Volume-Outcome Relationships for Percutaneous Coronary Interventions in the Stent Era

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Background—Most studies that are the basis of recommended volume thresholds for percutaneous coronary interventions (PCIs) predate the routine use of stent placement.

Methods and Results—Data from New York’s Percutaneous Coronary Interventions Reporting System in 1998 to 2000 (n = 110,713) were used to examine the impact of annual hospital volume and annual operator volume on in-hospital mortality, same-day coronary artery bypass graft (CABG) surgery, and same-stay CABG surgery after adjustment for differences in patients’ severity of illness. For a hospital-volume threshold of 400, the odds ratios for low-volume hospitals versus high-volume hospitals were 1.98 (95% CI, 1.17, 3.35) for in-hospital mortality, 2.07 (95% CI, 1.36, 3.15) for same-day CABG surgery, and 1.51 (95% CI, 1.03, 2.21) for same-stay CABG surgery. For an operator-volume threshold of 75, the odds ratios for low-volume versus high-volume operators were 1.65 (95% CI, 1.05, 2.60) for same-day CABG surgery and 1.55 (95% CI, 1.10, 2.18) for same-stay CABG surgery. Operator volume was not significantly associated with mortality. Also, for hospital volumes below 400 and operator volumes below 75, the respective odds of mortality, same-day CABG surgery, and same-stay CABG surgery were 5.92, 4.02, and 3.92 times the odds for hospital volumes of 400 or higher and operator volumes of 75 or higher.

Conclusions—Higher-volume operators and hospitals continue to experience lower risk-adjusted PCI outcome rates. (Circulation. 2005;112:1171-1179.)

Key Words: angioplasty • coronary disease • mortality • revascularization • stents

In the past 25 years, there have been a large number of studies that have investigated the relationship between short-term outcomes and provider volume for a wide variety of medical conditions and surgical procedures, and many of these studies have been related to coronary angioplasty, or percutaneous coronary interventions (PCIs).1–13 Excellent summaries of volume-outcome studies, including those devoted to angioplasty, are provided by Halm et al14 and Dudley et al.15 Although this work did not receive much attention for many years with regard to potential for changing the landscape of our medical system, in the past few years there have been advocates for change based on what we know about volume-outcome relationships. One of the most vocal of these advocates has been the Leapfrog Group, which has recommended that payers contract with hospitals whose annual volume of selected procedures exceeds certain thresholds that Leapfrog has set on the basis of its review of the volume-outcome literature. For coronary angioplasty (PCI), Leapfrog recommends contracting with hospitals having annual volumes of at least 400 procedures a year,16 and the American College of Cardiology/American Heart Association (ACC/AHA) also recommends more than 400 procedures per year per hospital and at least 75 procedures per year for operators.17

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The purpose of this study was to examine the volume-outcome relationship for PCI hospitals and operators in New York State in 1998 to 2000 for 3 different outcomes (in-hospital mortality, same-day coronary artery bypass graft (CABG) surgery, and same-stay CABG surgery using clinical data from New York’s Percutaneous Coronary Interventions Reporting System (PCIRS). As part of the study, we will also examine the interaction effect of hospital volume and operator volume on these 3 outcomes.

Methods

Data

The database for the study is New York’s PCIRS, which contains detailed information on all patients undergoing PCI in New York State in each of the hospitals that are approved to perform the procedure by the New York State Department of Health. The system...

<table>
<thead>
<tr>
<th>Demographic characteristics</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean‡</td>
<td>60.8</td>
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<tr>
<td>Female sex</td>
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<table>
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<tr>
<th>Ventricular function</th>
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<tr>
<td>Ejection fraction ≤19%</td>
<td>0.6</td>
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<tr>
<td>20%–29%</td>
<td>3.1</td>
</tr>
<tr>
<td>30%–39%</td>
<td>8.2</td>
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<tr>
<td>Recent MI</td>
<td></td>
</tr>
<tr>
<td>&lt;6 h</td>
<td>5.1</td>
</tr>
<tr>
<td>6–23 h</td>
<td>4.7</td>
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<tr>
<td>1–7 d</td>
<td>16.1</td>
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<table>
<thead>
<tr>
<th>Vessels</th>
<th>Prevalence (%)</th>
</tr>
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<tr>
<td>LMCA diseased‡</td>
<td>2.8</td>
</tr>
<tr>
<td>No. of vessels diseased ‡</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>28.0</td>
</tr>
<tr>
<td>3</td>
<td>14.4</td>
</tr>
<tr>
<td>Vessels attempted ‡</td>
<td></td>
</tr>
<tr>
<td>LMCA attempted</td>
<td>0.7</td>
</tr>
<tr>
<td>Two vessels other than LMCA attempted</td>
<td>10.1</td>
</tr>
<tr>
<td>Three vessels other than LMCA attempted</td>
<td>0.4</td>
</tr>
<tr>
<td>Type of worst lesion attempted‡</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>66.8</td>
</tr>
<tr>
<td>C</td>
<td>21.4</td>
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</table>

<table>
<thead>
<tr>
<th>Hemodynamic state</th>
<th>Prevalence (%)</th>
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<tbody>
<tr>
<td>Hemodynamic instability</td>
<td></td>
</tr>
<tr>
<td>Shock</td>
<td>0.6</td>
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<tr>
<td>Unstable</td>
<td>1.0</td>
</tr>
<tr>
<td>CPR</td>
<td>0.2</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Comorbidities</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous stroke†</td>
<td>2.9</td>
</tr>
<tr>
<td>Carotid/cerebrovascular disease</td>
<td>3.4</td>
</tr>
<tr>
<td>Aortoiliac disease‡</td>
<td>1.7</td>
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<tr>
<td>Femoral/popliteal disease</td>
<td>4.1</td>
</tr>
<tr>
<td>Malignant ventricular arrhythmia</td>
<td>2.0</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease‡</td>
<td>6.9</td>
</tr>
<tr>
<td>Diabetes*</td>
<td>26.8</td>
</tr>
<tr>
<td>Renal failure</td>
<td></td>
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<tr>
<td>Dependent on dialysis</td>
<td>1.1</td>
</tr>
<tr>
<td>Creatinine &gt;2.5 mg/dL</td>
<td>1.2</td>
</tr>
<tr>
<td>Congestive heart failure‡</td>
<td></td>
</tr>
<tr>
<td>This admission</td>
<td>4.7</td>
</tr>
<tr>
<td>Before this admission</td>
<td>3.7</td>
</tr>
<tr>
<td>Stent thrombosis</td>
<td>0.5</td>
</tr>
<tr>
<td>Emergency PCI because of diagnostic catheterization complication</td>
<td>0.1</td>
</tr>
<tr>
<td>Previous PCI‡</td>
<td>21.5</td>
</tr>
<tr>
<td>Previous open-heart operations‡</td>
<td>12.8</td>
</tr>
<tr>
<td>Use of stent‡</td>
<td>82.3</td>
</tr>
</tbody>
</table>

LMCA indicates left main coronary artery.

*P<0.05 for the test of the difference of each variable between two volume groups.
†P<0.01.
‡P<0.001.
contains demographics, patient preprocedural risk factors, complications of care, discharge disposition, and provider (hospital and operator) identifiers as well as patient identifiers. Because there is also a CABG surgery registry in New York (the Cardiac Surgery Reporting System, or CSRS), data from the PCIRS were linked to the CSRS using social security number, medical record number, date of birth, date of admission, and date of discharge so that same-day CABG surgery and same-stay CABG surgery could be obtained as other measures of adverse events. Data consisting of all PCI discharges in the years 1998 to 2000 except from 3 hospitals during their first year of PCI were used in the study.

**Protocols**

For each of 2 annual hospital-volume ranges (on either side of 400), the prevalences of the patient risk factors contained in the registry were compared by use of y² tests after categories had been created for the continuous variable ejection fraction. For each outcome measure, a variety of risk factors relating to demographics, cardiac function, coronary vessels diseased, previous open heart surgery, and previous myocardial infarctions that were significantly related to it were used as candidate independent variables in a logistic regression model with P<0.05. Generalized estimating equations were used to account for clustering of observations within providers.

Three hospital-volume thresholds (400, 500, and 600 procedures per year) were identified on the basis of other studies and recommended thresholds, and the percentage of patients and number of hospitals with annual volumes on either side of each threshold were calculated along with the 3-year observed adverse outcome rates for hospitals on either side of each threshold. Predicted outcome rates for the period 1998 to 2000 were calculated for the volume groups on either side of each of the thresholds by summing the predicted probabilities of adverse outcome of all of its patients obtained from the relevant logistic regression model and then averaging over the number of patients. For each outcome, the logistic regression models mentioned above were recreated by adding a binary variable representing which of the 2 provider volume groups was associated with the patient (with “1” representing the lower-volume group). The regression coefficient of this binary variable was then exponentiated to obtain the adjusted odds ratio for the adverse outcome occurring in the lower-volume group relative to adverse outcome occurring in the higher-volume group. Confidence intervals for the adjusted odds ratios were also obtained. The analyses were then repeated using operator-volume groups. Operator-volume thresholds were set at 75 (on the basis of ACC/AHA recommendations) and at slightly higher levels of 100 and 125 procedures per year.

For each hospital-volume threshold, the percentage of adverse events that would have been avoided if all patients were treated in hospitals with volumes above the threshold was calculated for each of the 3 outcome measures.

The relationship between risk-adjusted outcomes and mean annual provider volume was plotted, and smoothed curves were developed to characterize the relationship.

To test the interaction effects of hospital volume and operator volume, each of 2 hospital-volume thresholds (400 and 600 procedures per year) were combined with an operator-volume threshold of 75 to create 2 groupings of 4 hospital-volume/operator-volume categories. For each outcome and for each volume grouping, the resulting 4 hospital-volume/operator-volume groups were then compared by adding 3 binary variables (using the fourth category “high hospital volume/high operator volume” as a reference group) and then adding these variables to the patient characteristics identified in earlier logistic regression models as having been significantly related to the outcome. Adjusted odds ratios were calculated for each of the groups.

The analyses were repeated after limiting the database to patients who underwent stent placement.

**Volume-outcome relationships for primary angioplasty (angioplasty for acute myocardial infarction) were examined using volume of primary angioplasty cases as the volume measure (because it proved to be a more powerful predictor of outcomes than total PCI volume).**

All analyses were conducted using SAS Version 8.2 (SAS Institute).

**Results**

There were 34 hospitals and 263 operators included in the analyses. Table 1 presents patient characteristics for patients in hospitals with annual volumes of fewer than 400 procedures and hospitals with annual volumes of at least 400. Patients in higher-volume hospitals were significantly older and were significantly more likely to have had left main disease, more vessels diseased and attempted, a type C lesion, previous stroke, aortoiliac disease, congestive heart failure, previous PCIs and open heart operations, and stents during the index procedure. Patients in lower-volume hospitals were significantly more likely to have had chronic obstructive pulmonary disease and diabetes. It is important to note that these statistically significant differences are more likely to be attributable to large sample sizes rather than to clinical significance.

**Table 2** presents rates and adjusted odds ratios for the outcomes for 3 different annual hospital-volume thresholds: 400, 500, and 600 procedures per year. For all 3 groupings, the lower-volume hospital group had significantly higher

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**TABLE 2. Association Between Hospital Volume and Adverse In-Hospital Events for PCI in New York State, 1998–2000**

<table>
<thead>
<tr>
<th>Annual Hospital-Volume Threshold</th>
<th>No. of Patients (%)</th>
<th>No. of Events (Observed Rate, %)</th>
<th>Predicted Rate, %</th>
<th>Adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-Hospital Mortality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>400</td>
<td>&lt;400 4–5</td>
<td>2453 (2.3)</td>
<td>0.72</td>
<td>1.98 (1.17, 3.35)</td>
</tr>
<tr>
<td></td>
<td>400 9–10</td>
<td>1057 (9.7)</td>
<td>0.79</td>
<td>1.00 (Reference)</td>
</tr>
<tr>
<td>500</td>
<td>&lt;500 6–7</td>
<td>6585 (5.2)</td>
<td>0.97</td>
<td>1.58 (2.0, 2.10)</td>
</tr>
<tr>
<td></td>
<td>500 11–20</td>
<td>1029 (15.8)</td>
<td>0.97</td>
<td>1.58 (2.0, 2.10)</td>
</tr>
<tr>
<td>600</td>
<td>&lt;600 20–30</td>
<td>10150 (9.8)</td>
<td>0.93</td>
<td>1.51 (1.0, 1.97)</td>
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<tr>
<td></td>
<td>600 35–50</td>
<td>8750 (10.2)</td>
<td>0.80</td>
<td>1.00 (Reference)</td>
</tr>
</tbody>
</table>

**Same-Day CABG Surgery**

<table>
<thead>
<tr>
<th>No. of Events (Observed Rate, %)</th>
<th>Predicted Rate, %</th>
<th>Adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>14 (0.57)</td>
<td>0.29</td>
</tr>
<tr>
<td>500</td>
<td>319 (0.30)</td>
<td>0.31</td>
</tr>
<tr>
<td>600</td>
<td>25 (0.45)</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>306 (0.30)</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>40 (0.38)</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>293 (0.30)</td>
<td>0.31</td>
</tr>
</tbody>
</table>

**Same-Stay CABG Surgery**

<table>
<thead>
<tr>
<th>No. of Events (Observed Rate, %)</th>
<th>Predicted Rate, %</th>
<th>Adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>29 (1.19)</td>
<td>0.81</td>
</tr>
<tr>
<td>500</td>
<td>950 (0.90)</td>
<td>0.91</td>
</tr>
<tr>
<td>600</td>
<td>69 (1.24)</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>910 (0.89)</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>1121 (1.07)</td>
<td>0.82</td>
</tr>
</tbody>
</table>

OR for mortality adjusted for age, sex, ejection fraction, vessels attempted, worst lesion type, previous myocardial infarction (MI), femoral/popliteal disease, hemodynamic instability, cardiopulmonary resuscitation, congestive heart failure, malignant ventricular arrhythmia, chronic obstructive pulmonary disease, diabetes, and renal failure. OR for same-day CABG adjusted for left main coronary artery disease, multiple vessels diseased, worst lesion type, previous MI, hemodynamic instability, previous open heart surgery, and emergency PCI because of diagnostic catheterization complications. OR for same-stay CABG adjusted for left main coronary artery disease, multiple vessels diseased, worst lesion type, previous PCI, previous MI, carotid/cerebrovascular disease, hemodynamic instability, previous open heart surgery, and emergency PCI because of diagnostic catheterization complications.
odds of in-hospital mortality in relation to the higher-volume group. The volume threshold with the highest odds ratio was 400 procedures per year, for which patients in lower-volume hospitals had odds of dying in the hospital that were 1.98 (95% CI, 1.17, 3.35) times higher than the odds of dying for patients undergoing PCI in higher-volume hospitals. The odds ratio was 1.58 (95% CI, 1.20, 2.10) when annual volume was split at 500 procedures and 1.51 (95% CI, 1.15, 1.97) when annual volume was split at 600 procedures.

The overall rate of same-day CABG surgery for PCI patients in the study was 0.31%. PCI patients in “low-volume” hospitals had significantly higher odds of experiencing same-day CABG surgery when low volume was defined as either fewer than 400 procedures a year or fewer than 500 procedures a year. The respective odds ratios were 2.07 (95% CI, 1.36, 3.15) and 1.63 (95% CI, 1.13, 2.36).

For same-stay CABG surgery, the overall rate was 0.91%. PCI patients in “low-volume” hospitals experienced higher odds of undergoing same-stay CABG surgery for all 3 definitions of low volume. The odds ratios were 1.51 (95% CI, 1.03, 2.11) when volumes were split at 400, 1.60 (95% CI, 1.20, 2.13) when volumes were split at 500, and 1.35 (95% CI, 1.06, 1.72) when volumes were split at 600.

Predicted adverse event rates for mortality and same-stay CABG surgery tended to be somewhat higher for higher-volume hospitals than lower-volume hospitals, reflecting higher percentages of emergency patients in those hospitals. Predicted rates of same-day CABG surgery were approximately the same for low-volume and high-volume hospitals.

Figure 1 notes that if PCI referrals were made only to hospitals with volumes of 400 procedures or more and that if outcome rates mirrored those of other patients at these hospitals, roughly 50% of deaths and same-day CABG surgery that now occur in lower-volume hospitals could have been avoided and 34% of the same-stay CABG surgery could have been avoided.

Figures 2 to 4 present risk-adjusted outcome rates for the adverse outcomes as a function of mean annual hospital volume. Figure 2 indicates that risk-adjusted mortality continues to drop with increasing volume for most of the entire volume range. The rate of risk-adjusted same-day CABG surgery drops with increasing volume until approximately 700 procedures, levels off, and then drops again until approximately 1100 procedures per year. For risk-adjusted same-stay CABG surgery, the inverse relationship holds until approximately 1500 procedures per year. In Figures 3 and 4, the apparent upturn in mortality after an annual volume of approximately 1500 may be a result of the small number of data points in this range.

Figures 5 to 7 present risk-adjusted outcome rates for the adverse outcomes as a function of mean annual operator volume (in groups of 10). Figure 5 demonstrates risk-adjusted mortality...
rates that fluctuate but are above the statewide rate up to a volume of approximately 175, and then decrease monotonically with volume. Operator risk-adjusted same-day CABG rates decrease gradually with increasing volume and go below the statewide rate at an annual volume of approximately 200 (Figure 6). Operator risk-adjusted same-stay CABG rates also decrease steadily with increasing volume and are below the statewide rate for volumes in excess of 200 (Figure 7).

Table 3 examines differences in adverse event rates as a function of operator volume. There were no differences in risk-adjusted mortality (no significant odds ratios) between patients undergoing PCI performed by lower-volume operators and patients undergoing PCI performed by higher-volume operators for any of the 3 volume thresholds that were examined.

All 3 volume thresholds yielded significant operator-volume differences for same-day CABG surgery. For example, PCI patients with operators having annual volumes of fewer than 75 had odds of undergoing same-day CABG surgery that were 1.65 (95% CI, 1.05, 2.60) times higher than patients undergoing PCI performed by operators with annual volumes of 75 or more.

Patients undergoing PCI performed by lower-volume operators also had significantly higher odds of undergoing same-stay CABG surgery than patients undergoing the procedure when it was performed by higher-volume operators. For instance, the odds ratio was 1.55 (95% CI, 1.10, 2.18) when volumes were split at 75.

Also, higher-volume operators tended to have patients with a slightly higher predicted risk(s) of in-hospital mortality and same-stay CABG surgery, whereas patient risks for same-day CABG surgery were approximately the same for high- and low-volume operators.
Table 4 presents comparisons of PCI risk-adjusted adverse event rates for various combinations of high- and low-volume hospitals and operators. Patients undergoing PCI performed by operators with volumes of fewer than 75 per year in hospitals with volumes of fewer than 400 (OLV/HLV) were found to have significantly higher odds of dying in the hospital than patients undergoing PCI performed by operators with volumes of 75 or more in hospitals with volumes of 400 or more (OR = 5.92; 95% CI, 3.25, 10.97). The other 2 groups did not have significantly higher odds of dying than patients with high-volume operators and hospitals.

Patients undergoing PCI in the OHV/HHV group experienced significantly lower same-day CABG rates than patients in the OLV/HLV and OHV/HLV groups when hospital volume was split at 400 (OR = 4.02 and 1.91, respectively). Also, patients undergoing PCI in the OLV/HLV group and the OLV/HHV groups had significantly higher same-stay CABG surgery than patients in the OHV/HHV group (OR = 3.19; 95% CI, 1.51, 6.77 for the OLV/HLV group) when hospital volume was split at 400 procedures per year. When formal tests for interactions between hospital volume and operator volume were conducted for all of the combinations of volumes and outcome measures presented in Table 4, the only one with significant interactions was mortality for (HV, OV = 400, 75), meaning that both low hospital volume and low operator volume contributed significantly to obtaining a worse risk-adjusted outcome. However, it should be noted that other interactions may not have been significant, in part because of lower statistical power resulting from splitting on the basis of both hospital and operator volume.

For an annual hospital-volume threshold of 400, 82.3% of the patients in the lower-volume group underwent stent placement, compared with 86.0% in the higher-volume group. These per-
Percutaneous coronary intervention has been one of the many procedures that have been reported as having significant inverse volume-outcome relationships in the medical and health services research literature. However, most PCI studies were conducted in the prestent era or when stents were used for a relatively small percentage of patients. Two recent studies that are exceptions were conducted by McGrath et al.6 and by Epstein et al.5 McGrath et al analyzed 1997 Medicare claims data in which 58% of all PCI patients had stent placements. Their findings were that patients treated by low-volume (<30 Medicare procedures) operators had a significantly higher risk of 30-day mortality than patients treated by high-volume (>60 Medicare procedures) operators (2.25% versus 1.55%, P<0.001).6 They also found that patients undergoing PCI in low-volume hospitals (<30 Medicare procedures) had higher rates of CABG surgery during the index hospitalization than patients undergoing PCI in high-volume hospitals (>60 Medicare procedures).

**TABLE 3. Association Between Operator Volume and Adverse In-Hospital Events for PCI in New York State, 1998–2000**

<table>
<thead>
<tr>
<th>Annual Operator Volume Threshold</th>
<th>Volume Group</th>
<th>No. of Operator Per Year (%)</th>
<th>No. of Events (Observed Rate, %)</th>
<th>Predicted Rate, %</th>
<th>Adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;75</td>
<td>&lt;75</td>
<td>66–72</td>
<td>7544 (7.0)</td>
<td>68 (0.90)</td>
<td>0.73</td>
</tr>
<tr>
<td>≥75</td>
<td>≥75</td>
<td>148–171</td>
<td>100 169 (93.0)</td>
<td>786 (0.78)</td>
<td>0.80</td>
</tr>
<tr>
<td>100</td>
<td>&lt;100</td>
<td>86–99</td>
<td>13 835 (12.0)</td>
<td>117 (0.85)</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>≥100</td>
<td>128–144</td>
<td>93 878 (87.2)</td>
<td>737 (0.79)</td>
<td>0.80</td>
</tr>
<tr>
<td>125</td>
<td>&lt;125</td>
<td>111–114</td>
<td>20 282 (18.8)</td>
<td>167 (0.82)</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>≥125</td>
<td>103–129</td>
<td>87 431 (81.2)</td>
<td>667 (0.79)</td>
<td>0.80</td>
</tr>
</tbody>
</table>

See Table 2 for variables in the risk-adjustment models.
...volume hospitals for all 3 outcome measures. The volume threshold with the highest odds ratio was 400, with odds ratios of 1.97 for in-hospital mortality, 2.07 for same-day CABG surgery, and 1.82 for same-stay CABG surgery, respectively. The operator-volume threshold with the highest odds ratio was 75, with respective odds ratios for low-volume operators versus high-volume operators of 1.30, 1.65, and 1.55.

For patients undergoing PCIs in hospitals with volumes below 400 performed by operators with volumes below 75, the respective odds of mortality, same-day CABG surgery, and same-stay CABG surgery were 5.92, 4.02, and 3.43%, respectively.2

Another possible limitation is that for patients presenting with acute myocardial infarction, CABG surgery during the same stay may have been planned rather than a complication. However, when patients with acute myocardial infarction were removed from the analyses, significant volume-outcome differences remained, even for same-stay CABG surgery. The adjusted odds ratios for low-volume hospitals versus high-volume hospitals were 1.82 \( P<0.001 \) for mortality, 1.69 \( P<0.001 \) for same-day surgery, and 1.41 \( P=0.01 \) for same-stay CABG surgery, respectively.

The findings of the study suggest that volume-based criteria should be considered for referrals to higher-volume hospitals until better data become available for assessing quality. A primary reason that a PCI registry was established in New York was so that assessment of relative quality of care could be based on risk-adjusted outcomes, not on much cruder criteria, such as provider volume. However, we are not aware of any other states in which population-based clinical data are available for risk-adjusting PCI outcomes.

It is notable that in the case of procedures with low short-term mortality rates, such as PCI, additional outcome measures from clinical data bases need to be defined and validated. Possibilities for PCI are the 2 other measures presented in this study: same-day CABG surgery and same-stay CABG surgery. An-
other possibility is readmissions within a short period of time
(say 30 days) for complications related to the index admission,
which has been studied extensively as an outcome measure
for CABG surgery.20–25
Once we have valid measures for assessing quality, it is
important that we enable providers with low quality ratings
to improve. In this regard, process measures that are consistent
with the highest quality of care must be identified and collected.
Stent placement has been demonstrated to be superior to balloon
angioplasty10,26,27 and has now become the preferred treatment
for PCIs. In addition, other process measures have been rec-
commended in the recent joint ACC/AHA guidelines.17 These
measures include the use of antiplatelet and antithrombotic
therapies such as aspirin, clopidogrel, and glycoprotein IIb/IIIa
inhibitors as well as stent placement.

Of these process measures, only stent placement was avail-
able in the New York registry for the years of this study.
Although higher-volume providers used stent placements more
frequently (eg, 82.3% of patients in hospitals with volumes
below 400 underwent stent placement, compared with 86.0% in
the higher-volume group), there was not a large difference in use
between low-volume and high-volume providers. Furthermore,
when the analyses were restricted to patients undergoing stent
placement, the outcome advantage for high-volume providers
actually increased slightly. Thus, it would appear that the use of
more stenting would not be a panacea for low-volume providers’
higher adverse outcome rates.

We look forward to new efforts to identify processes of
care that are related to PCI outcomes and the relationship
between PCI provider volumes and outcomes.

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