Effect of Aortic Clamping Strategy on Postoperative Stroke in Coronary Artery Bypass Grafting Operations

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IMPORTANCE Aortic clamping technique has been implicated in stroke risk at the time of on-pump coronary artery bypass grafting (CABG) procedures. We hypothesized that partial aortic clamping (PAC) use in performing proximal coronary anastomosis does not increase risk of stroke.

OBJECTIVE To determine whether postoperative stroke incidence is influenced by single aortic clamping (SAC) or side-biting PAC use in performing proximal anastomosis during CABG procedures.

DESIGN, SETTING, AND PARTICIPANTS In a retrospective cohort study, we analyzed data from 1819 patients who underwent conventional, isolated, nonemergent, first-time, arrested-heart, on-pump CABG at a single US major academic, tertiary/quaternary medical center from January 1, 2005, to December 31, 2013. Postoperative stroke was defined according to Society of Thoracic Surgeons (STS) criteria as any confirmed neurological deficit of abrupt onset that did not resolve within 24 hours. Institutional STS data including STS predicted risk of postoperative stroke score were used to compare patients receiving proximal aortic anastomoses performed with either SAC (n = 1107) or combined PAC (n = 712) techniques.

EXPOSURES Use of SAC or PAC in performing proximal coronary anastomosis.

MAIN OUTCOMES AND MEASURES Thirty-day periprocedural postoperative stroke rates.

RESULTS There were no significant differences in preoperative risk or STS predicted risk of mortality between groups. Patients in the SAC group had longer myocardial ischemic time compared with those in the PAC group (mean [SD], 73.2 [22.8] vs 66.5 [22.8] minutes, respectively; P < .001) but shorter overall perfusion time (mean [SD], 96.6 [30.1] vs 102.2 [30.1] minutes, respectively; P < .001). The 30-day observed mortality rates between the SAC and PAC groups were equally low (21 of 1107 patients [1.9%] vs 13 of 712 patients [1.8%], respectively; P > .99) and congruent with STS predicted risk of mortality. Preoperative STS predicted risk of postoperative stroke scores were nearly identical between the SAC and PAC groups (mean [SD], 1.5% [1.4%] vs 1.6% [1.4%]; P = .99), and the 30-day actual observed postoperative stroke rates between the SAC and PAC groups were similar (17 of 1107 patients [1.5%] vs 10 of 712 patients [1.4%], respectively; P > .99).

CONCLUSIONS AND RELEVANCE In this contemporary study of on-pump CABG, we did not identify any significant differences in the incidence of postoperative stroke regardless of the clamping method used to perform proximal anastomosis.

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Although rare, stroke following coronary artery bypass grafting (CABG) continues to be a significant life-altering major morbidity. The etiology of stroke after CABG is multifactorial.\(^1\)\(^3\) Atherosclerotic aortic emboli from ascending aortic manipulation, and hemodynamic changes during cardiopulmonary bypass (CPB) in the setting of cerebrovascular disease, have been implicated to cause postoperative stroke after CABG.\(^2\)

In an effort to minimize aortic manipulation and avoid CPB, the technique of off-pump CABG was developed and became an accepted method of performing CABG with good outcomes in experienced centers.\(^4\)\(^6\) However, the potential reduction of postoperative stroke in off-pump CABG has not been definitively proven.\(^7\)\(^9\) Several well-designed, large, multicenter, prospective, randomized trials failed to demonstrate any significant risk reduction of postoperative stroke in off-pump CABG compared with traditional on-pump CABG.\(^10\)\(^12\)

Stroke prevention in cardiac surgery has been a recent initiative championed by national societies such as the Society of Thoracic Surgeons (STS) as an overall effort to improve quality of care.\(^13\)\(^15\) Recent literature has suggested that the use of side-biting partial aortic clamping (PAC) in conventional on-pump CABG procedures for performing proximal anastomosis increases the risk of postoperative stroke.\(^16\)\(^17\) Nevertheless, several high-volume, high-performing cardiac surgery centers continued to perform on-pump CABG using the PAC technique with relatively low stroke rates, and controversy exists on whether the use of the PAC technique increases postoperative stroke risk.\(^18\)\(^20\) We hypothesized that the use of PAC for proximal coronary anastomosis is not associated with increased incidence of postoperative stroke in on-pump CABG.

### Methods

#### Data Source

Data were obtained from the institutional STS adult cardiac surgery database of the University of Pittsburgh Medical Center. The database was maintained by trained professionals using versions 2.52.1, 2.6.1, and 2.73 and included standard STS-defined patient-level variables and outcomes including predicted risk of postoperative stroke (PROPS) and predicted risk of mortality (PROM) scores.\(^21\) The use of single aortic clamping (SAC) or side-biting PAC for performing proximal coronary artery anastomosis is an institution-specific data field captured since 2005. The institutional review board at the University of Pittsburgh Medical Center approved this study and granted a waiver of consent owing to the retrospective nature of the study.

#### Patient Population

After excluding cases of missing records, off-pump CABG, and previous cardiac operations, we identified 1819 consecutive patients who underwent conventional, isolated, nonemergent, arrested-heart, on-pump CABG from January 1, 2005, to December 31, 2013. Postoperative stroke was defined according to STS criteria as any confirmed neurological deficit of abrupt onset that did not resolve within 24 hours. Delirium was not considered postoperative stroke if it resolved completely prior to discharge. An overwhelming majority of postoperative stroke was confirmed by a board-certified neurologist and/or brain imaging. Institutional STS data including STS PROPS and PROM scores were used to compare outcomes between patients who underwent CABG with the use of SAC (n = 1107) and patients who underwent CABG with the use of side-biting PAC (n = 712) for the performance of proximal coronary artery anastomosis. The decision to use SAC or PAC for performance of proximal coronary artery anastomosis was left to the discretion of the attending cardiac surgeon.

#### Study End Points

The primary end point of the study was occurrence of postoperative stroke within 30 days of operation, defined according to STS criteria as any confirmed neurological deficit of abrupt onset that did not resolve within 24 hours.\(^21\) The secondary end point was the incidence of 30-day mortality.

#### Statistical Analysis

Data from categorical variables were summarized as proportions, which were compared between groups by using the \(\chi^2\) test or the Fisher exact test when appropriate. Data from continuous variables were summarized as means (with standard deviations), which were compared between groups by using the \(t\) test. \(P < .05\) was considered statistically significant.

### Results

Patients in the SAC group were older than those in the PAC group (mean [SD], 66.3 [10.6] vs 64.9 [10.6] years, respectively; \(P = .003\), had a higher incidence of preoperative arrhythmia (52 of 1107 patients [4.7%] vs 11 of 712 patients [1.5%], respectively; \(P < .001\), and had a higher incidence of previous myocardial infarction (562 of 1107 patients [50.8%] vs 281 of 712 patients [39.5%], respectively; \(P < .001\)). There were no significant differences in STS PROM between the SAC and PAC groups (mean [SD], 2.1% [2.8%] vs 2.1% [2.8%], respectively; \(P = .88\) (Table).

Despite a similar number of distal coronary anastomoses (Table), there were significant differences in myocardial ischemic and CPB times between the 2 groups. The SAC group had longer myocardial ischemic time compared with the PAC group (mean [SD], 73.2 [22.8] vs 66.5 [22.8] minutes, respectively; \(P < .001\)) but shorter overall CPB perfusion time (mean [SD], 96.6 [30.1] vs 102.2 [30.1] minutes, respectively; \(P < .001\)).

Preoperative STS PROPS scores were similar between the SAC and PAC groups (mean [SD], 1.5% [1.4%] vs 1.6% [1.4%], respectively; \(P = .95\), as was the primary outcome of 30-day actual observed postoperative stroke rate between the SAC and PAC groups (17 of 1107 patients [1.5%] vs 10 of 712 patients [1.4%], respectively; \(P > .99\) (Figure)). The 30-day observed mortality rates, the secondary outcome, between the SAC and PAC groups (21 of 1107 patients [1.9%] vs 13 of 712 patients [1.8%], respectively; \(P > .99\) were equally low and congruent with STS PROM (Table).
Discussion

In this single-institution retrospective observational study, we demonstrated that the use of PAC for performing proximal coronary anastomosis in CABG is not associated with increased risk of postoperative stroke or mortality when compared with the SAC technique. Both groups of patients had similarly low predicted and observed postoperative stroke rates (Figure). Although the incidences of postoperative stroke were similar, there were statistically significant differences in some notable intraoperative parameters between groups. Specifically, the SAC group had 5% shorter CPB time and 10% longer myocardial ischemic time compared with the PAC group despite a similar number of distal coronary anastomoses.

Logic dictates that minimizing manipulation of the ascending aorta during CABG should decrease the risk of distal emboli from aortic atherosclerotic debris causing stroke. However, this theory has not been proven as evidenced by several large, multicenter, prospective, randomized trials in off-pump vs on-pump CABG.10-12 In on-pump CABG, literature continues to be conflicting regarding use of the proximal anastomotic technique of SAC vs PAC in terms of stroke risk.17,20,22-24 More striking was a recent study by Daniel et al,36 who demonstrated in a retrospective observational propensity score study of 706 patients that PAC use was associated with 2.6 times higher incidence of postoperative stroke compared with SAC in patients undergoing on-pump CABG. However, in our current study of 1819 patients, we were unable to demonstrate any statistical difference in the incidence of postoperative stroke in the SAC vs PAC groups with similar STS PROPS scores.

Because postoperative stroke is one of the most potentially devastating complications in patients undergoing CABG, the STS adult cardiac surgery database developed a predictive risk model using 25 patient-level and procedure-specific variables to arrive at the STS PROPS score.13-15 We used the well-validated STS PROPS score in risk adjusting our 2 groups of patients undergoing SAC vs PAC techniques and found no observable difference in the actual incidence of postoperative stroke in a large sample of patients. Previous studies on the topic of SAC vs PAC technique had relatively low numbers of patients and were mostly published more than a decade ago.16,17,20,22-24 Our contemporary study of 1819 patients represents one of the largest studies to date to associate postoperative stroke risk with the SAC vs PAC technique of performing proximal coronary anastomosis.

Although our sample size was relatively robust, our study may have type II statistical error in measuring a relatively low-frequency outcome such as incidence of postoperative stroke. Assuming 2.6 times increased risk of postoperative stroke when using PAC compared with SAC in patients undergoing CABG as reported by the most recent study,16 our current study of 1819 patients should be able to detect such a striking difference with α of 0.05 and power of 0.8. We were unable to demonstrate such a difference in postoperative stroke risk despite the adequately powered sample size. Other limitations of our study were those inherent to retrospective design, including but not limited to se-

Table. Cohort Demographic Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Aortic Clamping Strategy</th>
<th>P Value</th>
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<tbody>
<tr>
<td></td>
<td>Single Aortic Clamping</td>
<td>Partial Aortic Clamping</td>
</tr>
<tr>
<td></td>
<td>(n = 1107)</td>
<td>(n = 712)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>66.3 (10.6)</td>
<td>64.9 (10.6)</td>
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<tr>
<td>Male, No. (%)</td>
<td>816 (73.7)</td>
<td>513 (71.2)</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>30.1 (5.9)</td>
<td>30.3 (5.9)</td>
</tr>
<tr>
<td>Previous stroke, No. (%)</td>
<td>69 (6.2)</td>
<td>45 (6.3)</td>
</tr>
<tr>
<td>Cerebral vascular disease, No. (%)</td>
<td>202 (18.2)</td>
<td>120 (16.9)</td>
</tr>
<tr>
<td>Hypertension, No. (%)</td>
<td>938 (84.7)</td>
<td>591 (83.0)</td>
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<tr>
<td>Diabetes mellitus, No. (%)</td>
<td>470 (42.5)</td>
<td>325 (45.6)</td>
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<tr>
<td>Previous myocardial infarction, No. (%)</td>
<td>562 (50.8)</td>
<td>281 (39.5)</td>
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<tr>
<td>Peripheral vascular disease, No. (%)</td>
<td>284 (25.7)</td>
<td>173 (24.3)</td>
</tr>
<tr>
<td>Arrhythmia, No. (%)</td>
<td>52 (4.7)</td>
<td>11 (1.5)</td>
</tr>
<tr>
<td>Total distal anastomoses, mean (SD), No.</td>
<td>3.9 (1.2)</td>
<td>3.8 (1.2)</td>
</tr>
<tr>
<td>STS PROM, mean (SD), %</td>
<td>2.1 (2.8)</td>
<td>2.1 (2.8)</td>
</tr>
<tr>
<td>Observed mortality, No. (%)</td>
<td>21 (1.9)</td>
<td>13 (1.8)</td>
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<tr>
<td>STS PROPS score, mean (SD), %</td>
<td>1.5 (1.4)</td>
<td>1.6 (1.4)</td>
</tr>
<tr>
<td>Observed stroke, No. (%)</td>
<td>17 (1.5)</td>
<td>10 (1.4)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); PROM, predicted risk of mortality; PROPS, predicted risk of postoperative stroke; STS, Society of Thoracic Surgeons.

Figure. Thirty-Day Predicted and Observed Postoperative Stroke Rates

PROPS indicates predicted risk of postoperative stroke; STS, Society of Thoracic Surgeons.
lection bias and potential unmeasured confounders. However, the use of validated STS PROPS scores served to minimize such bias and equilibrated our 2 cohorts in terms of stroke risk, which was our primary outcome measure. Postoperative stroke as a primary outcome may have underestimated actual atherosclerotic embolic events that might be clinically irrelevant and/or self-limiting such as transient delirium.

Conclusions

In this study, we were unable to identify any significant differences in the incidence of postoperative stroke between the SAC and PAC groups in the performance of on-pump CABG. The PAC technique appears noninferior to SAC for the performance of proximal coronary anastomosis. Not surprisingly, the PAC group had shorter myocardial ischemic times and a similar short-term mortality rate compared with the SAC group. In patients with significantly compromised myocardial function who are undergoing complex cardiac operations, PAC may provide a safe alternative. To validate our findings, a prospective randomized trial designed to assess aortic clamping strategy for performing proximal coronary anastomosis as well as risk of postoperative stroke and distal embolic burden in CABG operations appears justified.

ARTICLE INFORMATION

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

Study concept and design: Chu, Schaeheen, Morell, Wei, Badhwar.

Acquisition, analysis, or interpretation of data: Chu, Schaeheen, Gleason, Cook, Wei, Badhwar.

Drafting of the manuscript: Chu, Schaeheen, Badhwar.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Chu, Schaeheen.

Administrative, technical, or material support: Chu, Gleason, Cook, Wei, Badhwar.

Study supervision: Chu, Morell, Wei, Badhwar.

Conflict of Interest Disclosures: None reported.

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REFERENCES