Off-Pump Bypass Surgery and Postoperative Stroke: California Coronary Bypass Outcomes Reporting Program

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Background. Coronary artery bypass surgery (CABG) is associated with a significant risk of stroke. Some studies suggest that off-pump CABG (OPCAB) may reduce postoperative stroke rate. We performed this study to evaluate the relationship between postoperative stroke and OPCAB compared with conventional on-pump CABG (CCB) in a recent, large cohort of patients.

Methods. Data from the California CABG Outcomes Reporting Program were analyzed in patients who had OPCAB or CCB for isolated CABGs in 2006 to 2007. Two multivariable logistic regression models were developed for the analysis, and the “recycled predictions” method was used to compute risk-adjusted postoperative stroke rates in the two surgical groups.

Results. Of 30,426 isolated CABGs, 7,720 (23.7%) were OPCAB. The model developed in the CCB subset indicated that CCB had a lower predicted stroke risk than OPCAB, yet the observed rate of stroke was higher in the CCB subset. The model using both CCB and OPCAB patients revealed that OPCAB was associated with a reduction in postoperative stroke (adjusted odds ratio: 0.76, 95% confidence interval [CI] 0.59 to 0.98). For patients with cardiogenic shock, OPCAB was also associated with a lower risk-adjusted postoperative stroke rate compared with CCB (OPCAB: 3.06%, 95% CI 2.83% to 3.28%; CCB: 4.05%, 95% CI 3.76% to 4.33%, p < 0.001). However, the 793 (11%) OPCAB patients who were converted to CCB intraoperatively had an increased postoperative stroke rate (with conversion: 2.02%, 95% CI 1.04% to 3.00% versus without conversion: 0.96%, 95% CI 0.73% to 1.20%, p < 0.001).

Conclusions. The OPCAB was associated with a significantly lower postoperative stroke rate compared with CCB even for older and higher risk patients. However, intraoperative OPCAB to CCB conversion was associated with the highest postoperative stroke rate.


Off-pump coronary artery bypass surgery (OPCAB) was developed to reduce complications associated with cardiopulmonary bypass surgery [1, 2]. Stroke is one of the most serious complications of conventional on-pump coronary bypass (CCB). Several mechanisms for this complication have been proposed [3–5], with OPCAB potentially addressing cannulation, pump time, inflammation, and microembolization. Several randomized and observational trials have reported no difference or a trend toward reduced postoperative stroke in patients undergoing OPCAB compared with CCB [6–10]. However, these trials are limited by relatively small sample size or incomplete data. Our objective was to evaluate the relationship between postoperative stroke and OPCAB compared with CCB in a large, contemporary cohort of patients.

Material and Methods

Source

Data were obtained from the California Coronary Artery Bypass Graft (CABG) Outcomes Reporting Program (CCORP) data registry on patients who underwent CABG surgery in 2006 and 2007 from 121 reporting hospitals. Since 2003, California state law has required that all state-licensed hospitals report isolated and nonisolated CABGs to CCORP. Isolated CABG is defined as CABG performed without other major procedures such as valve repair, carotid endarterectomy, aortic surgery, lung surgery, or ventricular surgery during the same operation. The study was approved by the Committee for the Protection of Human Subjects of the California Health and Human Services Agency on June 11, 2009 (Project No. 04-08-58).

The CCORP clinical data registry utilizes a subset of data elements collected by the Society of Thoracic Surgeons for the National Database of Cardiac Surgery. After data submission by hospitals, CCORP performs data validation procedures, including verification of complete submissions, using the statewide hospital patient...
Continuous variables were compared by the Student’s t test. Differences were considered statistically significant if the p value was less than 0.05.

To determine the impact of OPCAB on postoperative stroke while controlling for individual patient demographic and clinical characteristics, we used two different multivariable regression models and the “recycled predictions” method [14, 15] to compute and compare the mean risk-adjusted marginal effects for OPCAB versus CCB. The first logistic model was developed for all patients who underwent CCB only (ie, excluding OPCAB patients); this model was then applied to OPCAB patients to compare the risk of stroke in the CCB and OPCAB groups. The second risk model was developed on both CCB and OPCAB patients, and applied to all isolated CABGs in 2006 to 2007. However, because the raw logistic regression coefficients and odds ratios are nonlinear expressions of the impact of individual covariates on the response variables, they provide an imperfect picture of the impact of OPCAB on predicted risk for postoperative stroke. The method of recycled predictions, also referred to as “averaging the individual marginal effects” or “predictive margins,” provides more easily interpreted statistics than raw logistic regression coefficients [14, 15].

Marginal effects measure the expected instantaneous change in the dependent variable (ie, postoperative stroke) as a function of a change in a certain explanatory variable (ie, surgery type: OPCAB vs CCB) while keeping all the other covariates constant. By using the recycled predictions method for the first run, we assumed all isolated CABGs were performed with CCB, and for the second run we assumed all were performed with OPCAB. With the same multivariate logistic regression model we calculated the mean predicted marginal probability of postoperative stroke for OPCAB and CCB independently, while keeping the same attributes for all other covariates fixed.

A further subgroup analysis was performed for selected risk factors based on their significance in affecting postoperative stroke as demonstrated by the regression model. Within the OPCAB group we further compared the risk-adjusted postoperative stroke rates between patients who were converted from OPCAB to CCB during the operation (converters) and patients who underwent OPCAB without intraoperative conversion (nonconverters), and applied a multivariable logistic regression model to identify patient characteristics associated with intraoperative conversion from OPCAB to CCB. All data analyses were conducted with SAS version 9.2 (SAS Inc, Cary, NC).

Results
During the two-year study period, a total of 30,426 isolated CABG procedures were performed, of which 7,220 (23.7%) were OPCAB. This is consistent with 2003 to 2005, in which OPCAB accounted for 22.9% of all isolated CABGs. Compared with CCB (Table 1), OPCAB patients were older, more likely female, and had a higher prevalence of cerebrovascular disease, peripheral arterial disease, dialysis, immunosuppressive treatment, and prior CABG, but had a lower prevalence of diabetes, hypertension, recent myocardial infarction (MI) (1 to 7 days prior to CABG), New York Heart Association class IV heart failure or angina, cardiogenic shock, and 3-vessel or greater coronary artery disease (all \( p < 0.01 \)).

Using the multivariable logistic risk model developed with the CCB-only subset, the predicted risk of postoperative stroke was slightly lower for the CCB subset (CCB: 1.42%, 95% confidence interval [CI]: 1.40% to 1.44%; OPCAB: 1.46%, 95% CI: 1.43% to 1.49%, \( p = 0.026 \)). However, the observed postoperative stroke rate was lower for the OPCAB group (CCB: 1.42%, 95% CI 1.27% to 1.57%; OPCAB: 1.08%, 95% CI 0.84% to 1.32%, \( p = 0.018 \)). This model has a c-statistic of 0.728 and a \( p \) value of 0.5552 for the Hosmer-Lemeshow goodness-of-fit test, indicat-
Table 1. Isolated CABG Patient Preoperative Clinical Profile Comparison: Off-Pump (OPCAB) Versus On-Pump (CCB), California, 2006 to 2007a

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>OPCAB</th>
<th>CCB</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years, mean ± SDa)</td>
<td>66.6 (11.2)</td>
<td>65.7 (10.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Females</td>
<td>27.2%</td>
<td>25.0%</td>
<td>0.0002</td>
</tr>
<tr>
<td>Body mass index (&lt;18.5)</td>
<td>1.1%</td>
<td>0.7%</td>
<td>0.0003</td>
</tr>
<tr>
<td>Urgent needs definition</td>
<td>49.4%</td>
<td>49.1%</td>
<td>0.001</td>
</tr>
<tr>
<td>Last creatinine preop (mg/dL) (mean [SDb])</td>
<td>1.31 (0.25)</td>
<td>1.30 (0.23)</td>
<td>0.001</td>
</tr>
<tr>
<td>Dialysis</td>
<td>3.5%</td>
<td>2.9%</td>
<td>0.012</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>14.9%</td>
<td>13.2%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>14.6%</td>
<td>12.9%</td>
<td>0.0002</td>
</tr>
<tr>
<td>CVA timing (&gt;2 weeks)</td>
<td>8.0%</td>
<td>7.5%</td>
<td>0.158</td>
</tr>
<tr>
<td>Immunosuppressive treatment</td>
<td>2.5%</td>
<td>1.9%</td>
<td>0.005</td>
</tr>
<tr>
<td>Prior CABC surgery</td>
<td>4.7%</td>
<td>3.9%</td>
<td>0.005</td>
</tr>
<tr>
<td>Interval from prior PCI to CABC Surgery (&gt;6 hours):</td>
<td>21.9%</td>
<td>19.5%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>40.9%</td>
<td>43.0%</td>
<td>0.002</td>
</tr>
<tr>
<td>Hypertension</td>
<td>83.2%</td>
<td>84.6%</td>
<td>0.003</td>
</tr>
<tr>
<td>Myocardial infarction (1 to 7 days ago)</td>
<td>20.0%</td>
<td>23.1%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Atrial fibrillation/flutter</td>
<td>0.6%</td>
<td>0.8%</td>
<td>0.014</td>
</tr>
<tr>
<td>Myocardial infarction (21+ days ago)</td>
<td>16.8%</td>
<td>18.0%</td>
<td>0.017</td>
</tr>
<tr>
<td>Myocardial infarction (8 to 21 days ago)</td>
<td>4.0%</td>
<td>4.6%</td>
<td>0.015</td>
</tr>
<tr>
<td>NYHA class IVc</td>
<td>28.0%</td>
<td>30.2%</td>
<td>0.001</td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>1.6%</td>
<td>2.0%</td>
<td>0.018</td>
</tr>
<tr>
<td>Ejection fraction (&lt;0.40)</td>
<td>0.15</td>
<td>0.16</td>
<td>0.002</td>
</tr>
<tr>
<td>Three or more diseased vessels</td>
<td>69.1%</td>
<td>81.5%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Trivial mitral insufficiency</td>
<td>8.5%</td>
<td>11.3%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>No significant difference between OPCAB and CCB:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NonCaucasian</td>
<td>35.9%</td>
<td>34.8%</td>
<td>0.103</td>
</tr>
<tr>
<td>Body mass index (≥40)</td>
<td>3.6%</td>
<td>3.8%</td>
<td>0.371</td>
</tr>
<tr>
<td>Emergent/salvage</td>
<td>5.1%</td>
<td>5.3%</td>
<td>0.692</td>
</tr>
<tr>
<td>Heart block</td>
<td>1.0%</td>
<td>1.1%</td>
<td>0.822</td>
</tr>
<tr>
<td>CVA Timing (≤2 weeks)</td>
<td>0.2%</td>
<td>0.3%</td>
<td>0.892</td>
</tr>
<tr>
<td>Mild chronic lung disease:</td>
<td>10.4%</td>
<td>10.7%</td>
<td>0.467</td>
</tr>
<tr>
<td>Moderate chronic lung disease</td>
<td>5.3%</td>
<td>5.0%</td>
<td>0.379</td>
</tr>
<tr>
<td>Severe chronic lung disease</td>
<td>3.7%</td>
<td>3.6%</td>
<td>0.592</td>
</tr>
<tr>
<td>Sustained VT/VF</td>
<td>2.3%</td>
<td>2.1%</td>
<td>0.347</td>
</tr>
<tr>
<td>Myocardial infarction (&gt;6 and &lt;24 hours)</td>
<td>2.6%</td>
<td>2.6%</td>
<td>0.897</td>
</tr>
<tr>
<td>Myocardial infarction (within 6 hours)</td>
<td>1.6%</td>
<td>1.4%</td>
<td>0.211</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>15.8%</td>
<td>16.4%</td>
<td>0.264</td>
</tr>
<tr>
<td>Interval from prior PCI to CABC Surgery (≤6 hours):</td>
<td>1.2%</td>
<td>1.1%</td>
<td>0.332</td>
</tr>
<tr>
<td>Left main coronary artery disease (&gt;50% stenosis)</td>
<td>28.3%</td>
<td>27.5%</td>
<td>0.191</td>
</tr>
<tr>
<td>Mild mitral insufficiency</td>
<td>12.0%</td>
<td>12.5%</td>
<td>0.322</td>
</tr>
<tr>
<td>Moderate mitral insufficiency</td>
<td>4.0%</td>
<td>3.9%</td>
<td>0.918</td>
</tr>
<tr>
<td>Severe mitral insufficiency</td>
<td>0.4%</td>
<td>0.5%</td>
<td>0.319</td>
</tr>
</tbody>
</table>

a SD, standard deviation. b Except for age and last creatinine preop (mg/dL), all variables are transformed into dummy variables for a specific comparison between OPCAB and CCB. c The New York Heart Association classification represents the overall functional status of patient in relationship to both congestive heart failure and angina (STS v2.5).

CABG = coronary artery bypass graft; CVA = cerebrovascular accident; NYHA = New York Heart Association; PCI = Percutaneous coronary intervention; VF = ventricular fibrillation; VT = ventricular tachycardia.
The multivariable logistic risk model with OPCAB added as a risk factor (Table 2) has a c-statistic of 0.73 and a p value of 0.1263 for the Hosmer-Lemeshow goodness-of-fit test, also indicating a good discrimination and data calibration. Using this risk model and controlling for demographic and clinical variables, OPCAB was associated with a significantly lower rate of postoperative stroke (adjusted odds ratio: 0.76, 95% CI 0.59 to 0.98, p < 0.001). Using the recycled predictions method, the predicted risk for postoperative stroke, after controlling for patient demographic and clinical risk factors for OPCAB, was significantly less than that of CCB (OPCAB: 1.09%, 95% CI 1.08% to 1.10% vs CCB 1.43%, 95% CI 1.41% to 1.45%, p < 0.001). Even for patients with cardiogenic shock, OPCAB was associated with lower risk-adjusted postoperative stroke rates compared with CCB (OPCAB: 3.06%, 95% CI 2.83% to 3.28%; CCB: 4.05%, 95% CI 3.76% to 4.33%, p < 0.001). The odds ratio of predicted postoperative stroke for OPCAB (0.0109)/(1 to 0.0109) divided by the predicted postoperative stroke for CCB (0.0143)/(1 to 0.0143) = 0.76, is close to the odds ratio of

Table 2. Multivariate Logistic Risk Adjustment Model for Postoperative Stroke

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPCAB</td>
<td>0.755 (0.585–0.975)</td>
<td>0.0361</td>
</tr>
<tr>
<td>Age</td>
<td>1.032 (1.021–1.044)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1.528 (1.227–1.901)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Non-Caucasian</td>
<td>1.073 (0.863–1.336)</td>
<td>0.496</td>
</tr>
<tr>
<td>Body mass index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.5–39.9</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>1.403 (0.611–3.223)</td>
<td>0.4252</td>
</tr>
<tr>
<td>≥40.0</td>
<td>0.936 (0.530–1.654)</td>
<td>0.8197</td>
</tr>
<tr>
<td>Status of procedure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elective</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Urgent</td>
<td>1.024 (0.785–1.336)</td>
<td>0.8615</td>
</tr>
<tr>
<td>Emergent/salvage</td>
<td>1.704 (1.018–2.853)</td>
<td>0.0426</td>
</tr>
<tr>
<td>Last creatinine level preop</td>
<td>2.635 (1.655–4.194)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.260 (0.897–1.769)</td>
<td>0.1819</td>
</tr>
<tr>
<td>Dialysis</td>
<td>0.631 (0.337–1.181)</td>
<td>0.1495</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>0.907 (0.687–1.181)</td>
<td>0.4926</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>1.897 (1.391–2.587)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CVA timing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No CVA</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>&gt;2 weeks</td>
<td>1.148 (0.795–1.656)</td>
<td>0.4619</td>
</tr>
<tr>
<td>≤2 wks</td>
<td>3.540 (1.42–8.823)</td>
<td>0.0067</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.293 (1.042–1.605)</td>
<td>0.0198</td>
</tr>
<tr>
<td>Chronic Lung Disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>0.878 (0.622–1.240)</td>
<td>0.4611</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.959 (0.624–1.473)</td>
<td>0.8473</td>
</tr>
<tr>
<td>Severe</td>
<td>1.041 (0.654–1.656)</td>
<td>0.8654</td>
</tr>
<tr>
<td>Immunosuppressive treatment</td>
<td>1.115 (0.602–2.068)</td>
<td>0.7285</td>
</tr>
<tr>
<td>Arrhythmia type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Atrial Fibrillation/Flutter</td>
<td>1.149 (10.501–2.637)</td>
<td>0.7427</td>
</tr>
<tr>
<td>Heart Block</td>
<td>0.466 (0.147–1.471)</td>
<td>0.1929</td>
</tr>
<tr>
<td>Sustained VT/VF</td>
<td>1.197 (0.696–2.059)</td>
<td>0.5162</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>21 or more days ago</td>
<td>0.811 (0.584–1.126)</td>
<td>0.2107</td>
</tr>
<tr>
<td>8–20 days ago</td>
<td>0.996 (0.625–1.586)</td>
<td>0.9848</td>
</tr>
<tr>
<td>1–7 days ago</td>
<td>1.238 (0.937–1.636)</td>
<td>0.1336</td>
</tr>
<tr>
<td>≥6 and &lt;24 hours</td>
<td>1.774 (1.048–3.003)</td>
<td>0.0327</td>
</tr>
<tr>
<td>Within 6 hours</td>
<td>1.959 (1.021–3.758)</td>
<td>0.043</td>
</tr>
</tbody>
</table>

Table 2. Continued

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiogenic shock</td>
<td>1.048 (0.594–1.849)</td>
<td>0.8806</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>1.142 (0.876–1.489)</td>
<td>0.326</td>
</tr>
<tr>
<td>NYHA class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I,II,III</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>1.122 (0.884–1.423)</td>
<td>0.345</td>
</tr>
<tr>
<td>Prior CABG surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>One or more</td>
<td>1.470 (0.948–2.278)</td>
<td>0.0853</td>
</tr>
<tr>
<td>Prior PCI interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No prior PCI</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>&gt;6 hours</td>
<td>0.850 (0.642–1.127)</td>
<td>0.2603</td>
</tr>
<tr>
<td>≤6 hours</td>
<td>0.741 (0.307–1.788)</td>
<td>0.5049</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>0.990 (0.982–0.998)</td>
<td>0.0102</td>
</tr>
<tr>
<td>Left main disease (% stenosis)</td>
<td>1.002 (0.995–1.009)</td>
<td>0.5524</td>
</tr>
<tr>
<td>Number of diseased vessels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0, 1, 2</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>3 or more</td>
<td>1.094 (0.833–1.436)</td>
<td>0.5189</td>
</tr>
<tr>
<td>Mitral insufficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Trivial</td>
<td>0.764 (0.529–1.103)</td>
<td>0.1511</td>
</tr>
<tr>
<td>Mild</td>
<td>1.046 (0.788–1.390)</td>
<td>0.7355</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.187 (0.796–1.771)</td>
<td>0.3981</td>
</tr>
<tr>
<td>Severe</td>
<td>1.868 (0.796–4.384)</td>
<td>0.1508</td>
</tr>
</tbody>
</table>

CABG = coronary artery bypass grafting; CI = confidence interval; CVA timing = cerebrovascular accident timing; NYHA = New York Heart Association; OPCAB = off-pump coronary artery bypass; PCI = percutaneous coronary intervention; VF = ventricular fibrillation; VT = ventricular tachycardia.

The multivariable logistic risk model with OPCAB added as a risk factor (Table 2) has a c-statistic of 0.73 and a p value of 0.1263 for the Hosmer-Lemeshow goodness-of-fit test, also indicating a good discrimination and data calibration. Using this risk model and controlling for demographic and clinical variables, OPCAB was associated with a significantly lower rate of postoperative stroke (adjusted odds ratio: 0.76, 95% CI 0.59 to 0.98, p < 0.001). Using the recycled predictions method, the predicted risk for postoperative stroke, after controlling for patient demographic and clinical risk factors for OPCAB, was significantly less than that of CCB (OPCAB 1.09%, 95% CI 1.08% to 1.10% vs CCB 1.43%, 95% CI 1.41% to 1.45%, p < 0.001; Table 3). Even for patients with cardiogenic shock, OPCAB was associated with lower risk-adjusted postoperative stroke rates compared with CCB (OPCAB: 3.06%, 95% CI 2.83% to 3.28%; CCB: 4.05%, 95% CI 3.76% to 4.33%, p < 0.001). The odds ratio of predicted postoperative stroke for OPCAB (0.0109)/(1 to 0.0109) divided by the predicted postoperative stroke for CCB (0.0143)/(1 to 0.0143) = 0.76, is close to the odds ratio of
0.755 from the multivariable logistic parameter estimate. This similarity supports the marginal effects of OPCAB on the outcome computed with the recycled predictions method.

Table 3 presents subgroup analyses for other patient characteristics, and in all cases OPCAB resulted in a significantly lower risk of postoperative stroke than CCB. Further, the protective effect of OPCAB was not evenly distributed by patient age, this effect being more pronounced in older patients compared with younger patients (Fig 1).

The group of 793 (11%) OPCAB patients who converted intraoperatively to CCB had an increased postoperative incidence of stroke (with conversion: 2.02%, 95% CI 1.04% to 3.00% versus without conversion: 0.96%, 95% CI 0.73% to 1.20%, \( p = 0.041 \)), although both subgroups had similar predicted postoperative stroke rates (with conversion: 1.16%, 95% CI 1.08% to 1.25%; without conversion: 1.11% 95% CI 1.08% to 1.13%, \( p = 0.242 \); Table 4). Additionally, those patients with MI 24 hours or less prior to surgery, left main coronary artery stenosis, and 3-vessel or greater coronary disease were more likely to have intraoperative conversion from OPCAB to CCB (adjusted odds ratio for MI within 24 hours: 1.72, 95% CI 1.15 to 2.55, \( p = 0.008 \); for left main stenosis [each additional 1% increase]: 1.01, 95% CI 1.01 to 1.02, \( p < 0.001 \); for 3-vessel or greater disease: 2.29, 95% CI 1.88 to 2.78, \( p < 0.001 \)).

**Comment**

Our study demonstrates a significantly reduced risk of postoperative stroke in a large cohort of patients under-
going OPCAB compared with CCB. Three different methods of analysis were applied in this retrospective study comprising patients of differing risk profiles. First, in a multivariable model which was developed with CCB patients only, and then used to compare that subset to OPCAB patients, the predicted risk of stroke was similar in the two groups but the observed rate of stroke was significantly lower with OPCAB. In a second model, in which OPCAB was included as a predictor variable, OPCAB was associated with a significantly lower rate of postoperative stroke. Third, the recycled predictions method confirmed the previously demonstrated lower rate of stroke in the OPCAB subset.

Previous trials [6–10, 16] that suggested a protective effect of OPCAB on postoperative complications are limited by small sample sizes, the largest of which was only 281 patients [10]. By contrast, our findings are based on a large patient population and rigorous statistical analysis which revealed that the observed rate of postoperative stroke was significantly lower with OPCAB. In a second model, in which OPCAB was included as a predictor variable, OPCAB was associated with a significantly lower rate of postoperative stroke. Third, the recycled predictions method confirmed the previously demonstrated lower rate of stroke in the OPCAB subset.

Table 4. Observed and Mean Predicted Risk-Adjusted Postoperative Stroke Rates: Patients Undergoing Intraoperative Conversion From OPCAB to CCB

<table>
<thead>
<tr>
<th>OPCAB to CCB Conversion</th>
<th>n</th>
<th>Observed</th>
<th>p Value</th>
<th>Mean Recycle-Predicted</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converters*</td>
<td>793</td>
<td>2.02% (1.04–3.00%)</td>
<td>0.041</td>
<td>1.16% (1.08–1.25%)</td>
<td>0.242</td>
</tr>
<tr>
<td>Nonconverters</td>
<td>6,427</td>
<td>0.96% (0.73–1.20%)</td>
<td></td>
<td>1.11% (1.08–1.13%)</td>
<td></td>
</tr>
</tbody>
</table>

* The off-pump coronary artery bypass (OPCAB) procedure was intraoperatively converted to conventional coronary artery bypass (CCB).
is noted that conversion to CCB was associated with an increased risk of stroke. However, this study does provide a basis for a randomized controlled trial of the comparative risk of stroke associated with CCB and OPCAB.

In this large retrospective study, OPCAB was associated with a significantly lower postoperative stroke rate compared with CCB, even for older and higher risk patients. However, intraoperative conversion from OPCAB to CCB was associated with the highest postoperative stroke rate.

References