Association of Door-In to Door-Out Time With Reperfusion Delays and Outcomes Among Patients Transferred for Primary Percutaneous Coronary Intervention

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Primary percutaneous coronary intervention (PCI) is the preferred method of reperfusion for patients with ST-segment elevation myocardial infarction (STEMI), yet approximately 75% of hospitals in the United States currently do not have acute PCI capability. Patients with STEMI who present initially to these STEMI referral hospitals are frequently transferred to a STEMI receiving hospital for primary PCI. However, previous studies have highlighted the substantial delays in interhospital transfer that result in delayed reperfusion and can be associated with worse patient outcomes.

A critical component of the interhospital transfer process is related to its initiation at the STEMI referral hospital. Most important, the duration of time from arrival to discharge at the first hospital (ie, the door-in to door-out [DIDO] time) is largely unknown. Furthermore, patient characteristics related to substantial delays in DIDO time, as well as the effect of this initial delay on subsequent treatment and outcomes, are also uncertain. The DIDO measure is increasingly being advocated as an important metric of processes of care to expedite reperfusion, and a national benchmark of less than 30 minutes has been recommended by the 2008 American College of Cardiology/American Heart Association Guidelines: Get With the Guidelines—Primary PCI.

**Context** Patients with ST-elevation myocardial infarction (STEMI) requiring interhospital transfer for primary percutaneous coronary intervention (PCI) often have prolonged overall door-to-balloon (DTB) times from first hospital presentation to second hospital PCI. Door-in to door-out (DIDO) time, defined as the duration of time from arrival to discharge at the first or STEMI referral hospital, is a new clinical performance measure, and a DIDO time of 30 minutes or less is recommended to expedite reperfusion care.

**Objective** To characterize time to reperfusion and patient outcomes associated with a DIDO time of 30 minutes or less.

**Design, Setting, and Patients** Retrospective cohort of 14,821 patients with STEMI transferred to 298 STEMI receiving centers for primary PCI in the ACTION Registry–Get With the Guidelines between January 2007 and March 2010.

**Main Outcome Measures** Factors associated with a DIDO time greater than 30 minutes, overall DTB times, and risk-adjusted in-hospital mortality.

**Results** Median DIDO time was 68 minutes (interquartile range, 43-120 minutes), and only 1627 patients (11%) had DIDO times of 30 minutes or less. Significant factors associated with a DIDO time greater than 30 minutes included older age, female sex, off-hours presentation, and non-emergency medical services transport to the first hospital. Patients with a DIDO time of 30 minutes or less were significantly more likely to have an overall DTB time of 90 minutes or less compared with patients with DIDO times greater than 30 minutes (60% [95% confidence interval {CI}, 57%-62%] vs 13% [95% CI, 12%-13%]; P < .001). Among patients with DIDO times greater than 30 minutes, only 0.6% (95% CI, 0.5%-0.8%) had an absolute contraindication to fibrinolysis. Observed in-hospital mortality was significantly higher among patients with DIDO times greater than 30 minutes vs patients with DIDO times of 30 minutes or less (5.9% [95% CI, 5.5%-6.3%] vs 2.7% [95% CI, 1.9%-3.5%]; P < .001; adjusted odds ratio for in-hospital mortality, 1.56 [95% CI, 1.15-2.12]).

**Conclusion** A DIDO time of 30 minutes or less was observed in only a small proportion of patients transferred for primary PCI but was associated with shorter reperfusion delays and lower in-hospital mortality.
(ACC/AHA) Clinical Performance Measures for Acute Myocardial Infarction and is also a performance measure considered by the Centers for Medicare & Medicaid Services. The National Cardiovascular Data Registry (NCDR) Acute Coronary Treatment and Intervention Outcomes Network Registry–Get With the Guidelines (ACTION Registry–GWTG) provides a unique opportunity to examine DIDO times in a large national cohort of hospitals and patients. The specific objectives of this analysis were (1) to evaluate the proportion of STEMI patients who are transferred with a DIDO time of 30 minutes or less; (2) to assess the patient factors associated with delays in DIDO time; and (3) to examine the associations between a DIDO time greater than 30 minutes and overall time to reperfusion and risk-adjusted in-hospital mortality.

METHODS

Study Population

The ACTION Registry–GWTG is a voluntary quality improvement registry designed to promote evidence-based treatment of hospitalized patients with acute MI. Hospital participation is voluntary and open to all hospitals in the United States. Participation requires approval of the institutional review board at each hospital. Because patient information is collected anonymously without unique patient identifiers, institutional review boards waive the need for individual informed consent.

Between January 1, 2007, and March 30, 2010, 67,518 consecutive patients with STEMI were enrolled at PCI-capable hospitals in the ACTION Registry–GWTG. Among these, we focused on the 24,155 patients (36%) who initially presented to another hospital (STEMI referral hospital) and were subsequently transferred into an ACTION Registry–GWTG PCI facility (STEMI receiving hospital) for further treatment. Because we examined a performance measure related to timeliness of primary PCI, we excluded patients who received fibrinolytic therapy at the first hospital (ie, patients transferred for rescue PCI, facilitated PCI, or a planned pharmacoinvasive approach [n=7089]). We then excluded 2210 patients with either missing or inaccurate DIDO times. For patients with multiple admissions, we focused on the index admission (35 subsequent admissions excluded). These exclusions yielded a final analysis population of 14,821 patients with STEMI who were transferred into 298 ACTION Registry–GWTG STEMI receiving hospitals for primary PCI.

Data Collection and Definition

Hospitals participating in the ACTION Registry–GWTG collected detailed information on baseline demographic and clinical characteristics, processes of care, and in-hospital outcomes using a standardized set of data elements and definitions, as described. Patient data were captured retrospectively via chart review and entered by sites into a Web-based data-collection form. Data were screened on entry, and only those meeting predetermined criteria for completeness and accuracy could be entered into the database. Each quarter, sites received a report summarizing any observed data quality issues, thus iteratively improving the overall quality of the database.

The NCDR routinely collects race/ethnicity data for quality-of-care, outcomes, and disparity research. These data were retrospectively abstracted from the medical record based on patient self-report.

Patients cannot be tracked from one hospital to the next in this registry. Patient data from the initial STEMI referral hospital (whether or not this hospital participated in the ACTION Registry–GWTG), such as time of arrival and discharge, mode of transport to the first hospital, and initial presenting features (eg, hemodynamic stability, signs of heart failure), were retrospectively abstracted into the ACTION Registry–GWTG data collection form based on medical records sent with the patient to the second STEMI receiving hospital. However, hospital characteristics of the initial STEMI referral hospital, such as size, triage process, and distance to the closest STEMI receiving hospital, are not captured in this database. DIDO time was defined as the duration of time between arrival and discharge at the STEMI referral hospital. Off-hour presentation denotes presentation to the STEMI referral hospital anytime other than 8 AM to 5 PM Monday through Friday.

Statistical Analysis

Baseline clinical characteristics, inhospital treatment, and events were compared among patients stratified by DIDO time of 30 minutes or less vs greater than 30 minutes. Continuous variables are presented as medians with interquartile ranges (IQRs), while categorical variables are summarized as frequencies and percentages. Univariate comparisons between patients with a DIDO time of 30 minutes or less and those with a DIDO time greater than 30 minutes were performed using Wilcoxon rank sum tests for continuous variables and Mantel-Haenszel χ² tests for categorical variables. The Cochran-Armitage trend test was used to test the null hypothesis that the proportion of patients with a DIDO time of 30 minutes or less is the same for all months with the alternative hypothesis that the proportion of patients with a DIDO time of 30 minutes or less increases with time.

Multivariable logistic regression with generalized estimating equation (GEE) modeling was used to examine the association between DIDO status and in-hospital mortality. The GEE method was used to account for within-hospital clustering because patients at the same hospital are more likely to have similar responses relative to patients in other hospitals (ie, within-center correlation for response). Coefficients entered into the GEE model were adapted from a previously validated mortality model in this registry and included age, sex, race, body mass index, diabetes, hypertension, dyslipidemia, smoking status, prior MI,
prior PCI, prior coronary artery bypass graft surgery, prior heart failure, prior stroke, dialysis, peripheral arterial disease, heart rate and systolic blood pressure at the time of first medical contact, signs of heart failure on admission, and year of presentation. In addition, GEE multivariable logistic regression was used to identify baseline patient risk characteristics and presenting features independently associated with a DIDO time greater than 30 minutes.

In a secondary analysis, we created a propensity score for DIDO time of 30 minutes or less compared with DIDO time greater than 30 minutes using all the variables with \( P < .05 \). Plots of the Cramer V (\( \phi \)) measure of association for categorical variables and \( R^2 \) measure of association for continuous variables indicated good balance of all risk factors after propensity score adjustment. We then repeated the comparison between DIDO times of 30 minutes or less and greater than 30 minutes on associated mortality using inverse probability–weighted estimators.

For the main outcome variables such as in-hospital mortality, we did not have any patients with missing data. Overall door-to-balloon (DTB) time was missing in 2.4% of patients and we examined this outcome only among patients without missing data. Missing data occurred rarely (<1%) for all other reported variables. In multivariable modeling, missing values of continuous variables were imputed to the median value, while missing values of categorical variables were imputed to their most common value.

\( P < .05 \) was considered statistically significant for all tests. All analyses were performed using SAS software, version 9.1 (SAS Institute Inc, Cary, North Carolina).

**RESULTS**

**Baseline Characteristics**

Among 14,821 STEMI patients transferred to a STEMI receiving hospital for primary PCI, the median DIDO time was 68 minutes (IQR, 43-120 minutes). As shown in Figure 1, only 1,627 patients (11%) had a DIDO time of 30 minutes or less. Furthermore, 56% had a DIDO time of greater than 60 minutes and 35% had a DIDO time of greater than 90 minutes. The proportion of patients with a DIDO time of 30 minutes or less showed improvement over time (\( P < .001 \)) (Figure 2); median DIDO times were 90 minutes (IQR, 55-180 minutes) in January 2007 and 58 minutes (IQR, 38-103 minutes) in March 2010.

Patients with a DIDO time greater than 30 minutes were more likely to be older (median age, 61 vs 58 years; \( P < .001 \)), female (30.6% vs 22%; \( P < .001 \)), and more likely to have comorbidities such as hypertension, diabetes, prior heart failure, prior stroke, and chronic lung disease compared with patients with a DIDO time of 30 minutes or less (Table 1). Patients with a DIDO time greater than 30 minutes were more likely to have a left bundle branch block or signs of posterior MI on the presenting electrocardiogram (4.2% vs 1.0%; \( P < .001 \)). Only a small proportion of transferred patients with prolonged DIDO times had documented contraindications to fibrinolytic therapy; among patients with DIDO times greater than 30 minutes and greater than 60 minutes, 0.6% and 0.9% had absolute contraindications to fibrinolytic therapy, respectively.

After multivariable modeling, independent patient characteristics associated with a DIDO time greater than 30 minutes include older age, female sex, off-hours presentation, and non–emergency medical services transport to the first hospital (Table 2). In addition, comorbid conditions (such as diabetes and prior stroke) and initial hemodynamic instability (increasing heart rates and signs of heart failure on presentation) were also associated with a higher likelihood of a DIDO time greater than 30 minutes.

**Timeliness of Reperfusion**

Although patients in the study cohort were transferred for primary PCI, patients with a DIDO time of 30 minutes or less were more likely to undergo primary PCI after arriving at the STEMI receiving hospital compared with patients with a DIDO time greater than 30 minutes (95.9 vs 90.5%; \( P < .001 \)). In this transfer population, the median overall DTB time from first hospital presentation to second hospital PCI was 120 minutes (IQR, 96-159 minutes), and only...
19% of transferred patients achieved an overall DTB time of 90 minutes or less. Overall DTB time was significantly shorter for patients with a DIDO time of 30 minutes or less compared with those with a DIDO time greater than 30 minutes (median, 85 vs 127 minutes; \( P < .001 \)). The percentage of patients with an overall DTB time of 90 minutes or less was significantly higher for patients with a DIDO time of 30 minutes or less compared with those with a DIDO time greater than 30 minutes (60% vs 13%; \( P < .001 \)); similar results were observed for the percentage of patients achieving an overall DTB time of 120 minutes or less (91% vs 43%; \( P < .001 \)). Second hospital arrival to balloon time was longer for patients with a DIDO time greater than 30 minutes compared with those who had a DIDO time of 30 minutes or less (median, 31 vs 26 minutes; \( P < .001 \)).

Median length of hospitalization was similar between patients with DIDO times of 30 minutes or less and more than 30 minutes (median, 3 days; IQR, 2-5 days).

In-Hospital Mortality

During the study period, we observed a 5.5% in-hospital mortality rate that was significantly higher among patients with a DIDO time greater than 30 minutes (5.9%) compared with patients who had a DIDO time of 30 minutes or less (2.7%; \( P < .001 \)). This mortality difference persisted after adjusting for differences in baseline characteristics and presenting features (adjusted odds ratio [OR], 1.56; 95% confidence interval [CI], 1.13-2.21; \( P = .004 \)), and similar results were obtained in a secondary analysis using inverse probability–weighted estimators (OR, 1.55; 95% CI, 1.06-2.26; \( P = .02 \)). The difference in associated mortality was greater with incremental increases in DIDO time. Using patients with a DIDO time of 30 minutes or less as the reference, patients with DIDO times between 31 and 60 minutes had an adjusted OR of 1.34 (95% CI, 0.96-1.86), patients with DIDO times between 61 and 90 minutes had an adjusted OR of 1.41 (95% CI, 0.96-2.06), and patients with DIDO times greater than 90 minutes had an adjusted OR of 1.86 (95% CI, 1.36-2.54) for in-hospital mortality (FIGURE 3).

COMMENT

The timeliness of reperfusion therapy for STEMI patients transferred for primary PCI is often prolonged, with only a minority of transferred patients achieving a guideline-recommended overall DTB time of less than 90 minutes. DIDO time is a new performance measure that assesses the timeliness and quality of initial reperfusion care at the first or STEMI referral hospital, and we found that only 11% of transferred patients with STEMI met the recommended benchmark of a DIDO time of 30 minutes or less. Furthermore, patients with a DIDO time greater than 30 minutes had significantly longer overall DTB time, and the majority did not have any documented absolute contraindications to fibrinolytic therapy.

The direct relationship between total ischemic time and severity of myocardial injury and mortality has been well established for patients with STEMI11-14 and has fueled national campaigns to reduce system delays to reperfusion. For

Figure 2. Monthly Trends in Percentage of Patients With DIDO Times of 30 Minutes or Less Among 14 821 Patients With STEMI Transferred During the Study Period, January 2007 Through March 2010

Each point represents the observed percentage of patients with door-in to door-out (DIDO) times of 30 minutes or less among all transferred patients with ST-elevation myocardial infarction (STEMI) who were treated that month. Error bars represent the approximation 95% binomial confidence interval. Sample sizes during each of these months range between 220 and 527 patients.
patients with STEMI who directly arrive at a PCI-capable hospital, several initiatives have effected significant reductions in DTB time.13-17 Nevertheless, with only a minority of hospitals having round-the-clock PCI capability2,3,18 and a substantial proportion of contemporary STEMI patients requiring interhospital transfer for primary PCI, there has been a growing interest in measuring the timeliness and quality of reperfusion for transferred STEMI patients, including performance at both the STEMI referral and STEMI receiving hospitals.

The traditional measure of overall DTB time, which for transfer patients is defined as the time from presentation at the STEMI referral hospital to the time of primary PCI at the STEMI receiving hospital, relies on efficient communication and coordination of care between STEMI referral and receiving hospitals as well as emergency transport services. A previous analysis from the NCDS CathPCI Registry shows that less than 10% of transferred patients with STEMI between 2005 and 2007 met the metric of overall DTB time of less than 90 minutes.4 Our analysis shows that overall DTB time has further improved for transferred patients with STEMI, with approximately 1 in 5 patients treated within an overall DTB time of less than 90 minutes.

To further delineate quality improvement targets for STEMI patients transferred for primary PCI, the 2008 ACC/AHA Performance Measures for STEMI designated a new performance benchmark, DIDO time, which assesses the amount of time spent at the STEMI referral hospital prior to transfer and reflects the transfer process between STEMI referral and receiving centers. Based largely on regionally designed STEMI systems of care,19-21 a benchmark of 30 minutes or less is recommended for this measure. Our study shows that while there has been a significant downward secular trend in DIDO time, only 1 in 10 patients achieved a DIDO time of 30 minutes or less at the STEMI referral hospital. In fact, more than one-third of patients had a DIDO time greater than 90 minutes and more than 58% had a DIDO time greater than 60 minutes, rendering an overall DTB time of 90 minutes or less realistically unachievable. Moreover, the majority of patients with prolonged DIDO time did not have absolute contraindications for fibrinolytic therapy,22,23 which is the preferred reperfusion strategy for STEMI when access to timely primary PCI is not a viable option.24-27

Our results underscore the importance of optimizing regional and state-wide networks for STEMI systems of care. DIDO time is a performance measure that informs how efficiently the

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**Table 1. Baseline Patient Characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>DIDO Time ≤30 Minutes (n = 1627)</th>
<th>DIDO Time &gt;30 Minutes (n = 13194)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, median (IQR), y</td>
<td>58 (50-67)</td>
<td>61 (52-71)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Male</td>
<td>1269 (78.0)</td>
<td>9151 (69.4)</td>
<td>.001</td>
</tr>
<tr>
<td>White race</td>
<td>1418 (87.2)</td>
<td>11486 (87.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Insurance status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private/HMO</td>
<td>910 (55.9)</td>
<td>7066 (53.6)</td>
<td>.001</td>
</tr>
<tr>
<td>Medicare/Medicaid/VA</td>
<td>408 (25.1)</td>
<td>4109 (31.1)</td>
<td>.001</td>
</tr>
<tr>
<td>Self/none</td>
<td>299 (18.4)</td>
<td>1989 (14.4)</td>
<td>.001</td>
</tr>
<tr>
<td>Other/missing</td>
<td>10 (0.6)</td>
<td>121 (0.9)</td>
<td>.001</td>
</tr>
<tr>
<td>Clinical characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>910 (55.9)</td>
<td>8277 (62.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>792 (48.7)</td>
<td>6673 (50.6)</td>
<td>.15</td>
</tr>
<tr>
<td>Previous PCI</td>
<td>281 (17.3)</td>
<td>2298 (17.4)</td>
<td>.89</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>271 (16.7)</td>
<td>3246 (24.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>263 (16.2)</td>
<td>2333 (17.7)</td>
<td>.14</td>
</tr>
<tr>
<td>Chronic lung disease</td>
<td>106 (6.1)</td>
<td>962 (11.3)</td>
<td>.03</td>
</tr>
<tr>
<td>Previous CABG</td>
<td>75 (4.6)</td>
<td>875 (6.6)</td>
<td>.002</td>
</tr>
<tr>
<td>Peripheral arterial disease</td>
<td>65 (4.0)</td>
<td>753 (5.7)</td>
<td>.004</td>
</tr>
<tr>
<td>Previous stroke</td>
<td>50 (3.1)</td>
<td>723 (5.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Previous heart failure</td>
<td>49 (3.0)</td>
<td>663 (5.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Contraindication to fibrinolytic therapy</td>
<td>4 (0.2)</td>
<td>83 (0.6)</td>
<td>.84</td>
</tr>
<tr>
<td>Presenting features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-hour presentationb</td>
<td>1001 (61.5)</td>
<td>8720 (66.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>EMS transport to first hospital</td>
<td>472 (29.0)</td>
<td>3589 (27.2)</td>
<td>.40</td>
</tr>
<tr>
<td>Prehospital ECG</td>
<td>615 (37.8)</td>
<td>5150 (39.0)</td>
<td>.28</td>
</tr>
<tr>
<td>ECG findings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST elevation</td>
<td>1610 (99.0)</td>
<td>12632 (95.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LBBB</td>
<td>11 (0.7)</td>
<td>481 (3.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Posterior MI</td>
<td>4 (0.3)</td>
<td>68 (0.5)</td>
<td>.53</td>
</tr>
<tr>
<td>Hypotension (SBP &lt;90 mm Hg)</td>
<td>92 (5.7)</td>
<td>696 (5.3)</td>
<td>.001</td>
</tr>
<tr>
<td>Tachycardia (heart rate ≥100/min)</td>
<td>194 (11.9)</td>
<td>2214 (16.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Signs of heart failurec</td>
<td>98 (6.0)</td>
<td>1602 (12.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Signs of cardiogenic shock</td>
<td>102 (6.3)</td>
<td>942 (7.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Creatinine clearance, median (IQR), mL/min15</td>
<td>93.8 (70.8-120.1)</td>
<td>86.2 (61.4-114.4)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: CABG, coronary artery bypass graft surgery; ECG, electrocardiogram; EMS, emergency medical services; HMO, health maintenance organization; IQR, interquartile range; LBBB, left bundle branch block; MI, myocardial infarction; PCI, percutaneous coronary intervention; SBP, systolic blood pressure; VA, veterans administration.

a Data are expressed as number (percentage) of patients unless otherwise indicated.
b Off-hour presentation denotes presentation between 5 PM and 8 AM Monday through Thursday and all day Saturday and Sunday.
c Signs of heart failure are dyspnea, orthopnea, paroxysmal nocturnal dyspnea, or lower-extremity edema associated with at least 1 of the following: rates of more than one-third of the lung fields, jugular venous distension, S3 gallop, pulmonary congestion on radiography, or elevated brain natriuretic peptide levels.

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STEMI referral hospital coordinates care and transfer, and achieving a DIDO time of 30 minutes or less was strongly associated with an overall DTB time of 90 minutes or less. Thus, DIDO can be used to inform the choice of reperfusion therapy. However, the ultimate choice of reperfusion therapy (fibrinolysis vs primary PCI) at STEMI referral hospitals should be individualized based on several factors, such as the patient’s mortality and bleeding risks and duration of symptoms, in addition to time needed to transfer to a PCI-capable hospital.

Although patient-level characteristics such as age, sex, diabetes, and heart failure contributed to DIDO time, the magnitude of their contributions were small, and most baseline patient variables were not associated with prolonged DIDO times (>30 minutes). Logistics such as presentation during off-hours or failure to use emergency medical services transport to the STEMI referral hospital were significant contributors, but additional STEMI referral hospital- and system-level variables are important and likely associated with the variability in DIDO time. These factors, described in previous literature, are not captured in this database but focus on early triage and treatment on the stretcher, a prespecified simple reperfusion strategy coordinated with the STEMI receiving hospital, availability of immediate transportation, use of a prehospital electrocardiogram to diagnose STEMI, and activating transport with earlier lead time. DIDO time provides a simple but useful metric for quality improvement programs that seek to design and evaluate STEMI systems of care, such as the AHA’s Mission: Lifeline.

Our study is the first to our knowledge to show a significantly higher mortality risk associated with a DIDO time greater than 30 minutes that persists after adjusting for many of the clinical and presenting patient features that contribute to MI mortality risk. Although we cannot exclude the contribution of unmeasured patient differences, we observed a large difference in time to reperfusion (42-minute difference in median overall DTB time) between groups, which is particularly remarkable given the generalizability of the study population (18% older than 75 years, 30% women, 24% diabetic). Therefore, the association of a DIDO time of 30 minutes or less with lower mortality may potentially be mediated by the reduction in overall reperfusion delays. These results lend support to this new performance measure as a target for quality improvement interventions given its strong correlation to total system delays in primary PCI and in-hospital mortality. Compared with patients with a DIDO time of 30 minutes or less, those with DIDO times of 31 to 60 and 61 to 90 minutes were associated with a nonsignificant increase in trend for higher mortality, and patients with DIDO times greater than 90 minutes were associated with the highest mortality risk (Figure 3).

Thus, optimizing systems of care to achieve a DIDO time of 30 minutes or less for the majority of patients transferred for primary PCI is a reasonable target, particularly because this is currently achieved in only 11% of transferred STEMI patients. DIDO time is a useful performance measure attributable to STEMI referral hospitals that can be used to assess and iteratively improve effectiveness of regional STEMI networks and may further emerge as a quality benchmark to ascertain performance and accountability.

The findings in our study need to be considered in the light of some limitations. First, the ACTION Registry–GWTG captures transfer patients from the perspective of the 298 participating STEMI receiving hospitals; therefore, we have no insight into the hospital characteristics and process descriptors of the initial STEMI referral hospitals.

### Table 2. Patient Characteristics Significantly Associated With a DIDO Time of 30 Minutes or Greater

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Adjusted OR (95% CI)</th>
<th>( \chi^2 )</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (per 10 beats/min increase)</td>
<td>1.08 (1.04-1.10)</td>
<td>28</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Female</td>
<td>1.42 (1.22-1.65)</td>
<td>21</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.39 (1.16-1.67)</td>
<td>13</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Off-hours presentation</td>
<td>1.30 (1.13-1.50)</td>
<td>13</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Signs of heart failure on admission</td>
<td>1.54 (1.20-1.92)</td>
<td>12</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Non-EMS transport to first hospital</td>
<td>1.26 (1.08-1.4)</td>
<td>9</td>
<td>.003</td>
</tr>
<tr>
<td>Prior stroke</td>
<td>1.47 (1.09-2.00)</td>
<td>6</td>
<td>.01</td>
</tr>
<tr>
<td>Current/recent smoker</td>
<td>0.83 (0.71-0.97)</td>
<td>6</td>
<td>.02</td>
</tr>
<tr>
<td>Age (per 5-y increase)</td>
<td>1.03 (1.00-1.06)</td>
<td>5</td>
<td>.03</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; DIDO, door-in to door-out; EMS, emergency medical services; OR, odds ratio.

### Figure 3. Association of DIDO Time With In-Hospital Mortality

For each door-in to door-out (DIDO) time group, the unadjusted mortality rate is presented, as well as the adjusted odds ratio and 95% confidence interval (CI; error bars) for each group, with DIDO time greater than 90 minutes as the reference group.
ral hospital (eg, triage process, decision to transfer, distance to closest STEMI receiving hospital), which are likely to significantly affect DIDO time. However, time of presentation as well as some of the presenting patient features at the initial hospital visit are captured in this database. Time clocks are not always standardized within and between institutions. We also do not collect data on symptom persistence or severity, which can also contribute to timeliness of transfer or selection of fibrinolytic therapy.

Second, this analysis population includes only patients transferred for primary PCI and excludes patients with STEMI who were eligible for primary PCI but were not transferred (those who did not receive any reperfusion therapy and those who died out of hospital). Because reperfusion is known to be underutilized in routine practice, the proportion of patients with STEMI requiring interhospital transfer for primary PCI is likely underestimated.

Third, while the observational nature of this study permits real-world assessment of care patterns, the association between DIDO time and mortality do not necessarily prove causality. Despite mulivariable adjustment, unmeasured confounding (eg, patients with a DIDO time ≤30 minutes may be healthier and easier to transport) may contribute to the lower mortality observed among patients with a DIDO time of 30 minutes or less. Future studies will need to examine the association with longitudinal outcomes because only in-hospital mortality data are collected in this study.

CONCLUSION

DIDO time is a new reperfusion performance measure for patients with STEMI who require interhospital transfer for primary PCI. Our study shows that patients with a DIDO time of 30 minutes or less are more likely to achieve an overall DTB time of less than 90 minutes and are associated with lower risk-adjusted mortality compared with patients who had a DIDO time greater than 30 minutes, thus affirming the importance of DIDO time as a metric for reperfusion quality. Significantly, the majority of transferred patients with STEMI nationwide do not meet the recommended 30-minute benchmark, suggesting that further attention and improvement of this performance measure will translate into substantial improvement in the timeliness of primary PCI and clinical outcomes for transferred STEMI patients.

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REFERENCES


The great business of study is to form a mind adapted and adequate to all times and all occasions; to which all nature is then laid open, and which may be said to possess the key of her inexhaustible riches.

—Sir Joshua Reynolds (1723-1792)