activation/routine transfer | ED physician + cardiologist activation/immediate transfer |
|------------------|--------------------------------------------|--------------------------------------------------------|
|                  | October 1, 2004–August 31, 2005 (N = 60)     | September 1, 2005–December 31, 2008 (N = 382)          |
| Door-to-balloon (min) |                                            |                                                       |
| ≤45              | 1 (1.7)                                    | 65 (17)                                                |
| 46–60            | 5 (8.3)                                    | 77 (20.2)                                              |
| 61–90            | 11 (18.3)                                  | 184 (48.2)                                             |
| 91–120           | 15 (25)                                    | 38 (9.9)                                               |
| >120             | 28 (46.7)                                  | 18 (4.7)                                               |
| Mean infarct size, peak creatinine kinase, IU/L | 2,623 ± 3,329                               | 1,677 ± 2,585                                           |
| Mean hospital length of stay, days | 6 ± 7                                       | 4 ± 3                                                  |
| Mean DRG relative weight | 3.67 ± 2.52                                 | 2.67 ± 1.57                                            |
| Mean total hospital costs, $ | 26,826 ± 29,497                            | 19,712 ± 15,338                                        |
| Mean direct hospital costs, $ | 19,585 ± 21,946                             | 13,395 ± 11,002                                        |
| Mean indirect hospital costs, $ | 7,240 ± 7,571                               | 6,317 ± 4,471                                          |
| All-cause in-hospital mortality | 3 (5.0)                                    | 16 (4.2)                                               |
| All-cause 30-day mortality | 3 (5.0)                                    | 20 (5.2)                                               |
| All-cause 180 day mortality | 4 (6.7)                                    | 24 (6.3)                                               |
| All-cause 1 year mortality | 4 (6.7)                                    | 29 (7.6)                                               |

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performance in door-to-balloon time was evident in patients at high risk for delayed door-to-balloon time, transfer patients, and patients requiring emergency PCI for indications other than STEMI (Fig. 5). Important secondary benefits included a 35% reduction in myocardial infarct size, a decrease in hospital length of stay by 2 days, and a more than $7,000 reduction in total costs for the hospital admission. Most importantly, although PCI-related mortality did not change, both unadjusted and risk-adjusted mortality for all acute myocardial infarction patients at 30 days were dramatically lower than national averages.

Delays in door-to-balloon time can be ascribed to either system-centered delays or patient-related reasons [12]. System-centered delays, such as delay in cath lab staff arrival, are believed to be amenable to process improvement. Patient-related reasons, such as cardiac arrest or the need for additional procedures, are believed to be appropriate justifications for delayed door-to-balloon times. However, our data indicate that virtually every patient subgroup including cardiorespiratory arrest, cardiogenic shock, and the need for additional procedures, can have PCI performed within a median door-to-balloon ≤ 90 min and even the more stringent criteria of 75% within 90 min. These findings refute the belief that delays in door-to-balloon time are inevitable in high-risk patients for patient-related reasons.

The applicability of our protocol extends beyond the focused population of patients who present to emergency departments with STEMI and underscores the heterogeneity of clinical presentations of patients needing emergency PCI (Fig. 1). Nearly 10% of all STEMI patients at high risk for delayed door-to-balloon time, transfer patients, and patients requiring emergency PCI for indications other than STEMI.

### Table III. Median Door-to-Balloon and Proportion of Door-to-Balloon Times Within 90 min

| Group (Fig. 2) | Category                   | N     | Median Door-to-balloon | Median ≤90 min | P value | (N) ≤90 min | 75% door-to-balloon | P value |
|----------------|----------------------------|-------|------------------------|----------------|---------|------------|---------------------|---------|
| A+B            | STEMI and emergent overall | 526   | 68 (53.75,82)          | <0.0001        | 85.7%   | (451)      | <0.0001             |         |
| A              | STEMI overall              | 466   | 68 (53.82)             | <0.0001        | 85.2%   | (397)      | <0.0001             |         |
| A1             | STEMI primary ED           | 312   | 62.5 (47.25,76)        | <0.0001        | 90.4%   | (282)      | <0.0001             |         |
| A1 Subgroups   | Regular hours              | 113   | 48 (43.62)             | <0.0001        | 94.7%   | (107)      | <0.0001             |         |
|                | Off hours                  | 199   | 69 (59.79)             | <0.0001        | 87.9%   | (175)      | <0.0001             |         |
|                | Female                     | 99    | 66 (50.78)             | <0.0001        | 88.9%   | (88)       | 0.0010              |         |
|                | Male                       | 213   | 61 (47.75)             | <0.0001        | 91.1%   | (194)      | <0.0001             |         |
|                | Ambulance arrival          | 174   | 61 (46.74)             | <0.0001        | 93.7%   | (163)      | <0.0001             |         |
|                | Nonambulance arrival       | 138   | 65.5 (49.80,25)        | <0.0001        | 86.2%   | (119)      | 0.0016              |         |
| <65 years      |                            | 201   | 61 (47.74.5)           | <0.0001        | 93%     | (187)      | <0.0001             |         |
| ≥65 years      |                            | 111   | 66 (48.81)             | <0.0001        | 85.6%   | (95)       | 0.0084              |         |
| Prior CABG     |                            | 16    | 83 (69,108.3)          | 0.4874         | 68.8%   | (11)       | 0.5669              |         |
| No prior CABG  |                            | 296   | 61 (47.74.75)          | <0.0001        | 91.6%   | (271)      | <0.0001             |         |
| Chest pain on presentation |             | 286   | 62 (47.75)             | <0.0001        | 92.3%   | (264)      | <0.0001             |         |
| No chest pain on presentation |           | 26    | 72.5 (48.75,94)        | 0.0456         | 69.2%   | (18)       | 0.4992              |         |
| Symptom onset to presentation known |     | 275   | 62 (48.75)             | <0.0001        | 92.4%   | (254)      | <0.0001             |         |
| Symptoms onset to presentation unknown |     | 37    | 71 (43.5,91)           | 0.0035         | 75.7%   | (28)       | <0.0001             |         |
| Field cardiopulmonary arrest |             | 13    | 50 (41.73)             | 0.0024         | 92.3%   | (12)       | 0.2069              |         |
| No field cardiopulmonary arrest |          | 299   | 63 (48.76)             | <0.0001        | 90.3%   | (270)      | <0.0001             |         |
| In-hospital cardiopulmonary arrest prior to PCI |         | 27    | 71 (45.77)             | 0.0020         | 81.5%   | (22)       | 0.5130              |         |
| No in-hospital cardiopulmonary arrest prior to PCI |         | 285   | 62 (47.5,76)           | <0.0001        | 91.2%   | (260)      | <0.0001             |         |
| Temporary pacemaker/IABP prior to PCI |         | 20    | 67 (45.75,74.25)       | 0.0020         | 95%     | (19)       | 0.0382              |         |
| No temporary pacemaker/IABP prior to PCI |         | 292   | 62 (47.25,76)          | <0.0001        | 90.1%   | (263)      | <0.0001             |         |
| Cardiogenic shock |                         | 49    | 68 (49.5,75.5)         | <0.0001        | 87.8%   | (43)       | 0.0461              |         |
| No cardiogenic shock |                   | 263   | 62 (47.76)             | <0.0001        | 90.9%   | (239)      | <0.0001             |         |
| Interventionalist experience <3 years |             | 68    | 70.5 (55,75,87,75)     | <0.0001        | 80.9%   | (55)       | 0.3267              |         |
| Interventionalist experience 3-10 years |            | 127   | 57 (45,72)             | <0.0001        | 93.7%   | (119)      | <0.0001             |         |
| Interventionalist experience >10 years |           | 117   | 64 (47.5,75)           | <0.0001        | 92.3%   | (108)      | <0.0001             |         |
| A2             | STEMI primary ED 1st ECG No ST elevation | 32    | 66.5 (54.25,77)        | <0.0001        | 96.9%   | (31)       | 0.0012              |         |
| A3             | STEMI transfer ED          | 70    | 84 (74.98,25)          | 0.1659         | 62.9%   | (44)       | 0.9917              |         |
| A4             | STEMI transfer ED 1st ECG No ST Elev | 9     | 75 (62,83.5)           | 0.0117         | 88.9%   | (8)        | 0.3003              |         |
| A5             | STEMI in-hospital          | 43    | 70 (63,92)             | <0.0001        | 74.4%   | (32)       | 0.6145              |         |
| B              | Emergent overall           | 60    | 68 (57,81.5)           | <0.0001        | 90%     | (54)       | 0.0031              |         |
| B1             | Emergent primary ED        | 30    | 67.5 (56.5,80.5)       | 0.0021         | 86.7%   | (26)       | 0.0979              |         |
| B2             | Emergent transfer ED       | 5     | 79 (69.5,94)           | 0.4375         | 80%     | (4)        | 0.6328              |         |
| B3             | Emergent in-hospital       | 25    | 66 (55.81)             | <0.0001        | 96%     | (24)       | 0.0070              |         |
Fig. 4. All-cause 30-day mortality rate during the time period of this study compared to national averages. The protocol led to a substantial reduction in unadjusted mortality and risk-standardized mortality ratios for all-cause 30-day mortality compared to national averages in both 2005–2008 and 2006–2009.
presentations have an initial ECG without ST-elevation [13]. The in-hospital development of STEMI is also an important source of patients needing emergency PCI with a very high mortality rate [6,12,14]. In fact, our study is the first study to demonstrate the ability to provide reperfusion to in-hospital STEMI within 90 min from detection. We also included patients who require emergency catheterization for reasons other than STEMI including unstable angina/non-ST-elevation myocardial infarction complicated by refractory angina, hemodynamic or electrical instability, cardiac arrest, and cardiogenic shock. Attention to all of these patients extends the focus of timely reperfusion from the emergency department STEMI populations to the broader population of all patients who require emergency catheterization and revascularization.

A Michigan study revealed that the decrease in door-to-balloon time led to no improvement in PCI in-hospital mortality [15]. Furthermore, at a national level, improvements in door-to-balloon time also led to no temporal improvement in PCI in-hospital or 30-day mortality [16]. Current public reporting criteria and national clinical registries allow for exclusion of patients for CPR, defibrillation, and intubation within 90 min of arrival or those with clinical reasons documented within the medical record (i.e., difficulty with access, the need for additional workup or procedures prior to PCI, or time required for patient). These allowances have led to “erosion of the denominator” of the public reporting door-to-balloon metric as the number of patients excluded for nonsystem delays has increased from 3.7% to 8.1% between the years 2005 and 2010 [2]. The potentially excluded populations account for only 18.1% of patients but 54% of deaths [4]. Similarly, in the United States CathPCI registry, in-hospital mortality for patients without reported nonsystem delays was 2.5% compared with 15.1% for those with a reported nonsystem delay [5]. As the benefits of improved door-to-balloon time are concentrated in high-risk subgroups [17], public reporting and clinical registries should require reporting of door-to-balloon times for all patients undergoing emergency PCI.

Hospitals typically require STEMI patients to wait in the emergency department until a certain number of catheterization staff have arrived and for the catheterization lab to be ready prior to transfer [18]. Time spent within the emergency department and transferring to the catheterization lab is the largest component of door-to-balloon time. Immediate transfer to an immediately available cath lab by an in-house nursing staff is one of the most effective steps to reduce door-to-balloon time. This process has now been validated by our experience, in academic medical settings, and outside the United States [8,19,20]. Widespread adoption clinically and within the guidelines should be strongly encouraged.

There has been considerable focus on prehospital identification of STEMI. However, only 36% of emergency PCI patients in our study were eligible for prehospital identification and treatment. Of note, self-transportation is a common mode of presentation by STEMI patients occurring approximately 50%–70% of the time—a figure which is consistently seen worldwide [21]. Thus, systems of care like ours that ensure equally rapid treatment for patients presenting via ambulance or self-transportation should be instituted.

**LIMITATIONS**

Although the historical and process improvement cohorts were clinically similar, baseline differences cannot be completely accounted for because of our study’s nonrandomized nature. Our before and after outcome and cost comparisons (Table II) are limited to primary and transfer ED STEMI patients; data from the other emergency PCI patient populations in this study (i.e., initial ECG without ST-elevation, in-hospital, and activation indications other than STEMI) were not collected during the historical time period. However, these primary and ED transfer patients did account for more than 70% of the patients treated with PCI. Our study describes a cohort of patients from 2004 to 2008; however, we believe that the system design remains relevant today particularly given ongoing challenges with rapid treatment of in-hospital and transfer STEMI. Our study reflects a single center.
United States experience and may not be applicable outside the United States. Our acute myocardial infarction mortality data reflect only our Medicare population. We could not analyze mortality data prior to July 2005 as it is not available from the Centers of Medicare and Medicaid Services. The start date of the public reporting mortality data (July 2005) do not identically match the start date for our process improvement (September 2005) as the two projects were performed independently. Our mortality findings were statistically and clinically significant, but the study was not primarily designed to measure mortality.

CONCLUSION

Optimal door-to-balloon times can be achieved across a hospital system by broad implementation of ED physician or cardiology one-call activation of the catheterization lab and immediate transfer protocol by an in-house nursing staff. The strategy can be further extended to patients who do not have ST-elevation on initial ECG, to in-hospital STEMI, and to patients who undergo emergency catheterization for clinical indications other than STEMI. Ultimately, this system can align improvements in door-to-balloon time with reduced myocardial infarction mortality rates. Widespread adoption of this comprehensive strategy can substantially improve the care of a broad population of patients undergoing emergency PCI worldwide.

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Editorial Comment

Come One, Come All . . . the Sooner the Better!

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Key Points:

- This study demonstrates improved clinical outcomes with reduced D2B times in an “all-comers no exclusion” population.
- Implementation of systematic, hospital wide protocols to reduce D2B times consistently across a heterogeneous population may improve clinical outcomes and reduce costs.
- These results should encourage registry reporting “without exclusions” and inclusion of challenging subpopulations such as in-hospital STEMI, transfer patients, and cardiac arrest.

Door to balloon (D2B) times are subject to intense scrutiny in the context of primary percutaneous coronary intervention (PCI), for ST elevation myocardial infarction (STEMI). Current guidelines recommend the D2B time for patients with STEMI presenting to a PCI facility be ≤ 90 min and ≤ 120 min for patients transferred from a non-PCI facility. Public reporting and national initiatives such as the NCDR CathPCI registry, ACC D2B Project, and AHA Mission: Lifeline have focused attention on D2B and STEMI systems and enabled assessment of changes in outcome following implementation of novel strategies or therapies. However, national registry data includes only STEMI patients undergoing PCI and frequently excludes challenging subpopulations such as in-hospital STEMI, transfer patients, pharmacoinvasive-treated patients, and cardiac arrest [1]. In addition, accurate reporting is limited by exclusion of patients due to perceived acceptable non-system delays, thereby not necessarily providing a true measure of D2B times in “all-comers” due to “erosion of the denominator” [2].

In this issue of CCI, Khot et al. describe the impact of a hospital-wide system to deliver rapid D2B time

Conflict of interest: Nothing to report.

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