Is the Impact of Hospital and Surgeon Volumes on the In-Hospital Mortality Rate for Coronary Artery Bypass Graft Surgery Limited to Patients at High Risk?

Chuntao Wu, MD, PhD; Edward L. Hannan, PhD; Thomas J. Ryan, MD; Edward Bennett, MD; Alfred T. Culliford, MD; Jeffrey P. Gold, MD; O. Wayne Isom, MD; Robert H. Jones, MD; Barbara McNeil, MD, PhD; Eric A. Rose, MD; Valavanur A. Subramanian, MD

Background—Restriction of volume-based referral for CABG surgery to high-risk patients has been suggested, and earlier studies have reached different conclusions regarding volume-based referral for low-risk patients.

Methods and Results—Patients who underwent isolated CABG surgery in New York from 1997 through 1999 (n = 57,150) were separated into low-risk and moderate-to-high-risk groups with a predicted probability of in-hospital death of 2% as the cutoff point. The provider volume-mortality relationship was examined for both groups. For annual hospital volume thresholds between 200 and 600 cases, the adjusted ORs of in-hospital mortality for high-volume to low-volume hospitals ranged from 0.45 to 0.77 and were all significant for the low-risk group; for the moderate-to-high-risk group, ORs ranged from 0.62 to 0.91, and most were significant. The number needed to treat at higher-volume hospitals to avoid 1 death was greater for the low-risk group (a range of 114 to 446 versus 37 to 184). As the annual surgeon volume threshold increased from 50 to 150 cases, the ORs for high- to low-volume surgeons increased from 0.43 to 0.74 for the low-risk group; for the moderate-to-high-risk group, ORs ranged from 0.79 to 0.86. Compared with patients treated by surgeons with volumes of <125 in hospitals with volumes of <600, patients treated by higher-volume surgeons in higher-volume hospitals had a significantly lower risk of death; in particular, the OR was 0.52 for the low-risk group.

Conclusions—For both low-risk and moderate-to-high-risk patients, higher provider volume is associated with lower risk of death. (Circulation. 2004;110:784-789.)

Key Words: bypass ■ mortality ■ risk factors

It has been well documented that hospitals and surgeons with higher CABG surgery volumes have experienced lower mortality rates.1-6 Given the evidence that higher hospital volume is frequently related to better outcomes for CABG surgery, the Leapfrog Group has recently recommended that purchasers contract with hospitals that have an annual CABG surgery volume of at least 450 cases.7 Many deaths could potentially be avoided if this volume-based referral were applied to all CABG patients. However, implementation of this volume guideline will result in thousands of patients being referred away from low-volume CABG surgery hospitals to high-volume CABG surgery hospitals. A possible alternative to reduce the disruption that would be caused by movement of patients while still reducing mortality is to restrict the referral to high-risk patients. However, for this policy to be effective, the differential in risk-adjusted mortality rates between high- and low-volume hospitals would ideally be higher for high-risk patients.

Two recent studies have arrived at different conclusions regarding the volume-mortality relationship for CABG surgery among patients with different levels of surgical risk.8,9 Also, a recent study in New York State found that higher-volume hospitals and surgeons continued to have lower risk-adjusted mortality rates after CABG surgery from 1997 to 1999.1 As an extension to that study, the present study examined the impact of hospital and surgeon volumes on in-hospital mortality for CABG surgery among patients with different levels of risk.

Methods

Database and Patient Population

The New York State Cardiac Surgery Reporting System (CSRS) was used in this study. Each patient undergoing CABG surgery in New York State has been registered in the CSRS since January 1, 1989. The CSRS contains patients’ demographic variables, clinical risk factors and complications, and discharge status. The study popula-

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From University at Albany (C.W., E.L.H.), State University of New York, Albany, NY; Boston University School of Medicine (T.J.R.), Boston, Mass; St. Peter’s Hospital (E.B.), Albany, NY; New York University Medical Center (A.T.C.), New York, NY; Montefiore Medical Center (J.P.G.), Bronx, NY; New York Hospital-Cornell (O.W.I.), New York, NY; Duke University Medical Center (R.H.I.), Durham, NC; Harvard Medical School (B.M.), Boston, Mass; Columbia-Presbyterian Medical Center (E.A.R.), New York, NY; and Lenox Hill Hospital (V.A.S.), New York, NY.

Correspondence to Chuntao Wu, MD, PhD, University at Albany, State University of New York, One University Place, Rensselaer, NY 12144-3456. E-mail ctw09@health.state.ny.us

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EuroSCORE cardiac surgery model and the Society of Thoracic risk factors in this model were also significant predictors in the /H11005

4 died, 0 lived); the independent variable of interest in each risk group to obtain the adjusted OR that compared the odds of death between patients treated by high- and low-volume patients in each risk group.

by computing the mean predicted probability of death of all patients calculated for low- and high-volume hospitals. In addition, predicted (between 200 and 600 cases, in units of 100 cases) were created. For each hospital volume threshold, we fit a logistic model for annual surgeon/hospital volume groups were created by separating each type of LVH indicates low-volume hospitals; HVH, high-volume hospitals.

Annual hospital volume thresholds for isolated CABG surgery (between 200 and 600 cases, in units of 100 cases) were created. For each group of patients, the observed in-hospital mortality rates were calculated for low- and high-volume hospitals. In addition, predicted mortality rates were calculated for low- and high-volume hospitals by computing the mean predicted probability of death of all patients in each volume group.

For each hospital volume threshold, we fit a logistic model for patients in each risk group to obtain the adjusted OR that compared the odds of death between patients treated by high- and low-volume hospitals. The outcome variable in each logistic model was patient’s death status (1=died, 0=lived); the independent variable of interest was a binary variable that represented high-volume hospital (1=high-volume hospital, 0=low-volume hospital). Each logistic model adjusted for patient’s risk score, which was the value of logarithm of the odds of the predicted probability of death for each patient. The adjusted OR was used to compute the percentage of deaths that were potentially avoidable for each risk group at each hospital volume threshold; the number of patients needed to treat (NNT) in higher-volume hospitals to avoid 1 death was also calculated. The same analyses were repeated for annual surgeon volume thresholds (between 50 and 150 cases, in units of 25 cases).

The interaction effects of hospital volume and surgeon volume was all 57,150 patients who underwent isolated CABG surgery (CABG surgery without any other major open heart procedures in the same admission) in New York State and who were discharged between January 1, 1997, and December 31, 1999.

Analysis

A logistic model was developed in our recent study to identify significant patient risk factors that predict in-hospital mortality in the study population (see Appendix and Hannan et al14 for details). Many risk factors in this model were also significant predictors in the EuroSCORE cardiac surgery model10 and the Society of Thoracic Surgeons (STS) CABG model14 for 30-day mortality. All but left main disease, hemodynamic state, ventricular arrhythmia, and hepatic failure were represented in the EuroSCORE model, and all but hepatic failure and calcified ascending aorta were used in the STS model.

This model was used to predict each patient’s probability of death, which represents surgical risk. A predicted probability of death of 2% was chosen as a cutoff point to separate patients into low-risk (<2%) and moderate-to-high-risk groups.

In general, the differences in observed mortality rates were more striking when a hospital volume threshold was low (mean 116, interquartile range 48 to 165). For both risk groups, patients in hospitals with a volume above a threshold consistently had lower observed mortality rates than those in hospitals with a volume below a threshold. In general, the differences in observed mortality rates were more striking when a hospital volume threshold was low (Table 1).

Table 2 shows that at all hospital volume thresholds between 200 and 600, for both risk groups, patients in higher-volume hospitals consistently had a lower risk of death than those in lower-volume hospitals, as evidenced by adjusted ORs <1. For the low-risk group, adjusted ORs ranged from 0.45 to 0.77; the adjusted ORs ranged from 0.62 to 0.91 for the moderate-to-high-risk group. The percentage of deaths avoidable decreased for both risk groups when volume threshold increased but was always higher for the low-risk group (Figure 1). The NNT for the low-risk group

| TABLE 1. Observed and Predicted In-Hospital Mortality Rates by Annual Hospital Volume Stratified by Surgical Risk Among Patients Who Underwent Isolated CABG Surgery in New York State, 1997–1999 |
| --- | --- | --- | --- | --- | --- |
| Definition of LVH: Annual Volume Less Than Year | No. of Hospitals per | Risk Group (Predicted Probability of In-Hospital Death) | No. of Patients Treated by LVH (%) | No. of Deaths (Observed Mortality Rate, %) | Predicted Mortality Rate, % |
| | LVH | HVH | LVH | HVH | LVH | HVH |
| 200 | 3–4 | 29–30 | Low (<2%) | 897 (2.3) | 13 (1.45) | 299 (0.77) | 0.86 | 0.86 |
| | Moderate to high (≥2%) | 324 (1.8) | 23 (7.10) | 925 (3.54) | 4.41 | 5.23 |
| 300 | 5–7 | 26–28 | Low (<2%) | 2313 (5.9) | 37 (1.60) | 275 (0.74) | 0.85 | 0.86 |
| | Moderate to high (≥2%) | 812 (4.6) | 52 (6.40) | 896 (3.52) | 4.58 | 5.25 |
| 400 | 10–14 | 19–23 | Low (<2%) | 6161 (15.6) | 72 (1.17) | 240 (0.72) | 0.86 | 0.86 |
| | Moderate to high (≥2%) | 2526 (14.3) | 148 (8.66) | 800 (5.29) | 5.12 | 5.24 |
| 500 | 14–17 | 16–19 | Low (<2%) | 10 084 (25.5) | 97 (0.96) | 215 (0.73) | 0.86 | 0.85 |
| | Moderate to high (≥2%) | 4317 (24.4) | 247 (5.72) | 701 (5.25) | 5.20 | 5.22 |
| 600 | 18–21 | 12–15 | Low (<2%) | 14 300 (36.2) | 142 (0.99) | 170 (0.67) | 0.86 | 0.86 |
| | Moderate to high (≥2%) | 6120 (34.7) | 368 (6.01) | 580 (5.03) | 5.18 | 5.24 |

Results

There were 1260 (2.20%) in-hospital deaths among 57,150 patients with isolated CABG surgery in New York State from 1997 through 1999. A total of 312 (0.79%) patients died among 39,491 low-risk patients, who comprised 69% of all isolated CABG surgery cases; 948 patients (5.37%) died among 17,659 patients with moderate to high risk. Between 1997 and 1999, 192 surgeons performed CABG surgeries in 33 hospitals in New York State. The median annual hospital volume was 527 cases (mean 577, interquartile range 331 to 816), and the median annual surgeon volume was 109 cases (mean 116, interquartile range 48 to 165).

For both risk groups, patients in hospitals with a volume above a threshold consistently had lower observed mortality rates than those in hospitals with a volume below a threshold. In general, the differences in observed mortality rates were more striking when a hospital volume threshold was low (Table 1).

Despite the small number of deaths, the NNTs were all less than 6 for low-risk patients, and 10 or more for moderate-to-high-risk patients.
was greater than that for the moderate-to-high-risk group for each volume threshold; it ranged from 114 to 446 for the low-risk group and from 37 to 184 for the moderate-to-high-risk group (Figure 2). For both risk groups, the number of avoidable deaths in New York State from 1997 through 1999 reached a maximum with a volume threshold of 600.

At all surgeon volume thresholds between 50 and 150, for both risk groups, patients treated by higher-volume surgeons always had a lower risk of death than those treated by lower-volume surgeons. For the low-risk group, adjusted ORs ranged from 0.43 to 0.74; for the moderate-to-high-risk group, the adjusted ORs ranged from 0.79 to 0.86. Although in general the percentage of avoidable deaths decreased for the low-risk group when annual surgeon volume threshold increased (57% versus 26% at the thresholds of 50 and 150 cases, respectively), it was ≈20% for most volume thresholds in the moderate-to-high-risk group. The number of avoidable deaths increased when the volume threshold increased from 50 to 150 cases for both risk groups.

Table 3 shows that in the low-risk group, the odds of death among patients with high surgeon (≥125)/high hospital (≥600) volumes, low surgeon/high hospital volumes, and high surgeon/low hospital volumes were 52%, 65%, and 60%, respectively, of the odds of patients treated by low-volume surgeons in low-volume hospitals. In the moderate-to-high-risk group, patients treated by high-volume surgeons in high-volume hospitals had significantly lower odds of death than patients treated by low-volume surgeons in low-volume hospitals (OR 0.76); the odds of death among patients with low surgeon/high hospital volumes and high surgeon/low hospital volumes were not significantly different from the odds of patients treated by low-volume surgeons in low-volume hospitals. When we accounted for the clustering of patients within surgeons and hospitals by the generalized estimating equation method, confidence intervals usually became wider, but all significant ORs remained significant. Similar ORs were obtained with hierarchical logistic regression analyses.

**Discussion**

Based on a population of 57 150 patients who underwent isolated CABG surgery in New York State between 1997 and 1999, the present study examined the relationship between provider volumes and in-hospital mortality among patients of low and moderate-to-high surgical risk with a predicted probability of death of 2% as a cutoff point between the 2 risk groups.

### TABLE 2. Potentially Avoidable Deaths, Stratified by Surgical Risk if Applying Hospital Volume–Based Referral for Isolated CABG Surgery in New York State, 1997–1999

<table>
<thead>
<tr>
<th>Definition of LVH: Annual Volume Less Than</th>
<th>Risk Group</th>
<th>Adjusted OR (95% CI)</th>
<th>% of Deaths Avoidable (95% CI)</th>
<th>NNT (95% CI)</th>
<th>No. of Deaths Avoidable in New York (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (&lt;2%)</td>
<td>0.53 (0.30 to 0.93)*</td>
<td>47 (7 to 70)</td>
<td>147 (99 to 969)</td>
<td>6 (1 to 9)</td>
</tr>
<tr>
<td></td>
<td>Moderate to high (≥2%)</td>
<td>0.62 (0.40 to 0.96)*</td>
<td>38 (4 to 60)</td>
<td>37 (24 to 367)</td>
<td>9 (1 to 14)</td>
</tr>
<tr>
<td>200</td>
<td>Low (&lt;2%)</td>
<td>0.45 (0.32 to 0.64)‡</td>
<td>55 (36 to 68)</td>
<td>114 (92 to 173)</td>
<td>20 (13 to 25)</td>
</tr>
<tr>
<td></td>
<td>Moderate to high (≥2%)</td>
<td>0.72 (0.53 to 0.96)*</td>
<td>28 (4 to 47)</td>
<td>55 (33 to 400)</td>
<td>15 (2 to 24)</td>
</tr>
<tr>
<td>300</td>
<td>Low (&lt;2%)</td>
<td>0.62 (0.47 to 0.80)‡</td>
<td>38 (20 to 53)</td>
<td>223 (162 to 437)</td>
<td>28 (14 to 38)</td>
</tr>
<tr>
<td></td>
<td>Moderate to high (≥2%)</td>
<td>0.87 (0.72 to 1.05)</td>
<td>13 (5 to 28)</td>
<td>134 (62 to 72)</td>
<td>19 (7 to 41)</td>
</tr>
<tr>
<td>400</td>
<td>Low (&lt;2%)</td>
<td>0.77 (0.60 to 0.98)*</td>
<td>23 (2 to 40)</td>
<td>446 (261 to 4307)</td>
<td>23 (2 to 39)</td>
</tr>
<tr>
<td></td>
<td>Moderate to high (≥2%)</td>
<td>0.91 (0.78 to 1.05)</td>
<td>9 (5 to 22)</td>
<td>184 (78 to 28)</td>
<td>23 (13 to 247)</td>
</tr>
<tr>
<td>500</td>
<td>Low (&lt;2%)</td>
<td>0.68 (0.54 to 0.85)‡</td>
<td>32 (15 to 46)</td>
<td>314 (220 to 670)</td>
<td>46 (21 to 65)</td>
</tr>
<tr>
<td></td>
<td>Moderate to high (≥2%)</td>
<td>0.81 (0.71 to 0.93)†</td>
<td>19 (7 to 29)</td>
<td>87 (56 to 234)</td>
<td>70 (26 to 108)</td>
</tr>
</tbody>
</table>

LVH indicates low-volume hospitals; adjusted OR, odds of mortality in high-volume hospitals relative to LVH, adjusted for patient risk.

*P<0.05.
†P<0.01.
‡P<0.001.
groups. For annual hospital volume thresholds between 200 and 600 cases, the adjusted ORs of in-hospital mortality for high- to low-volume hospitals ranged from 0.45 to 0.77 for the low-risk group; for the moderate-to-high-risk group, ORs ranged from 0.62 to 0.91. As the annual surgeon volume thresholds increased from 50 to 150, the ORs for high- to low-volume surgeons increased from 0.43 to 0.74 for the low-risk group; for the moderate-to-high-risk group, ORs ranged from 0.79 to 0.86. In addition, the added benefit of undergoing surgery performed by high-volume surgeons in high-volume hospitals was observed in both risk groups.

The present study used a predicted probability of death of 2%, which is close to the average in-hospital mortality rate (2.20%) after CAGB surgery in New York from 1997 to 1999, as a cutoff point to separate patients into low-risk and moderate-to-high-risk groups. The same cutoff was applied in the study by Nallamothu and colleagues. A patient’s predicted probability of death is determined by both patient risk factors and the model being used. Therefore, the cutoff points in these 2 studies are similar but not exactly the same.

Unlike the study by Nallamothu and colleagues, the present study found that patients in the low-risk group treated by higher-volume hospitals had a lower risk of dying after CAGB surgery. We also found that higher surgeon volume was associated with lower mortality in low-risk patients. To explore whether the reason for inconsistent findings is a statistical power issue, we combined both minimal-risk (predicted probability of death <0.5%) and low-risk (predicted probability of death between 0.5% and 2%) groups in the study by Nallamothu et al to form a group of patients that was similar to the low-risk group in the present study and compared the odds of death between high- and low-volume hospitals (annual volume <200 CAGB cases). An OR of 0.64 (95% CI 0.34 to 1.21; \(P=0.13\)) was obtained, which indicated a weaker volume-mortality relationship for the low-risk group in their study population than that in the present study, in which an OR of 0.53 (95% CI 0.30 to 0.93, \(P<0.05\)) was identified at the volume threshold of 200.

Recent discussions have recommended that the volume-mortality relationship be examined for the group of patients with a predicted probability of death <0.5% in the present study, a total of 11721 patients (20.5%) were in this minimal-risk group, with an observed mortality rate of 0.32% (38 deaths). We attempted to examine differences in the impact of hospital and surgeon volumes on in-hospital mortality in 3 subgroups of patients (minimal, low, and moderate-to-high risk, defined as <0.5%, 0.5% to <2.0%, and \(\geq 2.0\%\), respectively). Small sample sizes and numbers of deaths thwarted these investigations in the minimal-risk (<0.5%) and low-risk (0.5% to <2.0%) groups. However, for a hospital volume threshold of 300, the respective ORs were 0.33, 0.47, and 0.72 for the risk groups <0.5%, 0.5% to <2.0%, and \(\geq 2.0\%\), and all of these ORs were significantly lower than 1 (with respective probability values of 0.01,

### Table 3. Joint Effect of Hospital and Surgeon Volumes on In-Hospital Mortality Rate for CAGB Stratified by Surgical Risk Among Patients Who Underwent Isolated CAGB Surgery in New York State, 1997–1999

<table>
<thead>
<tr>
<th>Risk Group (Predicted Probability of In-Hospital Death)</th>
<th>Hospital Annual Volume (\geq 600)</th>
<th>Hospital Annual Volume &lt;600</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surgeon Annual Volume (\geq 125)</td>
<td>Surgeon Annual Volume &lt;125</td>
</tr>
<tr>
<td>No. of surgeons per year</td>
<td>48–62</td>
<td>38–41</td>
</tr>
<tr>
<td>No. of patients (%)</td>
<td>20,608 (52.2)</td>
<td>4583 (11.6)</td>
</tr>
<tr>
<td>Observed mortality rate, %</td>
<td>0.65</td>
<td>0.81</td>
</tr>
<tr>
<td>Predicted mortality rate, %</td>
<td>0.85</td>
<td>0.86</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>0.52 (0.40–0.66)</td>
<td>0.65 (0.44–0.95)</td>
</tr>
<tr>
<td>Adjusted OR accounting for clustering (95% CI)</td>
<td>0.52 (0.39–0.70)</td>
<td>0.65 (0.45–0.93)</td>
</tr>
<tr>
<td>Adjusted OR estimated from hierarchical model (95% CI)</td>
<td>0.51 (0.35–0.75)</td>
<td>0.69 (0.44–1.09)</td>
</tr>
<tr>
<td>Moderate to high risk ((&gt;2%))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients (%)</td>
<td>9389 (53.2)</td>
<td>2150 (12.2)</td>
</tr>
<tr>
<td>Observed mortality rate, %</td>
<td>4.63</td>
<td>6.74</td>
</tr>
<tr>
<td>Predicted mortality rate, %</td>
<td>5.20</td>
<td>5.42</td>
</tr>
<tr>
<td>Adjusted OR (95% CI)</td>
<td>0.76 (0.64–0.91)</td>
<td>1.12 (0.89–1.41)</td>
</tr>
<tr>
<td>Adjusted OR accounting for clustering (95% CI)</td>
<td>0.76 (0.61–0.96)</td>
<td>1.12 (0.83–1.50)</td>
</tr>
<tr>
<td>Adjusted OR estimated from hierarchical model (95% CI)</td>
<td>0.74 (0.55–1.01)</td>
<td>1.19 (0.85–1.67)</td>
</tr>
</tbody>
</table>

Adjusted OR indicates odds of mortality in a surgeon volume/hospital volume group relative to low surgeon volume/low hospital volume group, adjusted for patient risk; adjusted OR accounting for clustering, adjusted OR with adjustment for patient risk and taking into account clustering of patients within surgeons and hospitals; adjusted OR estimated from hierarchical model, adjusted OR estimated from hierarchical logistic regression adjusted for patient risk, with average surgeon and hospital volumes used instead of annual volumes.
When examining the benefit of volume-based referral in the low-risk group, it is useful to consider both relative reduction and absolute reduction in mortality rates. For hospital volume, the greatest reduction in both relative scale (55% of deaths were avoidable) and absolute scale (a decrease in mortality rate of 0.88%) occurred at the threshold of 300 cases. The NNT (number needed to treat by higher-volume hospitals to avoid 1 death) is another indicator that should be considered. The minimum NNT was 114 for hospital volume with a threshold of 300. Another indicator, number of avoidable deaths, should also be studied. However, this measure is strongly influenced by the total number of cases in lower-volume hospitals in a study population.

Compared with other studies, the present study has several important strengths. First, the study population is large and includes all isolated CABG surgery patients in New York State from 1997 to 1999. Second, the data are from a comprehensive clinical registry, the CSRS, which allows for a comprehensive adjustment of patients’ severity of illness with clinical risk factors. Third, this study provides the opportunity to study the effect of surgeon volume on mortality and the joint effect of hospital volume and surgeon volume.

A few caveats should be noted. First, the number of patients in very-low-volume hospitals was small because of the existence of Certificate of Need regulations in New York State. This small sample size limits our ability to study the effect of very low volumes. Second, for more than a decade, the New York State Department of Health has been reporting CABG surgery outcomes to healthcare providers and the public, and this practice has contributed to an improvement in the quality of care. Therefore, it is reasonable to speculate that the volume-mortality relationship is weaker in New York than in other areas because of the concerted quality improvements in New York. Third, in-hospital mortality was the outcome in the present study. Another important outcome measure, 30-day mortality, was unavailable to us on a timely basis; if available, this measure would have been preferred because of the decreasing length of stay in hospitals and the fact that deaths after discharge are usually associated with complications of surgery. Fourth, the observed volume-mortality relationship does not necessarily prove a causal relationship between volume and mortality. A competing hypothesis is “selective referral,” which hypothesizes that high-volume providers have high volume because their better quality attracts more patients rather that more practice makes the quality better.14

Although volume-based referral could be beneficial in areas where there are no better quality indicators (eg, risk-adjusted mortality rates) available, its implementation may cause travel difficulties for patients and further reduction of volume for low-volume hospitals.2,15–17 Also, not all low-volume hospitals have poor outcomes, and not all high-volume hospitals have good outcomes.17,18 Thus, it is preferable to improve outcomes by identifying processes of care associated with superior outcomes and implementing these processes in both high-volume and low-volume hospitals rather than to contemplate referring all patients to high-volume centers. Also, it is preferable to identify high-quality hospitals by developing databases that will enable researchers and policy makers to calculate risk-adjusted outcomes for providers.

### TABLE 4. Risk Factors in Logistic Regression Model for In-Hospital Mortality of Patients Who Underwent Isolated CABG Procedures in New York State From 1997 to 1999*

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.95</td>
</tr>
<tr>
<td>Age squared/100</td>
<td>1.08 †</td>
</tr>
<tr>
<td>Female gender</td>
<td>2.12 †</td>
</tr>
<tr>
<td>Ventricular function</td>
<td></td>
</tr>
<tr>
<td>Ejection fraction &lt; 20%</td>
<td>4.13 †</td>
</tr>
<tr>
<td>Ejection fraction 20%–29%</td>
<td>2.47</td>
</tr>
<tr>
<td>Ejection fraction 30%–39%</td>
<td>2.07</td>
</tr>
<tr>
<td>Previous myocardial infarction &lt; 6 hours</td>
<td>3.80 †</td>
</tr>
<tr>
<td>Previous myocardial infarction 6–23 hours</td>
<td>2.62</td>
</tr>
<tr>
<td>Previous myocardial infarction 1–7 days</td>
<td>2.12</td>
</tr>
<tr>
<td>Previous myocardial infarction ≥ 8 days</td>
<td>1.66</td>
</tr>
<tr>
<td>Left main coronary artery disease</td>
<td>1.67 †</td>
</tr>
<tr>
<td>Hemodynamic state</td>
<td></td>
</tr>
<tr>
<td>Unstable</td>
<td>3.52</td>
</tr>
<tr>
<td>Shock</td>
<td>6.60</td>
</tr>
<tr>
<td>Cardiopulmonary resuscitation</td>
<td>7.45 †</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>2.14 †</td>
</tr>
<tr>
<td>Aortoiliac disease</td>
<td>2.85</td>
</tr>
<tr>
<td>Malignant ventricular arrhythmia</td>
<td>2.35 †</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>2.07</td>
</tr>
<tr>
<td>Extensively calcified ascending aorta</td>
<td>2.43</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.92 †</td>
</tr>
<tr>
<td>Hepatic failure</td>
<td>9.05</td>
</tr>
<tr>
<td>Renal failure, creatinine &gt; 2.5 mg/dL</td>
<td>3.13</td>
</tr>
<tr>
<td>Renal failure requiring dialysis</td>
<td>7.13</td>
</tr>
<tr>
<td>Previous open heart operations</td>
<td>3.47</td>
</tr>
<tr>
<td>Number of categorical risk factors squared</td>
<td>0.96 †</td>
</tr>
</tbody>
</table>

* C-statistic = 0.7996. † P < 0.001. ‡ P < 0.0001.

### Disclosure

Dr Subramanian has served as a scientific advisor to Guidant/CTS and Cardiovations/Ethicon.
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References
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