Association of Hospital Primary Angioplasty Volume in ST-Segment Elevation Myocardial Infarction With Quality and Outcomes

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Several studies have demonstrated an inverse relationship between hospital primary angioplasty volume and mortality in patients presenting with ST-segment elevation myocardial infarction (STEMI). Analysis of data by the National Registry of Myocardial Infarction 2 investigators between 1994 and 1998 indicated that high primary angioplasty volume hospitals (>33 procedures per year) had a 28% lower inhospital mortality compared with low primary angioplasty volume hospitals (5-11 procedures per year). Another recent analysis using the same data set, but slightly different thresholds (<12 procedures per year, 12-36 procedures per year, and >36 procedures per year), yielded similar results.

Based on these and other studies, current American College of Cardiology/American Heart Association (ACC/AHA) guidelines for the management of patients with STEMI recommend that primary angioplasty in patients with STEMI be conducted by cardiac catheterization laboratories performing at least 36 primary angioplasties a year, as well as at least 200 total angioplasties a year.

The majority of these studies were conducted before the regular use of stents and the routine use of newer adjunctive pharmacotherapy, such as dual antiplatelet therapy and glycoprotein IIb/IIIa inhibitors, both of which have been associated with better outcomes in these patients. However, more contemporary data are lacking.

Context Earlier studies indicate an inverse relationship between hospital volume and mortality after primary angioplasty for patients presenting with ST-segment elevation myocardial infarction (STEMI). However, contemporary data are lacking.

Objective To assess the relationship between hospital primary angioplasty volume and outcomes and quality of care measures in patients presenting with STEMI.

Design, Setting, and Patients An observational analysis of data on 29,513 patients presenting with STEMI and undergoing primary angioplasty in the American Heart Association’s Get With the Guidelines registry. Patients were treated between July 5, 2001, and December 31, 2007, at 166 angioplasty-capable hospitals across the United States. Hospitals were divided into tertiles (<36 procedures per year, 36-70 procedures per year, and >70 procedures per year) based on their annual primary angioplasty volume.

Main Outcome Measures Door-to-balloon (DTB) times, length of hospital stay, adherence with evidence-based quality of care measures, and in-hospital mortality.

Results Compared with low- and medium-volume centers, high-volume centers had better median DTB times (98 vs 90 vs 88 minutes, respectively; P for trend < .001). High-volume centers were more likely than low-volume centers to follow evidence-based guidelines at discharge. Length of stay was similar between the 3 groups (P for trend = .13). There was no significant difference in the crude mortality between the tertiles of volume (incidence rate, 3.9% vs 3.2% vs 3.0% for low-, medium-, and high-volume centers, respectively; P = .26 and P = .99 for low- and medium- vs high-volume hospitals, respectively). Sequential multivariable modeling using generalized estimating equations revealed no significant association between hospital primary angioplasty volume and in-hospital mortality (adjusted odds ratio [OR], 1.22; 95% confidence interval [CI], 0.78-1.91; P = .38 and adjusted OR, 1.14; 95% CI, 0.78-1.66; P = .49 for low- and medium- vs high-volume hospitals, respectively).

Conclusion In a contemporary registry of patients with STEMI, higher-volume primary angioplasty centers vs lower-volume centers were associated with shorter DTB times and more use of evidence-based therapies, but not with adjusted in-hospital mortality or length of hospital stay.

JAMA. 2009;302(20):2207-2213

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(Reprinted) JAMA, November 25, 2009—Vol 302, No. 20 2207
primary data supporting a relationship between hospital primary angioplasty volume and outcomes are not available.

Accordingly, we explored the relationship between primary angioplasty volume and patient outcomes (specifically, in-hospital mortality, door-to-balloon [DTB] times, length of stay, and the use of evidence-based therapies) in patients presenting with STEMI, using data from the AHA’s Get With the Guidelines—Coronary Artery Disease (GWTG-CAD) national database.

**METHODS**

**Data Source and Study Population**

Details of the AHA’s GWTG-CAD have been previously published. A detailed description is also available in the eMethods (available online at http://www.jama.com). For the purpose of our analysis, patients were included if the initial electrocardiogram showed new ST-segment elevation or a new left bundle-branch block. In addition, patients having a cardiac diagnosis of STEMI were also included. Admissions staff, medical staff, or both recorded self-reported race/ethnicity, usually as the patient was registered. Patients were assigned to race/ethnicity categories using options defined by the electronic case report form. Case finding was based on clinical identification of patients with CAD diagnoses or National Center for Health Statistics International Classification of Diseases, Ninth Revision identification of CAD diagnoses with clinical verification for data abstraction.

Participating institutions submitted the GWTG protocol for review and approval by their institutional review board. Because data were used primarily at the local site for quality improvement, sites were granted a waiver of informed consent under the common rule. Additional details about the data source are available in the eMethods (available online at http://www.jama.com).

At the time of the analysis, the registry included a total of 332,050 patients between July 5, 2001, and December 31, 2007. We excluded 274,364 patients without STEMI and 21,561 patients who did not undergo primary angioplasty. In addition, we excluded 1,480 patients receiving thrombolytic therapy (except those patients who received rescue angioplasty), as well as 697 patients who were transferred out, to avoid double-counting, and to ensure accurate reporting of outcomes such as mortality and length of stay. To ensure adequate data quality, we excluded an additional 2,686 patients from 30 hospitals that had 25% or more missing data on past medical history. We excluded 11 hospitals with 425 patients that had missing site characteristics data. We also excluded 1,324 patients who were treated at 122 hospitals that submitted less than 30 primary angioplasty cases over the 6-year duration of the study, because this represented underreporting, with the possibility of selection bias. Patients who were transferred in were included, resulting in 29,513 patients.

**Assessment of Hospital Volume and Outcomes**

The chief independent variable was hospital primary angioplasty volume. Primary angioplasty was defined as angioplasty performed as primary reperfusion therapy for acute STEMI. Annual primary angioplasty volume for each hospital was calculated as the total number of primary angioplasty patients in a hospital after baseline. Patients who were transferred in were included, resulting in 29,513 patients.

**Statistical Analysis**

Volume was analyzed both as a categorical (tertiles) variable as well as a continuous variable. The hospital was the unit of analysis for assignment to a hospital-volume group. However, the patient was the unit of analysis for the evaluation of clinical variables and mortality. The patient and hospital characteristics, crude in-hospital mortality, and adherence to the evidence-based therapies were compared across the hospital primary percutaneous coronary intervention volume tertiles.

The mean (SD) and percentages are reported for continuous and categorical variables, respectively, except for DTB time, where medians (interquartile ranges [IQRs]) are reported.
cause volume tertiles is an ordinal variable, Cochran-Mantel-Haenszel row mean scores and Cochran-Mantel-Haenszel nonzero correlation tests were used to test the trend of categorical variables and continuous variables over the primary percutaneous coronary intervention volume tertiles, respectively. Sequential multivariable logistic regression, using generalized estimating equation approach to take into account within-hospital clustering, was performed to study the relationship between volume and the different outcomes. Several additional analyses (described in the eMethods; available online at http://www.jama.com) were conducted, including using different volume thresholds, volume as a continuous variable, and all patients presenting with STEMI. All statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary, North Carolina). All P values were 2-tailed, with statistical significance set at .05. All confidence intervals (CIs) were calculated at the 95% level.

RESULTS

A total of 29,513 patients with STEMI were treated with primary angioplasty at 166 hospitals across the United States. Hospital annual primary angioplasty volume ranged between 9 and 225 patients, with a mean of 59.8 and a median (IQR) of 49 (27-78) patients. Of the 166 hospitals, 65% (108) met the ACC/AHA recommended minimum of 36 primary angioplasties per year. Annual total hospital angioplasty volume ranged between 39 and 1264 patients, with a mean of 389 and a median (IQR) of 301 (192-552) patients. Baseline characteristics of the study population are shown in Table 1 and admission, laboratory data, and hospital characteristics are shown in Table 2.

Compared with low- and medium-volume centers, median DTB times were the lowest in high-volume centers (98 vs 90 vs 88 minutes, respectively; P for trend <.001). The proportion of patients meeting ACC/AHA guidelines of DTB time of 90 minutes or less was highest in the high-volume centers (44% vs 50% vs 53%, respectively; P for trend <.001). After adjusting for patient and hospital characteristics, patients presenting to low-volume hospitals (odds ratio [OR], 0.72; 95% CI, 0.54-0.96; P = .03) but not medium-volume hospitals (OR, 0.96; 95% CI, 0.72-1.28; P = .79) were less likely to achieve a DTB time of 90 minutes or less when compared with high-volume hospitals. In the subgroup of patients who achieved a DTB time of 90 minutes or less, mortality was similar between low-, medium-, and high-volume hospitals (2.7% vs 2.8% vs 2.4%, respectively; P for trend = .35).

Mean (4.6 vs 4.5 vs 4.7 days) and median (3 days each) lengths of stay were similar between low-, medium-, and high-volume hospitals, respectively (P for trend = .13).

By multivariable analysis, medium-volume hospitals (OR, 2.53; 95% CI, 1.08-5.92; P = .03) but not low-volume hospitals (OR, 1.73; 95% CI, 0.78-3.86; P = .18) were more likely than high-volume hospitals to give aspirin acutely (within 24 hours) to eligible patients (eTable; available online at http://www.jama.com). There was no difference between low-volume (OR, 0.94; 95% CI, 0.49-1.79; P = .85) and me-

*Table 1. Baseline Patient Characteristics by Hospital Primary Angioplasty Volume*

<table>
<thead>
<tr>
<th>Hospital Primary Angioplasty Volume</th>
<th>Low (n = 3900)</th>
<th>Medium (n = 9008)</th>
<th>High (n = 16 605)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sociodemographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>60.5 (13.0)</td>
<td>60.5 (12.9)</td>
<td>61.1 (13.3)</td>
<td>.002</td>
</tr>
<tr>
<td>Female sex</td>
<td>1089 (27.9)</td>
<td>2480 (27.3)</td>
<td>4875 (29.4)</td>
<td>.01</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>28.6 (5.9)</td>
<td>28.6 (6.0)</td>
<td>28.9 (6.0)</td>
<td>.02</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>White</td>
<td>2502 (64.2)</td>
<td>6874 (76.3)</td>
<td>13 887 (83.6)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>211 (5.4)</td>
<td>605 (6.7)</td>
<td>799 (4.8)</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>463 (12.4)</td>
<td>651 (7.2)</td>
<td>821 (4.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Health insurance</strong></td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Medicare</td>
<td>978 (25.1)</td>
<td>2282 (25.3)</td>
<td>4608 (27.8)</td>
<td></td>
</tr>
<tr>
<td>Medicaid</td>
<td>1267 (3.2)</td>
<td>358 (4.0)</td>
<td>490 (3.0)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>498 (12.8)</td>
<td>1265 (14.0)</td>
<td>2214 (13.3)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2296 (58.9)</td>
<td>5103 (56.7)</td>
<td>9293 (56.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Past medical history</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>893 (22.9)</td>
<td>2003 (22.2)</td>
<td>3537 (21.3)</td>
<td>.01</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1495 (38.3)</td>
<td>4016 (44.6)</td>
<td>7070 (42.6)</td>
<td>.01</td>
</tr>
<tr>
<td>Hypertension</td>
<td>2074 (53.2)</td>
<td>4824 (63.6)</td>
<td>9064 (64.6)</td>
<td>.06</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>140 (3.5)</td>
<td>346 (3.8)</td>
<td>798 (4.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td>502 (12.9)</td>
<td>1155 (12.8)</td>
<td>2506 (15.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>History of heart failure</td>
<td>172 (4.4)</td>
<td>365 (4.1)</td>
<td>953 (6.7)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CVA/TIA</td>
<td>149 (3.8)</td>
<td>317 (3.5)</td>
<td>690 (4.2)</td>
<td>.07</td>
</tr>
<tr>
<td>Chronic or recurrent AF</td>
<td>200 (3.1)</td>
<td>259 (2.9)</td>
<td>587 (3.5)</td>
<td>.02</td>
</tr>
<tr>
<td>COPD or asthma</td>
<td>268 (6.9)</td>
<td>664 (7.4)</td>
<td>1500 (8.0)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Smoking history</td>
<td>1671 (42.9)</td>
<td>4015 (44.6)</td>
<td>7099 (42.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Chronic renal insufficiency</td>
<td>113 (2.9)</td>
<td>262 (2.9)</td>
<td>533 (3.2)</td>
<td>.17</td>
</tr>
<tr>
<td>Renal dialysis</td>
<td>33 (0.9)</td>
<td>55 (0.6)</td>
<td>112 (0.7)</td>
<td>.47</td>
</tr>
<tr>
<td>Anemia</td>
<td>12 (0.3)</td>
<td>27 (0.3)</td>
<td>51 (0.3)</td>
<td>.98</td>
</tr>
<tr>
<td>Depression</td>
<td>23 (0.6)</td>
<td>126 (1.4)</td>
<td>143 (0.9)</td>
<td>.63</td>
</tr>
<tr>
<td>Alcohol abuse</td>
<td>200 (5.1)</td>
<td>433 (4.8)</td>
<td>594 (3.8)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Abbreviations: AF, atrial fibrillation; BMI, body mass index, calculated as weight in kilograms divided by height in meters squared; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; TIA, transient ischemic attack.

*<sup>a</sup> Data are shown as No. (%) unless otherwise specified. Because of rounding, percentages may not total 100. Low volume indicates less than 36 primary angioplasty procedures performed per year; medium volume, 36 to 70 primary angioplasty procedures per year; and high volume, more than 70 primary angioplasty procedures per year.

*<sup>b</sup> Self-reported, usually as the patient was registered. Patients were assigned to race/ethnicity categories using options defined by the electronic case report form.

*<sup>c</sup> A payment source other than Medicare or Medicaid, such as Veterans Administration, CHAMPUS (TRICARE), workers’ compensation, or private insurance.

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-gible patients (OR, 0.79; 95% CI, 0.62-
1.00; P = .05), and to counsel current
smokers regarding smoking cessation
(OR, 0.54; 95% CI, 0.37-0.78; P = .001).
All or no adherence with 6 key qual-
ity of care measures was also less likely
in the low-volume hospitals com-
pared with the high-volume hospitals
(OR, 0.68; 95% CI, 0.49-0.94; P = .02).
The overall in-hospital mortality was
3.2% (incidence rate, 3.9% vs 3.2% vs
3.0% for low-, medium-, and high-
volume centers, respectively). In the un-
adjusted analysis for in-hospital mor-
tality, there was no difference between
low-volume (OR, 1.21; 95% CI, 0.87-
1.69; P = .26) or medium-volume hos-
pitals (OR, 1.00; 95% CI, 0.77-1.31;
P = .99) compared with high-volume hospitals. After sequential multivari-
able analysis, there was no difference
between the 3 groups and the ad-
justed mortality. Furthermore, there
was no relationship between volume as
a continuous variable and mortality
(Spearman correlation coefficient =
−0.004, P = .95) (TABLE 3 and FIGURE).
Various other thresholds were also
tested; however, none of these demon-
strated a significant volume-outcomes
relationship. For instance, using thresh-
olds of 25 or less procedures per year,
26 to 50 procedures per year, and 50
or more procedures per year yielded
mortality rates of 3.7% vs 3.2% vs 3.2%
for low-, medium-, and high-volume
hospitals, respectively. The multivari-
able adjusted ORs were 1.06 (95% CI,
0.74-1.52; P = .74) and 1.09 (95% CI,
0.78-1.52; P = .62) for low- and me-
dium-volume hospitals compared with
high-volume hospitals, respectively. When tertiles were defined as less than
12 procedures per year, 12 to 36 pro-
cedures per year, and more than 36 pro-
cedures per year, there were only 2 hos-
pitals (with 68 patients) that performed
less than 12 procedures per year, thus
resulting in mortality rates of 1.5% vs
3.9% vs 3.1%, respectively.
When all 30 837 patients were in-
cluded (ie, including hospitals that did
not submit <30 cases during the entire
study period), there was no difference
between low-, medium-, and high-
volume hospitals in in-hospital mor-
tality (3.3% vs 3.2% vs 3.1%, respec-
tively; P for trend = .12). When patients
who were transferred in were ex-
cluded (n = 9183), there was again no
difference in the crude in-hospital mor-
tality between the 3 groups (3.8% vs
3.2% vs 3.1%, respectively; P for trend = .08).
Although patients not undergoing
primary angioplasty were excluded
from the primary analysis, they consti-
tuted 30.1% of patients presenting with
STEMI. Of these, 13.1% received thrombolytics, 8.2% received both

Table 2. Patient Admission, Laboratory Data, and Hospital Characteristics by Hospital Primary Angioplasty Volume.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Low (n = 3900)</th>
<th>Medium (n = 9008)</th>
<th>High (n = 16605)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admission characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP, mean (SD), mm Hg²</td>
<td>135.0 (29.2)</td>
<td>133.0 (28.9)</td>
<td>133.1 (28.7)</td>
<td>.07</td>
</tr>
<tr>
<td>Diastolic BP, mean (SD), mm Hg²</td>
<td>78.5 (18.9)</td>
<td>79.3 (18.5)</td>
<td>78.6 (18.9)</td>
<td>.59</td>
</tr>
<tr>
<td>Heart rate, mean (SD), beats/min¹²</td>
<td>78.1 (18.9)</td>
<td>78.4 (19.0)</td>
<td>77.6 (19.8)</td>
<td>.21</td>
</tr>
<tr>
<td>Anterior STEMI²</td>
<td>399 (37.6)</td>
<td>730 (32.9)</td>
<td>2182 (34.2)</td>
<td>.20</td>
</tr>
<tr>
<td>New-onset atrial fibrillation</td>
<td>16 (0.4)</td>
<td>43 (0.5)</td>
<td>80 (0.5)</td>
<td>.62</td>
</tr>
<tr>
<td>Transfer in</td>
<td>666 (17.1)</td>
<td>1685 (18.7)</td>
<td>6832 (41.1)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Rescue angioplasty</td>
<td>214 (5.5)</td>
<td>303 (3.4)</td>
<td>310 (1.9)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Laboratory and echocardiographic data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol, mean (SD), mg/dL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>177.1 (45.1)</td>
<td>179.3 (47.9)</td>
<td>173.4 (44.6)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>LDL</td>
<td>109.7 (39.3)</td>
<td>110.0 (39.8)</td>
<td>106.7 (37.8)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>HDL</td>
<td>37.8 (12.2)</td>
<td>38.2 (12.1)</td>
<td>37.5 (11.5)</td>
<td>.004</td>
</tr>
<tr>
<td>Triglycerides, mean (SD), mg/dL</td>
<td>162.1 (124.3)</td>
<td>166.3 (129.2)</td>
<td>154.0 (117.9)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Glycated hemoglobin, mean (SD), %²</td>
<td>8.1 (2.2)</td>
<td>7.8 (2.1)</td>
<td>8.2 (2.2)</td>
<td>.10</td>
</tr>
<tr>
<td>Ejection fraction, mean (SD), %²</td>
<td>48.2 (12.8)</td>
<td>46.8 (12.4)</td>
<td>47.6 (12.3)</td>
<td>.91</td>
</tr>
<tr>
<td>Ejection fraction ≤40%</td>
<td>724 (18.6)</td>
<td>1909 (21.2)</td>
<td>3600 (21.7)</td>
<td>.01</td>
</tr>
<tr>
<td>Hospital characteristics</td>
<td>(n = 58)</td>
<td>(n = 57)</td>
<td>(n = 51)</td>
<td></td>
</tr>
<tr>
<td>Bed size, mean (SD)</td>
<td>309.1 (226.7)</td>
<td>353.8 (201.2)</td>
<td>487.7 (266.3)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Academic hospital</td>
<td>2117 (64.3)</td>
<td>3397 (37.7)</td>
<td>11214 (67.5)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Residents/fellows present</td>
<td>1112 (28.5)</td>
<td>2588 (28.7)</td>
<td>7920 (47.7)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Northeast</td>
<td>414 (10.6)</td>
<td>454 (5.0)</td>
<td>4739 (28.6)</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>780 (20.0)</td>
<td>2781 (30.9)</td>
<td>4132 (24.9)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>South</td>
<td>1093 (28.0)</td>
<td>3922 (43.5)</td>
<td>3246 (19.5)</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>1613 (41.4)</td>
<td>1851 (20.6)</td>
<td>4489 (27.0)</td>
<td></td>
</tr>
<tr>
<td>Onsite surgical backup</td>
<td>3198 (81.7)</td>
<td>7578 (84.1)</td>
<td>15985 (86.3)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Full intervention status</td>
<td>2823 (72.4)</td>
<td>6723 (74.6)</td>
<td>14412 (86.8)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Cardiac transplant capacity</td>
<td>347 (8.9)</td>
<td>788 (8.8)</td>
<td>4062 (24.5)</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Abbreviations: BP, blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; STEMI, ST-segment el-
eviation myocardial infarction.

1 Conversions: To convert total, HDL, and LDL cholesterol to mmol/L, multiply by 0.0259; triglycerides to mmol/L, multiply
by 0.0113.
2 Data are shown as No. (%) unless otherwise specified. Because of rounding, percentages may not total 100. Low volume
indicates less than 36 primary angioplasty procedures performed per year; medium volume, 36 to 70 primary angiop-
plasty procedures per year; and high volume, more than 70 primary angioplasty procedures per year.
3 More than 25% missing data.

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2210 JAMA, November 25, 2009—Vol 302, No. 20 (Reprinted)

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thrombolytics and angioplasty, 3.1% had missing data, and the remaining were medically managed. Patients who did not undergo primary angioplasty had a significantly higher mortality (11.8%) compared with patients undergoing primary angioplasty (3.2%), and for these patients, low- and medium-volume hospitals had a higher crude mortality than high-volume hospitals (14.2% vs 12.9% vs 10.7%, respectively; P for trend <.001). In multivariable-adjusted analysis, low-volume hospitals (OR, 1.51; 95% CI, 1.15-1.99; P = .003) but not medium-volume hospitals (OR, 1.29; 95% CI, 0.98-1.69; P = .07) had higher inhospital mortality compared with high-volume hospitals.

Similarly, the crude mortality for all patients presenting with STEMI (irrespective of management strategy) was higher in the low- and medium-volume hospitals compared with the high-volume hospitals (7.4% vs 6.0% vs 5.3%, respectively; P for trend <.001). In multivariable analysis, low-volume hospitals with high-volume hospitals had a higher mortality (OR, 1.52; 95% CI, 1.16-2.00; P = .003). There was however no difference between medium- and high-volume hospitals (OR, 1.23; 95% CI, 0.95-1.58; P = .12).

There was a strong association between total and primary angioplasty volume (Spearman correlation coefficient = 0.57, P < .001). Patients presenting to low total angioplasty volume hospitals (total annual angioplasty volume, <200) had a higher crude mortality compared with medium-volume (total annual angioplasty volume, 200-400) and high-volume hospitals (total annual angioplasty volume, >400) (3.5% vs 3.3% vs 3.0%, respectively; P for trend = .05). However, after sequential multivariable modeling, there was no difference in mortality between low-volume (OR, 1.20; 95% CI, 0.82-1.75; P = .35) and medium-volume hospitals (OR, 1.26; 95% CI, 0.94-1.68; P = .12) compared with high-volume hospitals.

**COMMENT**

Our analysis of contemporary data from approximately 30 000 patients presenting with STEMI at 166 hospitals across the United States indicates that compared with low-volume hospitals, high-volume hospitals have shorter DTB times, have a larger proportion of patients who achieve ACC/AHA recommended DTB times of 90 minutes or less, and demonstrate greater adherence with evidence-based therapies and recommendations. However, there was no difference in the length of stay or unadjusted or adjusted inhospital mortality between low-, medium-, and highvolume primary angioplasty hospitals.

There was also no difference in the adjusted mortality based on the total angioplasty volume of hospitals. Medium-volume hospitals performed as well as high-volume hospitals for all quality of care measures assessed.

Our results, especially with respect to in-hospital mortality, are contrary to other published registry studies in patients with STEMI. One of the main differences is that our study reflects...
more contemporary practice. Angioplasty techniques and adjunctive pharmacotherapy have seen substantial improvements over the past few years, and there has been a significant standardization of these practices nationwide. In addition, evidence-based therapies are much more widely adopted and practiced. A similar discrepancy between older and contemporary registries has been noted for surgical procedures as well. With standardization of processes of care for surgical procedures, several of the earlier observed differences in mortality between hospitals based on surgical volume are no longer significant.14-16

The thresholds that we used to classify hospitals into low, medium, and high volume are different from prior studies. Although we did not specifically study all reported thresholds individually, we examined various thresholds other than the primary analysis of less than 36 primary angioplasties per year, 36 to 70 primary angioplasties per year, and more than 70 primary angioplasties per year, but did not find an association between primary angioplasty volume and mortality. In addition, we did not find an association between volume as a continuous variable and mortality, making it unlikely that other thresholds would significantly alter our findings. Lower thresholds tended to further reduce the sample size in the low-volume group, thereby further reducing the power of this study to detect any difference between the groups.

We opted to use thresholds based on minimum primary angioplasty volume recommendations by the ACC/AHA. We did not observe any difference in in-hospital mortality between hospitals that followed these recommendations vs those who did not (<36 primary angioplasties per year vs ≥36 primary angioplasties per year). This is reassuring because our registry indicates that more than a third of US hospitals do not achieve the recommended minimum of 36 procedures annually.

For our primary analysis, we excluded hospitals submitting less than 30 procedures over the study period. This was performed to minimize selection bias and to account for hospitals that had participated for a short time or inconsistently. Even when these patients were included in the analysis, only 745 (2.4% of the total population undergoing primary angioplasty) were treated at hospitals performing less than 12 primary angioplasties annually. In contrast, the study by Cannon et al1 found that 17.5% of similar patients in the National Registry of Myocardial Infarction 2 registry were treated at hospitals performing less than 12 primary angioplasties annually. This may represent another reason for our failure to demonstrate a volume-outcomes relationship for in-hospital mortality. Rather than our study being inconsistent with earlier data, it is conceivable that with the incorporation of volume as a metric based on those earlier studies, fewer hospitals, particularly those participating in the GWTG-CAD registry, were functioning as true “low-volume” hospitals, with a resultant reduction in mortality differences between these hospitals based on volume.

The higher mortality in low-volume hospitals for all patients with STEMI and for patients who did not undergo primary angioplasty noted in our study is hypothesis-generating and warrants further investigation. It is plausible that lower-volume centers were being more selective in taking patients with STEMI for primary angioplasty.

One of the reasons our findings are important is that procedural volume is increasingly being used as a surrogate for quality of care. Some organizations have set standards for urban hospitals to meet before they would contract the care of their employees with them. These include minimum volumes for several procedures including angioplasty. Our study makes a case against such volume criteria.

Compared with low-volume centers, our finding that high-volume centers are more adept at achieving shorter DTB times, as well as in adhering to evidence-based therapies in patients with STEMI, is likely an indicator of better systems of care in these hospitals. Further analysis and quantification of these systems could enable standardization of health care delivery across hospitals. Because numerous studies have linked shorter DTB times and greater adherence to evidence-based medications with better outcomes, there are probably multiple reasons why a difference in in-hospital mortality between low- and high-volume hospitals was not observed, despite seeing a difference in DTB times and the use of evidence-based therapies between these hospitals. For instance, most of these studies assessed mortality over a longer period. Measurement of in-hospital mortality alone may thus represent inadequate follow-up. Additionally, inhospital mortality may not be the most sensitive discriminant of quality. From a statistical perspective, we could be underpowered to detect a difference in mortality between low- and high-volume primary angioplasty hospitals. To demonstrate a significant 0.9% difference in mortality between these 2 groups with 80% power, the low-volume tertile should have at least 6675 patients.

We acknowledge the limitations of our study. In addition to data being submitted voluntarily by participating hospitals, data were also collected by medical chart review and are thus dependent on the accuracy and completeness of documentation and abstraction. The GWTG-CAD is primarily a quality improvement registry and was not specifically designed to address the causal implication of hospital volume and mortality. Our analysis reflects a subgroup analysis performed in the context of hospitals actively engaged in quality improvement, without a control set. Analysis of data from a control group of hospitals, not in the GWTG-CAD registry, with low primary angioplasty volume is thus necessary to strengthen our findings. Another significant limitation is the inability to adjust for individual operator volume. It is conceivable that low-volume hospitals may be performing as well as other hospitals because they...
have 1 or 2 high-volume operators. Seven studies have demonstrated a relationship between high-operator volume for angioplasty and improved outcomes,6,7 although that difference seems to be getting smaller as well.24 Finally, data on total ischemic (symptom-to-door) time was not available. This would have enabled a more complete evaluation of differences in systems of care between hospitals, such as ambulance triage and prehospital electrocardiogram.

CONCLUSIONS

In a contemporary registry of patients with STEMI, higher-volume primary angioplasty centers compared with lower-volume centers were associated with shorter DTB times and greater use of evidence-based therapies, but not with adjusted in-hospital mortality or length of hospital stay. Further studies corroborating our findings with the use of stents and newer adjunctive pharmacotherapy are necessary, including longer-term follow-up.

Author Contributions: Dr Peterson had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Kumbhani, Askari, Bhatt.

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Analysis and interpretation of data: Kumbhani, Cannon, Fonarow, Liang, Askari, Peacock, Peterson, Bhatt.

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Administrative, technical, or material support: Askari, Peacock, Bhatt.

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Financial Disclosures: Dr Cannon reported receiving research grants from Accuminetics, AstraZeneca, Bristol-Myers Squibb, GlaxoSmithKline, Merck, Sanofi-Aventis, Schering-Plough, and Merck/Schering. Dr Bhatt reported receiving research grants from AstraZeneca, Bristol-Myers Squibb, Eisai, Ethicon, Heartscapes, Sanofi-Aventis, and The Medicines Company; receiving honoraria from AstraZeneca, Bristol-Myers Squibb, Centocor, Daiichi-Sankyo, Eisai, Eli Lilly, GlaxoSmithKline, Millennium, Paringenix, PDL, Sanofi-Aventis, Schering-Plough, and The Medicines Company; being on the speakers bureau of Bristol-Myers Squibb, Sanofi-Aventis, and The Medicines Company; being a consultative/advisory board member of Arena, Astellas, AstraZeneca, Bayer, Bristol-Myers Squibb, Cardax, Centocor, Daiichi-Sanyko, Eisai, Eli Lilly, GlaxoSmithKline, Johnson & Johnson, McNeil, Medtronic, Millennium, Molecular Insights, Otsuka, Paringenix, PDL, Philips, Portola, Sanofi-Aventis, Schering-Plough, Takeda, The Medicines Company, and Vertex; and providing expert testimony regarding antiplatelet therapy. Drs Kumbhani and Liang reported no financial disclosures.

Funding/Support: The Get With the Guidelines-Coronary Artery Disease is a program of the American Heart Association (AHA) and is supported by an unrestricted educational grant from Merck/Schering-Plough Pharmaceutical. Data collection and management were performed by Outcome Inc (Cambridge, Massachusetts). The analysis of registry data was performed at Duke Clinical Research Institute (Durham, North Carolina), which also receives funding from the AHA.

Role of the Sponsors: Merck and Schering-Plough had no role in the design and conduct of the study; in the collection, management, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript. The AHA provides Get With the Guidelines program management with a volunteer steering committee and AHA staff. The manuscript was submitted to the AHA for review and approval before submission.

Disclaimer: Dr Peterson, a contributing editor for JAMA, was not involved in the editorial review of or the decision to publish this article.

Additional Information: Online eMethods and eTable are available at http://www.jama.com.

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