The American College of Cardiology and American Heart Association guidelines recommend percutaneous coronary intervention (PCI) as the optimal therapy for ST-segment elevation myocardial infarctions (STEMIs) when promptly available. The time from hospital arrival to ST-segment elevation myocardial infarction diagnosis (door-to-activation time) on-door-to-balloon time in contemporary practice and evaluated factors that influence door-to-activation times. North American and European guidelines recommend a door-to-balloon time of ≤90 minutes. Two recommended strategies associated with reduced door-to-balloon times include autonomous emergency physician activation of the cardiac catheterization team and use of a centralized paging system for simultaneous activation of the entire team. Nevertheless, these quality improvement recommendations still depend on a prompt STEMI diagnosis. Prior studies generally conform to the broad exclusion criteria established by the Centers for Medicare and Medicaid Services. These criteria avoid penalizing performance measures due to patients who may require exclusion of other

Background—Little is known about the components of door-to-balloon time among patients with ST-segment elevation myocardial infarction undergoing primary percutaneous coronary intervention. We assessed the role of time from hospital arrival to ST-segment elevation myocardial infarction diagnosis (door-to-activation time) on door-to-balloon time in contemporary practice and evaluated factors that influence door-to-activation times.

Methods and Results—Registry data on 347 consecutive patients diagnosed with a STEMI in the emergency department over 30 months at 2 urban primary percutaneous coronary intervention centers were analyzed. The primary study end point was the time from hospital arrival to catheterization laboratory activation by the emergency department physician, and we assessed factors associated with this period. Door-to-balloon time and its other components were secondary study end points. The median door-to-activation time was 19 minutes (interquartile range, 9–54). Variation in door-to-activation times explained 93% of the variation in door-to-balloon times and demonstrated the strongest correlation with door-to-balloon times (r=0.97). Achieving a door-to-activation time of ≤20 minutes resulted in an 89% chance of achieving a door-to-balloon time of ≤90 minutes compared with only 28% for patients with a door-to-activation time >20 minutes. Factors significantly associated with door-to-activation time include the following: prehospital ECG use (61% shorter, 95% confidence interval, −50 to −72%; P<0.001) and computed tomography scan use in the emergency department (245% longer, 95% confidence interval, +50 to +399%; P=0.001).

Conclusions—The interval from hospital arrival to ST-segment elevation myocardial infarction diagnosis and catheterization laboratory activation (door-to-activation time) is a strong driver of overall door-to-balloon times. Achieving a door-to-activation time ≤20 minutes was key to achieving a door-to-balloon time ≤90 minutes. Delays in door-to-activation time are not associated with delays in other aspects of the primary percutaneous coronary intervention process. (Circ Cardiovasc Qual Outcomes. 2012;5:672-679.)

Key Words: outcome and process ◼ emergency department ◼ door-to-balloon time ◼ door-to-activation time ◼ primary percutaneous coronary intervention ◼ ST-segment elevation myocardial infarction

Impact of Door-to-Activation Time on Door-to-Balloon Time in Primary Percutaneous Coronary Intervention for ST-Segment Elevation Myocardial Infarctions

A Report From the Activate-SF Registry

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The American College of Cardiology and American Heart Association guidelines recommend percutaneous coronary intervention (PCI) as the optimal therapy for ST-segment elevation myocardial infarctions (STEMIs) when promptly available. The time from hospital arrival to reperfusion with PCI—the door-to-balloon time—is strongly associated with morbidity and mortality, and door-to-balloon time metrics have become a quality measure of hospital performance. North American and European guidelines recommend a door-to-balloon time of ≤90 minutes. Two recommended strategies associated with reduced door-to-balloon times include autonomous emergency physician activation of the cardiac catheterization team and use of a centralized paging system for simultaneous activation of the entire team. Nevertheless, these quality improvement recommendations still depend on a prompt STEMI diagnosis. Prior studies generally conform to the broad exclusion criteria established by the Centers for Medicare and Medicaid Services. These criteria avoid penalizing performance measures due to patients who may require exclusion of other
important diagnoses (eg, dissection). However, they may exclude a significant proportion of STEMI patients who could benefit from system improvements to enhance overall STEMI care. Furthermore, few registries collect data to divide door-to-balloon time into component times. These components include the time required to recognize an STEMI and activate the catheterization laboratory (door-to-activation time), the time required for catheterization laboratory preparation and patient transport (activation-to-laboratory time), and the time required from arrival in the laboratory to initial device used to open the culprit artery (laboratory-to-balloon time).

The aims of this study were to examine the impact of these 3 components on overall door-to-balloon time. We additionally sought to examine actionable factors associated with these components that may be improved in an effort to facilitate universally rapid treatment of STEMI patients with primary PCI.

WHAT IS KNOWN
• Door-to-balloon time in primary percutaneous coronary intervention for ST-elevation myocardial infarction is strongly related to both short- and long-term mortality.

WHAT THE STUDY ADDS
• The time from hospital arrival to ST-segment elevation myocardial infarction diagnosis and activation of the catheterization laboratory (door-to-activation time) varies widely at the hospital level and is more strongly correlated with overall door-to-balloon times than other components of the primary percutaneous coronary intervention process.
• A door-to-activation time <20 minutes may be key to achieving a door-to-balloon time <90 minutes consistently.

Methods
ACTIVATE-SF Registry
The ACTIVATE-SF Registry consists of consecutive patients with a clinical diagnosis of STEMI admitted to the emergency departments (EDs) of a tertiary care hospital (University of California, San Francisco) and an urban trauma center (San Francisco General Hospital) in San Francisco between October 2008 and April 2011. Registry details have been described previously.11,12 Briefly, both institutions have primary PCI capacity, and the ED physicians autonomously activated their respective cardiac catheterization teams via a centralized paging system for any clinical diagnosis of an STEMI. All ED physician-initiated STEMI activations that went to the catheterization laboratory were included in this analysis, irrespective of subsequent outcome or potential exclusion from Center for Medicare and Medicaid Services reporting. Eighty-four patients with a STEMI diagnosis in the ED who did not ultimately undergo emergent diagnostic angiography because of contraindications, rapid demise, patient refusal, or a clinical decision by the interventional cardiologist that angiography was not warranted were excluded because the relationship between door-to-activation time and subsequent components of door-to-balloon time could not be assessed. Subjects were identified from the STEMI pager call logs and hospital quality assurance records compiled for the Joint Commission on Accreditation of Healthcare Organizations.

Data Collection
All clinical data were collected from the ED physician and nursing notes. These data reflect only the information on which ED decisions were formulated. The inciting STEMI ECGs (ie, the ECG that led to the decision to activate the catheterization laboratory) were deidentified and reread for key variables by 2 cardiologists blinded to clinical outcomes. Between-reader divergence in ECG characteristics greater than a priori limits of agreement was adjudicated by a third cardiologist. A waiver of consent was obtained from the Institutional Review Board at University of California, San Francisco. Study data were collected and managed using REDCap electronic data capture tools hosted at University of California, San Francisco.13

Time Variable Collection
Routine use of time-stamped centralized paging systems to activate the catheterization team and hospital quality assurance data allows for subinterval analysis of the door-to-balloon time based on universally recognized steps in the reperfusion process: time of arrival to the hospital (door); time of inciting STEMI ECG collection; time of STEMI team activation; time of patient arrival at the catheterization laboratory; and time of reperfusion (balloon). Key time points were collected from computerized time-stamped source documents. ECG times reflect the time of the ECG prompting catheterization laboratory activation and not necessarily the first ECG obtained.

Ambulance Data
During the study period, neither center had an established protocol in place to activate the catheterization laboratory before patient arrival based on a prehospital ECG with a computer-derived acute myocardial infarction designation. Per protocol, emergency medical services personnel were instructed to call the destination ED to alert them to the acute myocardial infarction (prehospital acute myocardial infarction) designation when interpreted by the computer as such. Given the nested and colinear nature of ambulance use, prehospital ECIs, and prehospital acute myocardial infarction designations, we chose to use prehospital ECG as the primary predictor of interest among the 3, consistent with prior studies.14,15

Definitions
We reread the ED ECGs, blind to patient details, defining ST-segment elevation as J-point elevation in ≥2 contiguous leads of ≥2 mm in leads V1, V2, or V3 or ≥1 mm in other leads; or ≥1 mm of ST depression in leads V1 to V3 consistent with a posterior STEMI; or left bundle-branch block. The culprit coronary artery was defined as any vessel with an acute thrombotic total or subtotal occlusion. A false-positive STEMI was defined by the absence of a culprit lesion on angiography.12 After-hours presentation was defined as any weekend presentation or presentation from 7 PM to 7 AM on a weekday. An anginal chief complaint was a primary complaint recorded as chest pain or chest pressure. Patient race/ethnicity was collected from self-reporting in the hospital intake records.

Statistical Analysis
Simple comparisons were performed using chi-square tests for categorical and binary data. Student t tests and Wilcoxon rank-sum test were used for normally and non-normally distributed continuous data, respectively. The door-to-balloon time was dichotomized at 90 minutes, and, based on our analyses, the door-to-activation time was dichotomized at 20 minutes. For univariate and multivariable analyses, linear regression was used with the primary end point variable of door-to-activation time in minutes. Key secondary end points included activation-to-laboratory time and laboratory-to-balloon time, as well as overall door-to-balloon time.

For analysis of factors associated with door-to-activation time, co-variates were either locked in the model a priori if likely confounders or selected using a directed acyclic graph based on clinical knowledge and prior studies. Explanatory variables were then prioritized for use in the regression models using a manual backward-stepwise
procedure. Candidate covariates for the final regression model included age, race, sex, chief complaint (anginal versus nonanginal), a known history of any coronary artery disease, number of known standard cardiovascular risk factors (diabetes mellitus, hypertension, dyslipidemia, active tobacco use, peripheral vascular disease), the extent of the diagnostic electrocardiographic changes on the inciting ECG (maximum millimeters of ST-segment elevation, specific territory with greatest ST-segment elevations, number of leads with ST-segment elevations, and presence of left bundle-branch block), after-hours presentation, bradycardia, emergency physician experience (in years), and prehospital ECG use.

The primary and key secondary time end points (in minutes) were log transformed for use in regression models to maintain normality. The statistical output is, therefore, reported as a percent change in time and 95% confidence interval. Continuous variables are presented as means and SD or median values and interquartile ranges (IQR). To adjust for multiple hypothesis testing, a Bonferroni-corrected P value of 0.0125 was considered significant. All statistical analyses were performed with Stata version 11 (College Station, TX).

Results
A total of 347 emergency physician–initiated STEMI activations were included in the registry between October 2008 and April 2011 (Table 1; Figure 1). The median door-to-balloon time was 78 minutes (IQR, 62–106 minutes). Among the components of door-to-balloon time, the median door-to-activation time was 19 minutes (IQR, 9–54 minutes). The median activation-to-laboratory time was 33 minutes (IQR, 23–40 minutes), and the median laboratory-to-balloon time was 28 minutes (IQR, 22–38 minutes). Within door-to-activation time, the median door-to-ECG time was 8 minutes (IQR, 3–19 minutes), which was moderately correlated with overall door-to-activation times (correlation coefficient \( r = 0.72 \)).

Relationship of Component Time Intervals to Overall Door-to-Balloon Time
The door-to-activation times were strongly correlated with overall door-to-balloon times (\( r = 0.97 \)) (Figure 2). In contrast, door-to-balloon time was not correlated with activation-to-laboratory time (\( r = 0.08 \)) or laboratory-to-balloon time (\( r = 0.47 \)). Figure 3 shows that there was a far greater spread, and therefore variability, in the door-to-activation times than other component times. In fact, the door-to-activation time accounted for 93% of the variability in door-to-balloon time (\( R^2 = 0.934 \)) and did not change appreciably during the duration of our study (\( R^2 = 0.959 \) for 2008 and 2009, 0.910 for 2010, and 0.901 for 2011). Thus, >90% of the variability in door-to-balloon time was related to the time to recognition of an STEMI and subsequent activation of the catheterization laboratory, rather than other components of the door-to-balloon time.

Door-to-activation times of ≤20 minutes were critical for achieving compliance with recommended door-to-balloon times. In this all-comer registry, 89% of patients with a door-to-activation time ≤20 minutes achieved a door-to-balloon time <90 minutes compared with only 28% of patients with a door-to-activation time >20 minutes \( (P < 0.001) \). Consistent with this finding, we could not discern an effect of door-to-activation time on activation-to-balloon time \( (P = 0.118 \); Figure 4).

### Table 1. Baseline Characteristics of All Patients Split by Door-to-Activation Time <20 min

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Door to Activation &lt;20 min (n=173)</th>
<th>Door to Activation ≥20 min (n=174)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (%)</td>
<td>129 (75)</td>
<td>132 (76)</td>
<td>0.78</td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>61 (14)</td>
<td>58 (14)</td>
<td>0.01</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>White, non-Hispanic (%)</td>
<td>76 (44)</td>
<td>62 (35)</td>
<td></td>
</tr>
<tr>
<td>Asian (%)</td>
<td>39 (23)</td>
<td>53 (31)</td>
<td></td>
</tr>
<tr>
<td>African American (%)</td>
<td>27 (15)</td>
<td>32 (19)</td>
<td></td>
</tr>
<tr>
<td>White-Hispanic (%)</td>
<td>24 (14)</td>
<td>19 (11)</td>
<td></td>
</tr>
<tr>
<td>Other (%)</td>
<td>7 (4)</td>
<td>8 (5)</td>
<td></td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>27 (5)</td>
<td>26 (6)</td>
<td>0.27</td>
</tr>
<tr>
<td>ED presentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical ischemic symptom* (%)</td>
<td>115 (66)</td>
<td>99 (57)</td>
<td>0.07</td>
</tr>
<tr>
<td>Cardiac arrest (%)</td>
<td>33 (19)</td>
<td>26 (15)</td>
<td>0.13</td>
</tr>
<tr>
<td>Intubated (%)</td>
<td>27 (16)</td>
<td>21 (12)</td>
<td>0.35</td>
</tr>
<tr>
<td>CT scan in the ED (%)</td>
<td>11 (6)</td>
<td>24 (14)</td>
<td>0.02</td>
</tr>
<tr>
<td>Systolic BP &lt;100 mm Hg (%)</td>
<td>32 (19)</td>
<td>22 (13)</td>
<td>0.13</td>
</tr>
<tr>
<td>Pressor requirement (%)</td>
<td>18 (10)</td>
<td>24 (14)</td>
<td>0.33</td>
</tr>
<tr>
<td>Heart rate &lt;50 bpm (%)</td>
<td>12 (7)</td>
<td>7 (4)</td>
<td>0.23</td>
</tr>
<tr>
<td>Off hours presentation (%)</td>
<td>111 (64)</td>
<td>114 (66)</td>
<td>0.79</td>
</tr>
<tr>
<td>ED doctor &gt;10 y experience (%)</td>
<td>97 (56)</td>
<td>90 (52)</td>
<td>0.42</td>
</tr>
<tr>
<td>Translator required (%)</td>
<td>35 (21)</td>
<td>34 (21)</td>
<td>0.9</td>
</tr>
<tr>
<td>Brought by ambulance (%)</td>
<td>108 (64)</td>
<td>88 (51)</td>
<td>0.02</td>
</tr>
<tr>
<td>Prehospital ECG (%)</td>
<td>79 (46)</td>
<td>33 (19)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Risk factors known in ED</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>32 (19)</td>
<td>44 (27)</td>
<td>0.1</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>79 (47)</td>
<td>89 (53)</td>
<td>0.33</td>
</tr>
<tr>
<td>Dyslipidemia (%)</td>
<td>52 (31)</td>
<td>49 (30)</td>
<td>0.75</td>
</tr>
<tr>
<td>Any prior coronary disease (%)</td>
<td>43 (25)</td>
<td>59 (34)</td>
<td>0.06</td>
</tr>
<tr>
<td>Prior PCI (%)</td>
<td>24 (15)</td>
<td>29 (17)</td>
<td>0.53</td>
</tr>
<tr>
<td>Prior CABG (%)</td>
<td>5 (3)</td>
<td>9 (5)</td>
<td>0.5</td>
</tr>
<tr>
<td>Active tobacco use (%)</td>
<td>47 (27)</td>
<td>57 (33)</td>
<td>0.26</td>
</tr>
<tr>
<td>Active drug abuse (%)</td>
<td>20 (13)</td>
<td>31 (19)</td>
<td>0.14</td>
</tr>
<tr>
<td>ECG characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary territory with ST elevations</td>
<td></td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Anterior (%)</td>
<td>70 (42)</td>
<td>84 (52)</td>
<td></td>
</tr>
<tr>
<td>Lateral (%)</td>
<td>11 (7)</td>
<td>13 (8)</td>
<td></td>
</tr>
<tr>
<td>Inferior (%)</td>
<td>70 (42)</td>
<td>40 (25)</td>
<td></td>
</tr>
<tr>
<td>Posterior (%)</td>
<td>8 (5)</td>
<td>8 (5)</td>
<td></td>
</tr>
<tr>
<td>None (%)</td>
<td>6 (4)</td>
<td>16 (10)</td>
<td></td>
</tr>
<tr>
<td>Left bundle branch block (%)</td>
<td>7 (4)</td>
<td>13 (7)</td>
<td>0.17</td>
</tr>
<tr>
<td>Median (IQR) height of ST elevations, mm</td>
<td>2 (1.5–3.5)</td>
<td>1.5 (1–2.5)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

(Continued)
Factors Related to Longer Catheterization Laboratory Activation Times

Because door-to-activation time was the primary driver of door-to-balloon time, we assessed factors related to activation times >20 minutes. In univariate analysis, typical anginal symptoms, an ambulance prehospital ECG, hypotension or bradycardia at presentation, inferior territory ST-segment elevations on ECG, and increasing height of ST elevation or number of leads with ST elevations were all associated with a significantly shorter door-to-activation time. Alternatively, use of a computed tomography (CT) scan in the ED and Asian

Table 1. Continued

<table>
<thead>
<tr>
<th>Door to Activation</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20 min (n=173)</td>
<td>≥20 min (n=174)</td>
</tr>
<tr>
<td>Median (IQR) number of leads with ST elevations on ECG</td>
<td></td>
</tr>
<tr>
<td>3.5 (2–5)</td>
<td>2.0 (0.5–3.5)</td>
</tr>
<tr>
<td>Angiographic findings</td>
<td></td>
</tr>
<tr>
<td>Culprit lesion present (%)†</td>
<td>135 (78)</td>
</tr>
<tr>
<td>Culprit vessel</td>
<td>0.19</td>
</tr>
<tr>
<td>Left main</td>
<td>2%</td>
</tr>
<tr>
<td>Left anterior descending</td>
<td>46%</td>
</tr>
<tr>
<td>Left circumflex</td>
<td>13%</td>
</tr>
<tr>
<td>Right coronary</td>
<td>37%</td>
</tr>
<tr>
<td>Bypass graft</td>
<td>3%</td>
</tr>
<tr>
<td>No coronary disease (%)‡</td>
<td>11 (6)</td>
</tr>
<tr>
<td>Door-to-balloon time, median (IQR)</td>
<td>66 (56–77)</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; ED, emergency department; CT, computed tomography; BP, blood pressure; bpm, beats per minute; PCI, percutaneous coronary intervention; CAGB, coronary artery bypass grafting; AMI, acute myocardial infarction; and IQR, interquartile range.

*Typical ischemic symptom was any chest pain, discomfort, or pressure.
†Culprit lesion was any thrombotic total or subtotal occlusion of a coronary artery.
‡No coronary artery disease is no luminal stenosis >20% on angiography.

Figure 1. Schematic representation of the breakdown of door-to-balloon time into component parts based on universal processes of care for ST-segment elevation myocardial infarction patients.

Figure 2. Scatter plot demonstrating the correlation between door-to-activation time and door-to-balloon time. Black circles are individual subjects with fitted regression line in gray. X and Y axes are log scale.

Figure 3. Relative variability in the 3 components of the door-to-balloon time: door-to-activation time (blue) vs activation-to-catheterization laboratory arrival time (red) and catheterization laboratory arrival-to-reperfusion time (green) among all STEMI activations (A) and just true positive ST-segment elevation myocardial infarction activations (B). Top and bottom box edges represent 25th and 75th interquartile range, and error bars represent SD. The Y axis is minutes on a log scale.
race was associated with significantly prolonged door-to-activation times (Table 2).

After multivariate adjustment for potential confounders, typical anginal symptoms (33% shorter) and ambulance prehospital ECG use (61% shorter) were significantly associated with shorter door-to-activation time, whereas CT scan use in the ED (245% longer) and Asian race (56% longer) was significantly associated with longer door-to-activation times (Table 3). Sensitivity analyses excluding the 45% of Asian patients who required a translator in the ED resulted in a non-significant association (adjusted odds ratio, 1.42; 95% confidence interval, 0.93–2.19; \( P = 0.106 \)). The magnitude of the diagnostic changes on the inciting ECG, basic demographic characteristics including age and sex, the patient’s risk profile, and the years of responsible ED physician experience did not significantly affect door-to-activation time after adjustment.

Among factors independently associated with changes in door-to-activation time, only prehospital ECG use (18% shorter, 95% confidence interval, −7 to −28%; \( P = 0.002 \)) and CT scan use in the ED (75% longer, 95% confidence interval, +40 to +117%; \( P < 0.001 \)) were associated with significant changes in door-to-balloon times (Table 3).

Figure 4. Landmark cumulative incidence plot from the time of catheterization laboratory activation onward for STEMI patients achieving reperfusion in the first 250 minutes stratified by a door-to-activation time of ≤20 minutes. STEMI indicates ST-segment elevation myocardial infarction.

Discussion

Among all-comers referred from the ED for primary PCI in contemporary practice, our data suggest that the time required for diagnosis of an STEMI and activation of the catheterization laboratory (door-to-activation time) is the primary source of variability and delay in door-to-balloon time. In particular, we found that a door-to-activation time of ≤20 minutes was critical to achieving reperfusion with primary PCI within the targeted 90-minute door-to-balloon time window. If validated in a separate cohort, door-to-activation times <20 minutes may prove to be a useful clinical target for improving the primary PCI process. Interestingly, delays in door-to-activation time do not appear to predict delays in other aspects of the primary PCI process.

Door-to-balloon time is an important metric for STEMI patients because it is strongly related to short- and long-term mortality. National guidelines from the American Heart Association and American College of Cardiology have focused on the adoption of best practice techniques to

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### Table 2. Univariate Analysis of Factors Associated With Change Door-to-Activation Time

<table>
<thead>
<tr>
<th>Variable</th>
<th>% Difference in Door-to-Activation Time</th>
<th>95% CI</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female vs Male</td>
<td>14%</td>
<td>−22% to +68%</td>
<td>0.496</td>
</tr>
<tr>
<td>Age (per y)</td>
<td>−1%</td>
<td>−2% to 0%</td>
<td>0.128</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>Ref</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Asian</td>
<td>72%</td>
<td>+14% to +162%</td>
<td>0.011</td>
</tr>
<tr>
<td>African American</td>
<td>45%</td>
<td>−10% to +135%</td>
<td>0.129</td>
</tr>
<tr>
<td>Hispanic</td>
<td>−7%</td>
<td>−45% to +59%</td>
<td>0.797</td>
</tr>
<tr>
<td>Other</td>
<td>65%</td>
<td>−22% to +230%</td>
<td>0.278</td>
</tr>
<tr>
<td>BMI (per kg/m²)</td>
<td>−2%</td>
<td>−5% to +1%</td>
<td>0.227</td>
</tr>
<tr>
<td>Typical ischemic symptoms vs atypical symptoms</td>
<td>−40%</td>
<td>−57% to −15%</td>
<td>0.004</td>
</tr>
<tr>
<td>Any CT scan in ED vs no CT</td>
<td>174%</td>
<td>+59% to 370%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBP &lt;100 mm Hg vs ≥100 mm Hg</td>
<td>−40%</td>
<td>−62% to −5%</td>
<td>0.030</td>
</tr>
<tr>
<td>Pressor use vs no presor use</td>
<td>7%</td>
<td>−17% to +38%</td>
<td>0.595</td>
</tr>
<tr>
<td>HR &lt;50 bpm vs HR ≥50 bpm</td>
<td>−63%</td>
<td>−83% to −22%</td>
<td>0.010</td>
</tr>
<tr>
<td>ED doctor experience (per y)</td>
<td>−1%</td>
<td>−3% to +1%</td>
<td>0.337</td>
</tr>
<tr>
<td>Ambulance transport vs other transport</td>
<td>−53%</td>
<td>−66% to −35%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>After hours presentation vs weekday work hours</td>
<td>6%</td>
<td>−26% to +51%</td>
<td>0.746</td>
</tr>
<tr>
<td>History of CAD vs no CAD</td>
<td>27%</td>
<td>−12% to +84%</td>
<td>0.198</td>
</tr>
<tr>
<td>Accumulated number risk factors*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>ref</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1</td>
<td>35%</td>
<td>−13% to +111%</td>
<td>0.183</td>
</tr>
<tr>
<td>2</td>
<td>44%</td>
<td>−9% to +127%</td>
<td>0.116</td>
</tr>
<tr>
<td>3</td>
<td>26%</td>
<td>−23% to +118%</td>
<td>0.410</td>
</tr>
<tr>
<td>4</td>
<td>203%</td>
<td>−8% to +901%</td>
<td>0.068</td>
</tr>
<tr>
<td>Illicit drug abuse vs no drug use</td>
<td>21%</td>
<td>−25% to +95%</td>
<td>0.434</td>
</tr>
<tr>
<td>ECG territory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>ref</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Lateral</td>
<td>−11%</td>
<td>−55% to +76%</td>
<td>0.742</td>
</tr>
<tr>
<td>Inferior</td>
<td>−45%</td>
<td>−62% to −19%</td>
<td>0.003</td>
</tr>
<tr>
<td>Posterior</td>
<td>−18%</td>
<td>−63% to +82%</td>
<td>0.626</td>
</tr>
<tr>
<td>Height of STE (per mm)</td>
<td>−13%</td>
<td>−20% to −7%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of STE leads (per lead)</td>
<td>−17%</td>
<td>−23% to −10%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LBBB vs no LBBB</td>
<td>44%</td>
<td>−31% to +200%</td>
<td>0.336</td>
</tr>
</tbody>
</table>

CT indicates computed tomography; BMI, body mass index; SBP, systolic blood pressure; HR, heart rate; ED, emergency department; CAD, coronary artery disease; STE, ST-segment elevation; LBBB, left bundle-branch block; and CI, confidence interval.

*Risk Factors include the following: diabetes mellitus, hypertension, dyslipidemia, active tobacco use, and peripheral vascular disease.
improve door-to-balloon times. Although door-to-balloon times are decreasing,20,21 most efforts are focused on services provided after a STEMI diagnosis is established. Continued emphasis on strategies to reduce door-to-balloon times that begin after recognition of a STEMI may fail to address a primary source of delay in achieving timely reperfusion for all STEMI patients.

Our findings are unique because large registry studies do not collect the time and motion data needed to parse out the components of door-to-balloon time for more detailed analysis. In addition, large registries, such as the Centers for Medicare and Medicaid services' STEMI database, allow for broad exclusion of patients or rely on hospital discharge diagnosis codes and procedural codes in the catheterization laboratory for classification of a STEMI rather than the diagnosis established in the ED. Accordingly, STEMI registries have the potential for significant selection bias because of reclassification or exclusion relative to the emergency physicians' STEMI diagnosis. Although these exclusions are useful for comparisons of standardized process measures across institutions, they may limit our understanding of how best to improve care for the significant proportion of subjects with STEMI who are typically excluded.

Furthermore, large registries often collect relevant comorbidities based on diagnostic codes of chronic illnesses rather than those known at the time of presentation. However, a patient's recorded cardiovascular risk factor profile and history are often clarified during the index hospitalization and may be different from what is known at the time of presentation. These exclusions may limit our understanding of how best to improve care for the significant proportion of subjects with STEMI.

Table 3. Variables Associated With Change in the Components Aspects of Door-to-Balloon Time After Adjustment for Confounders

<table>
<thead>
<tr>
<th>Component</th>
<th>Prehospital ECG</th>
<th>CT scan in ED</th>
<th>Asian race</th>
<th>Typical ischemic symptoms</th>
<th>After hours</th>
<th>Inferior ST elevations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door to Activation</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.050 to 0.720</td>
<td>0.0000</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.001</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>Activation to Laboratory</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td>95% CI</td>
<td>−10% to 0.11</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>P</td>
<td>0.995</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>Laboratory to Balloon</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td>95% CI</td>
<td>−9% to 0.17</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>P</td>
<td>0.571</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>Door to Balloon</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td>95% CI</td>
<td>−7% to 0.28</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
<tr>
<td>P</td>
<td>0.002</td>
<td>0.0010</td>
<td>0.0010</td>
<td>0.0130</td>
<td>0.0100</td>
<td>0.0100</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; CT, computed tomography; and ED, emergency department.

A Bonferroni-corrected P value of 0.0125 was considered significant.
door-to-balloon times, despite implemented best practice measures as outlined by Bradley et al.6

Recent strategies to further reduce door-to-balloon times often focus on out-of-hospital care and the development of increasingly sophisticated STEMI receiving center networks in a broad spectrum of settings.24,25 These approaches may include permutations in the process of alerting the STEMI team and bypassing the ED altogether for certain patients who receive a prehospital STEMI diagnosis.26–28 However, in the United States, this group typically constitutes a small fraction of the total STEMI population in each network.15,29 For the majority of STEMI patients, our data suggest that continued emphasis on the triage and diagnostic period in the ED is paramount to establishing lower time to reperfusion therapy.

Time to Diagnosis of an STEMI

Our study identifies actionable factors that may improve door-to-activation time and thus door-to-balloon time. These included ambulance-based prehospital ECGs and the use of CT scans in the ED. The magnitude of change in door-to-balloon time seen with prehospital ECG use in our registry is highly consistent with other larger registries’ data regarding ambulance34 and prehospital ECG use.14 There is presently limited information from national databases regarding the use of emergency CT scan before primary PCI. Using our registry, we have recently shown that CT scans were used relatively frequently before primary PCI to exclude other diagnoses or ensure patient safety and that such CT scans rarely altered the course of care.30

Limitations

This study has many important limitations. The ACTIVATE-SF registry comprises a diverse, urban patient population and these data may not reflect processes of care in other settings. For example, our registry includes a significant number of false-positive STEMI activations.13 However, the consistency of our findings with large, national databases (eg, reductions in door-to-balloon time among prehospital ECG users) lends validity to the applicability of our data. In addition, our data are based on a real-world, all-comer registry of emergency physicians’ STEMI diagnoses. Thus, our registry includes a high number of specific populations not often included in large STEMI databases. These include patients who have undergone CT scanning before primary PCI, critically ill and intubated patients, and a significant number of false-negative STEMI diagnoses.2 We feel inclusion of these populations is essential to adequately describe processes of care in the ED setting, where outcomes (such as presence or absence of a culprit coronary artery occlusion) are not yet known. However, given the paucity of data on such populations nationally, it is possible that the prevalence of these specific conditions within our cohort is not reflective of national averages. Furthermore, our registry was designed to study the diagnostic period; however, it is not possible to fully capture potentially false-negative STEMs, that is, cases that were missed in the ED. Although we anticipate this would account for a small fraction of patients, if any, we are unable to assess this definitively. Last, although we have precisely analyzed the inciting STEMI ECG for each patient in our registry, we were not able to accurately track how many ECGs were required to establish the STEMI diagnosis and whether the initial ECGs were indeed nondiagnostic. Requirements for serial ECGs to establish a STEMI diagnosis in some patients have been highlighted as a significant cause of diagnostic delay in nonprimary PCI centers31 and may have contributed to the variability in door-to-ECG and door-to-activation time documented here.

Conclusions

In a contemporary practice, the interval from hospital arrival to STEMI diagnosis and catheterization laboratory activation (door-to-activation time) remains highly variable and a key driver of overall door-to-balloon times. Achieving a triage and diagnosis period (door-to-activation time) <20 minutes was strongly associated with achieving a door-to-balloon time <90 minutes and may, therefore, be a valuable quality metric. In the current era, the catheterization team has limited impact on variations in door-to-balloon times, which are largely determined by the preceding events. Focusing solely on strategies to reduce door-to-balloon times that are initiated after an STEMI diagnosis is established may fail to address the primary source of delay in timely reperfusion with PCI.

Disclosures

None.

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Impact of Door-to-Activation Time on Door-to-Balloon Time in Primary Percutaneous Coronary Intervention for ST-Segment Elevation Myocardial Infarctions: A Report From the Activate-SF Registry

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