Avoiding aortic clamping during coronary artery bypass grafting reduces postoperative stroke

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Objective: The purpose of this study was to determine whether the incidence of postoperative stroke could be reduced by eliminating aortic clamping during coronary artery bypass grafting.

Methods: From 2002 to 2013, 12,079 patients underwent primary, isolated coronary artery bypass grafting at a single US academic institution. Aortic manipulation was completely avoided by using in situ internal thoracic arteries for inflow in 1552 patients (12.9%) (no-touch), a clampless facilitating device for proximal anastomoses in 1548 patients (12.8%), and aortic clamping in 8979 patients (74.3%). These strategies were assessed in a logistic regression model controlling for relevant variables.

Results: The overall incidence of postoperative stroke was 1.4% (n = 165), with an unadjusted incidence of 0.6% (n = 10) in the no-touch group, 1.2% (n = 18) in the clampless facilitating device group, and 1.5% (n = 137) in the clamp group ($P < .01$ for no-touch vs clamp). The ratio of observed to expected stroke rate increased as the degree of aortic manipulation increased, from 0.48 in the no-touch group, to 0.61 in the clampless facilitating device group, and to 0.95 in the clamp group. Aortic clamping was independently associated with an increase in postoperative stroke compared with a no-touch technique (adjusted odds ratio, 2.50; $P < .01$). When separated by cardiopulmonary bypass use, both the off-pump partial clamp and the on-pump crossclamp techniques increased the risk of postoperative stroke compared with no-touch (adjusted odds ratio, 2.52, $P < .01$; and adjusted odds ratio, 4.25, $P < .001$, respectively).

Conclusions: A no-aortic touch technique has the lowest risk for postoperative stroke for patients undergoing coronary artery bypass grafting. Clamping the aorta during coronary artery bypass grafting increases the risk of postoperative stroke, regardless of the severity of aortic disease. (J Thorac Cardiovasc Surg 2015;149:175-80)

See related commentary on pages 180-1.

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Coronary artery bypass grafting (CABG) is one of the most heavily scrutinized surgical procedures performed worldwide. Despite this, many questions regarding optimal strategies for reducing perioperative morbidity remain unanswered. Postoperative stroke (PS) is a rare but devastating complication of CABG surgery, occurring in approximately 1.5% to 3.5% of all surgeries.^{1,2} PS is the only major cardiovascular complication for which percutaneous coronary intervention has shown an advantage over CABG, so it is imperative to study PS and minimize its occurrence.³ Because manipulation of the ascending aorta has been proposed as the primary culprit leading to cerebral atheroembolism, much focus has been placed on exploring devices and operative techniques that minimize aortic manipulation.

In the United States, the majority of CABG procedures currently are performed with the use of cardiopulmonary bypass, which in almost all cases implies cannulation and clamping of the ascending aorta. Depending on the strategy for proximal anastomosis, the aorta may be clamped only once or a second time using a partial clamp. Off-pump coronary artery bypass (OPCAB) gives the surgeon more freedom to dictate the degree of aortic manipulation. Often, a partial aortic clamp is used to allow proximal anastomoses to be sewn in a bloodless field. However, aortic clamping

Abbreviations and Acronyms

AOR	= adjusted odds ratio
CABG	= coronary artery bypass grafting
CFD	= clampless facilitating device
CI	= confidence interval
OPCAB	= off-pump coronary artery bypass
PROPS	= predicted risk of postoperative stroke
PS	= postoperative stroke
STS	= Society of Thoracic Surgeons

can be avoided completely with the use of clampless facilitating devices (CFDs) or proximal anastomotic connectors. Finally, a “no touch” technique can be used in which aortic manipulation is avoided completely by providing inflow to all grafts from 1 or 2 in situ internal thoracic arteries or using a hybrid approach when clinically appropriate. The purpose of this study was to determine whether eliminating aortic clamping could reduce the incidence of PS in patients undergoing CABG surgery.

MATERIALS AND METHODS

Patients were identified by querying Emory University's Institutional Society of Thoracic Surgeons (STS) Adult Cardiac Surgery database for all patients undergoing primary, isolated CABG between January 2002 and July 2013. Patients undergoing redo or concomitant surgeries were excluded, as well as any on-pump CABG performed without aortic clamping. Individual chart review was performed to complement information entered in the STS database. This study was approved by Emory University's Institutional Review Board, which waived the need for individual patient consent. STS definitions were used to identify perioperative outcomes. Stroke was defined as any confirmed neurologic deficit of abrupt onset caused by a disturbance in blood supply to the brain that did not resolve within 24 hours.

Surgical Technique

All patients underwent on-pump or off-pump primary, isolated CABG. The clamping technique and use of cardiopulmonary bypass were dictated by the surgeon and the clinical scenario. For all on-pump cases, 1 or 2 (crossclamp and partial occluding clamp) aortic clamps were used. OPCAB surgeries included patients who underwent median sternotomy or minimally invasive CABG with thoracoscopic or robotic assistance via minithoracotomy. OPCAB clamping strategies for proximal anastomoses included (1) single partial clamp, (2) clampless technique with a facilitating device (Heartstring; Maquet Cardiovascular, San Jose, Calif), or (3) a “no-touch” technique without cannulation or proximal anastomosis involving the ascending aorta; these surgeries consisted of in situ single or double thoracic grafts with other conduits, when present, being anastomosed end-to-side to the thoracic pedicles.

Epi-aortic ultrasound was performed in the majority patients in this study.⁴⁻⁶ This practice was introduced at Emory University in 2002 and has been gradually adopted to now include all patients undergoing cardiac surgery via sternotomy in whom cannulation or clamping of the ascending aorta is being considered. Aortic grading ranges from 1 to 5: 1, normal (<2 mm thickness); 2, minimal disease (2-3 mm thickness); 3, moderate disease (3-5 mm thickness); 4, severe disease (>5 mm thickness); 5, mobile plaque present in the ascending aorta.

Statistical Analysis

Groups were analyzed retrospectively according to the aortic manipulation strategy used: no touch (N = 1550), facilitating (N = 1551), off-pump partial clamp (N = 6449), and on-pump (N = 2529). Numeric and categorical variables were compared across groups using general linear modeling and chi-square testing, respectively (Tables 1 and 2).

For modeling purposes, missing data were assessed for model terms and determined to be limited to the predicted risk variables (n = 2, 0.02%) and epiaortic grade (n = 367, 3.04%). A standard multiple imputation algorithm was used to avoid the deletion of these cases with missing data. Ten imputations were made and results were combined in such a way as to maintain the variance-covariance structure of the existing complete cases.

Multivariable logistic regression was used to model our outcomes of interest as a function of the manipulation groups. Each model was adjusted for the relevant STS Risk Score in an attempt to adjust for baseline risk; predicted risk of permanent stroke for stroke; predicted risk of mortality for death; predicted risk of morbidity and mortality for myocardial infarction, major adverse cardiac event, transfusion, and atrial fibrillation; predicted risk of reoperation for bleeding; predicted risk of prolonged ventilation for prolonged ventilation; and predicted risk of renal failure for renal failure. Each outcome model was also adjusted for year of surgery, epiaortic grade, and use of robotic or a thoracoscopic assistance. These variables were chosen because of their known covariate status with the outcomes and because the risk scores do not account for them. All of the possible pairwise comparisons of groups were calculated, resulting in 6 comparisons. Adjusted odds ratios (AORs) and 95% confidence intervals (CIs) were calculated. All analyses were performed using SAS 9.3 (SAS Institute, Inc, Cary, NC). All tests were evaluated at the 0.05 alpha level. No adjustments were made for multiple comparisons.

RESULTS

From January 2002 to July 2013, 12,079 patients meeting the study's inclusion and exclusion criteria underwent primary isolated CABG at our institution (Figure 1); 8978 patients (74.3%) were in the clamp group, with 6449 (53.4%) undergoing OPCAB using a partial clamp and 2529 (20.9%) undergoing on-pump CABG with 1 or 2 clamps. The CFD group consisted of 1551 patients (12.8%), and the “no-touch” group included 1550 patients (12.8%). Details of the demographics of these patient groups are listed in Table 1.

The overall incidence of PS was 1.4% (n = 165). This corresponded to 137 strokes in the clamp group (1.5%), 18 strokes in the CFD group (1.2%), and 10 strokes in the no-touch group (0.6%). On unadjusted comparison, there were significantly less strokes in the no-touch group compared with the clamp group. A summary of unadjusted comparisons is shown in Table 2. The observed to expected ratio of stroke in each group, compared with the STS predicted risk of postoperative stroke (PROPS) score, is depicted in Figure 2, and was 0.48, 0.61, and 0.95 for the no-touch, CFD, and clamp groups, respectively. Table 3 shows the ascending aortic atherosclerotic burden, as assessed by epiaortic ultrasound, according to group.

On multiple logistic regression analysis, controlling for pump group, epiaortic ultrasound grade, PROPS score, and operative approach, aortic clamping was independently

TABLE 1. Preoperative risk factors by aortic manipulation strategy

Variable	Group 1	Group 2	Group 3	Group 4	Groups 3-4	P value
	No touch N = 1550	Facilitating device N = 1551	Off-pump partial clamp N = 6449	On-pump clamp N = 2529	Any clamp N = 8978	All 4 groups
Patient age, y	62.1 ± 12.2	66.2 ± 10.5	62.9 ± 10.7	61.7 ± 10.3	62.6 ± 10.6	<.001
BMI	28.9 ± 5.9	28.6 ± 5.9	29.5 ± 6.1	29.4 ± 5.7	29.4 ± 6.0	<.001
HbA1c	6.3 ± 1.4	6.5 ± 1.5	6.7 ± 2.2	6.8 ± 1.8	6.7 ± 2.1	<.001
Creatinine	1.26 ± 1.36	1.34 ± 1.40	1.24 ± 1.22	1.24 ± 1.16	1.24 ± 1.20	.036
Ejection fraction	53.9 ± 11.3	51.0 ± 12.9	52.0 ±	49.7 ± 13.5	51.3 ± 12.5	<.001
Diseased vessels	2.9 ± 0.8	3.7 ± 0.5	3.7 ± 0.6	3.7 ± 0.5	3.7 ± 0.5	<.001
PROM	1.8 ± 3.2	2.7 ± 3.3	1.9 ± 2.6	2.1 ± 2.7	2.0 ± 2.6	<.001
PROPS	1.3 ± 1.8	1.9 ± 1.8	1.5 ± 1.4	1.5 ± 1.5	1.5 ± 1.4	<.001
Diabetes	515 (33.2)	629 (40.6)	2671 (41.4)	1078 (42.6)	3749 (41.8)	<.001
Insulin-dependent	169 (10.9)	219 (14.1)	930 (14.4)	379 (15.0)	1309 (14.6)	.002
Cerebrovascular disease	275 (17.7)	400 (25.8)	1041 (16.1)	417 (16.5)	1458 (16.2)	<.001
MI	831 (53.6)	657 (42.4)	3103 (48.1)	1128 (44.6)	4747 (52.9)	<.001
Moderate/severe COPD	83 (5.4)	150 (9.7)	429 (6.7)	90 (3.6)	519 (5.8)	<.001
Dyslipidemia	1342 (86.6)	1344 (86.7)	5394 (83.6)	2066 (81.7)	7460 (83.1)	<.001
Hypertension	1345 (86.8)	1408 (90.8)	5529 (85.7)	2144 (84.8)	7673 (85.5)	<.001
Immunocompromised	60 (3.9)	80 (5.2)	250 (3.9)	84 (3.3)	334 (3.7)	.033
PVD	212 (13.7)	359 (23.2)	928 (14.4)	345 (13.6)	1273 (14.2)	<.001
Stroke	167 (10.8)	212 (13.7)	579 (9.0)	222 (8.8)	801 (8.9)	<.001
Renal failure	99 (6.4)	131 (8.5)	401 (6.2)	151 (6.0)	552 (6.2)	.008
Dialysis	58 (3.7)	71 (4.6)	174 (2.7)	62 (2.5)	236 (2.6)	<.001
Heart failure	262 (16.9)	433 (27.9)	1379 (21.4)	622 (24.6)	2001 (22.3)	<.001
Elective status	952 (61.4)	767 (49.5)	3650 (56.6)	1615 (63.9)	5265 (58.6)	<.001

BMI, Body mass index; COPD, chronic obstructive pulmonary disease; HbA1c, hemoglobin A1c; MI, myocardial infarction; PROM, predicted risk of mortality; PROPS, predicted risk of postoperative stroke; PVD, peripheral vascular disease.

associated with an increase in PS compared with the no-touch technique (AOR, 2.50; CI, 1.27-4.92; $P < .01$). When comparing no-touch with CFD, and CFD with the clamp group, although the incidence of PS was numerically lower, the difference did not reach statistical significance (Table 4). The no-touch technique was also independently associated with a decreased risk of perioperative transfusion, prolonged ventilation, and atrial fibrillation compared with both the CFD and clamp techniques. When the analysis was repeated separating the clamp group into on-pump or off-pump, both groups showed a significantly greater risk of stroke compared with the no-touch technique (no-touch

vs on pump: AOR, 4.00; 95% CI, 1.76-9.07; $P < .001$; no-touch vs off-pump: AOR, 2.38; 95% CI, 1.07-5.27; $P = .03$). The risk of stroke in the CFD group did not significantly differ from the off-pump partial clamp (AOR, 1.37; 95% CI, 0.77-2.42; $P = .29$); however, it was significantly lower than in the on-pump clamped group (AOR, 2.30; 95% CI, 1.26-4.22; $P < .01$).

DISCUSSION

A number of large retrospective studies have shown OPCAB to be associated with a decreased incidence of PS compared with conventional on-pump CABG.⁷⁻⁹

TABLE 2. Postoperative outcomes by aortic manipulation strategy

Outcome	No touch	Facilitating device	Off-pump partial clamp	On-pump clamp	Any clamp	P value
	N = 1550	N = 1551	N = 6449	N = 2529	N = 8978	(all groups)
Stroke	10 (0.7)	18 (1.2)	86 (1.3)	51 (2.0)	137 (1.5)	.002
AF	225 (14.5)	324 (20.9)	1150 (17.8)	510 (20.2)	1660 (18.5)	<.001
MI	9 (0.6)	13 (0.8)	29 (0.5)	17 (0.7)	46 (0.5)	.25
Prolonged ventilation	121 (7.8)	246 (15.9)	685 (10.6)	366 (14.5)	1051 (11.7)	<.001
Renal failure	35 (2.3)	48 (3.1)	157 (2.4)	103 (4.1)	260 (2.9)	<.001
Bleeding	24 (1.6)	45 (2.9)	130 (1.1)	58 (2.3)	188 (2.1)	.053
Death	14 (0.9)	24 (1.6)	62 (1.0)	46 (1.8)	108 (1.2)	.003
Hospital LOS (d)	5.6 ± 5.2	7.1 ± 5.9	6.2 ± 4.7	7.1 ± 6.0	6.5 ± 5.1	<.001
ICU LOS (h)	50 ± 98	65 ± 97	51 ± 86	68 ± 163	56 ± 113	<.001

AF, Atrial fibrillation; ICU, intensive care unit; LOS, length of stay; MI, myocardial infarction.

FIGURE 1. Study population according to aortic manipulation strategy distribution. CABG, Coronary artery bypass grafting; CFD, clampless facilitating device; OPCAB, off-pump coronary artery bypass.

Conversely, any randomized study comparing the 2 revascularization strategies has failed to show an advantage with OPCAB regarding PS.¹⁰⁻¹² This apparent contradiction may be explained by the fact that stroke is a relatively rare occurrence after CABG surgery, and even the largest randomized studies are underpowered to find a difference in the incidence of stroke. On the other hand, it is possible that OPCAB using a partial aortic clamp has limited protection against PS, and the true benefit of off pump coronary surgery can be seen only when aortic clamping is avoided completely. This theory is in line with data using transcranial Doppler signals to identify cerebral emboli.¹³⁻¹⁵ These studies have shown that significant emboli occur not only during on-pump surgery but also after removal of the side-biting clamp during off-pump surgery. There are clinical data available suggesting that OPCAB performed using a partial clamp may expose patients to an even greater risk of stroke when compared with on-pump CABG using a single cross-clamp.¹⁶ Hammon and colleagues¹⁶ made this observation after evaluating neurocognitive function in 107 patients 6 months after undergoing CABG surgery. They found only 9% of patients in the on-pump single clamp group had any neuropsychologic deficits, whereas at least 26% showed deficits if a partial clamp was applied at the time of surgery.

FIGURE 2. Stroke rate according to manipulation strategy. CFD, Clampless facilitating device; O/E, observed to expected (according to the STS predicted risk of stroke score).

TABLE 3. Ascending aortic atherosclerotic burden according to aortic manipulation strategy

	Mean epiaortic grade	Severe aortic atherosclerosis (epiaortic grade 4 or 5)
No-touch	2.13	16.4%
CFD	2.38	12.6%
Off-pump clamped	1.35	0.6%
On-pump clamped	1.44	0.6%

CFD, Clampless facilitating device.

In the current study, we aimed to determine whether minimizing aortic manipulation results in a clinically relevant reduction in PS. Our results showed a stepwise increase in the risk of perioperative stroke as the magnitude of aortic manipulation increased. This held true both in the adjusted risk model and when considering the observed to expected ratio according to the STS PROPS score. The incidence of stroke with both the no-touch technique and the CFD technique was well below the expected, with an observed to expected ratio of 0.48 and 0.61, respectively, whereas the observed to expected ratio increased to 0.95 for the clamp group. Other studies on this subject have come to similar conclusions. In 2002, Kim and colleagues¹⁷ published data on 421 patients who underwent on-pump CABG surgery or OPCAB surgery with or without aortic manipulation. There were no strokes in the no-touch group compared with an incidence of 0.8% and 3.9% in the OPCAB clamped and on-pump groups, respectively. More recently, Emmert and colleagues reported on a group of 4314 patients and found a significantly lower incidence of stroke in the CFD group compared with the off-pump partial clamp group (0.7% vs 2.3%, $P = .04$).¹⁸

Edelman and colleagues¹⁹ performed a meta-analysis in 2011 evaluating the literature on CABG without manipulation of the ascending aorta. They found 7 nonrandomized studies comparing “an-aortic” OPCAB with on-pump CABG or OPCAB with partial aortic clamping or a CFD. The stroke rate with the no-touch technique was significantly lower than both on-pump CABG (0.38% vs 1.87%, $P < .0001$) and OPCAB with aortic manipulation (0.31% vs 1.35%, $P = .003$). More recently, Borgermann and colleagues²⁰ similarly found decreased strokes with a no-clamp off-pump technique compared with conventional on-pump. In addition to a smaller patient cohort, this study differs from the present one in that the authors grouped no-touch and CFD strategies together in the clampless group. In 2013, our group published a case-control study evaluating risk factors for stroke after cardiac surgery.²¹ This study found the use of a single, rather than double, clamp technique in on-pump CABG surgery to be associated with a lower risk of perioperative stroke. The present study complements these findings, showing that the risk of PS decreases progressively as the degree of aortic

TABLE 4. Adjusted odds ratios for relationship between a manipulation strategy and outcomes

End point	CFD vs no-touch AOR (95% CI)	Clamped vs no touch AOR (95% CI)	Clamped vs CFD AOR (95% CI)	On-pump vs off-pump AOR (95% CI)
Stroke	1.73 (0.71-4.25) <i>P</i> = .23	2.52 (1.17-5.44) <i>P</i> = .019	1.41 (0.80-2.48) <i>P</i> = .23	1.68 (1.17-2.41) <i>P</i> = .005
Death	1.79 (0.80-4.01) <i>P</i> = .16	1.78 (0.88-3.60) <i>P</i> = .11	0.76 (0.45-1.30) <i>P</i> = .32	1.86 (1.25-2.76) <i>P</i> = .002
MACE	1.90 (1.09-3.32) <i>P</i> = .024	1.96 (1.21-3.19) <i>P</i> = .007	0.88 (0.62-1.26) <i>P</i> = .49	1.61 (1.24-2.07) <i>P</i> < .001
Bleeding	2.54 (1.36-4.76) <i>P</i> = .004	1.95 (1.11-3.41) <i>P</i> = .02	0.68 (0.47-1.00) <i>P</i> = .05	1.06 (0.77-1.46) <i>P</i> = .70
Transfusion	2.42 (2.03-2.89) <i>P</i> < .001	2.40 (2.08-2.76) <i>P</i> < .001	0.90 (0.79-1.02) <i>P</i> = .10	1.50 (1.36-1.67) <i>P</i> < .001
Prolonged ventilation	1.49 (1.12-1.96) <i>P</i> = .005	1.49 (1.17-1.89) <i>P</i> = .001	0.89 (0.74-1.07) <i>P</i> = .21	1.44 (1.25-1.66) <i>P</i> < .001
Atrial fibrillation	1.41 (1.13-1.76) <i>P</i> = .002	1.38 (1.15-1.65) <i>P</i> < .001	0.93 (0.80-1.08) <i>P</i> = .33	1.17 (1.04-1.32) <i>P</i> = .01
Renal failure	1.27 (0.75-2.15) <i>P</i> = .36	1.29 (0.83-2.01) <i>P</i> = .25	0.82 (0.57-1.18) <i>P</i> = .29	1.72 (1.32-2.24) <i>P</i> < .001

Each model also controls for epiaortic grade, year of surgery, robotic approach, and thoracoscopic approach. AOR, Adjusted odds ratio; CFD, clampless facilitating device; CI, confidence interval; MACE, major adverse cardiac event.

manipulation decreases. We also found that the no-touch technique was protective against stroke across epiaortic grades. This suggests that the no-touch technique may be advantageous even in patients with minimal atherosclerotic burden of the ascending aorta. Epiaortic grade was not identified as an independent risk factor for stroke in the multivariable analysis. This is likely because the proximal anastomotic technique was modified to minimize aortic manipulation in these patients (ie, no-touch or CFD technique), thus mitigating the stroke risk.

Study Limitations

Although we believe the key findings of this study to be valid, several limitations must be recognized. This is a retrospective review with bias that is inherent to the study design. Selection bias may play a role, because the clamp group was dependent on surgeon preference in addition to the clinical context. Although this is true, both of these factors would likely cause more patients at greater risk of stroke to receive the clampless technique and could have increased the incidence of stroke in the group. Postoperative atrial fibrillation was more common in the facilitating device and clamped groups compared with the no-touch group. This could have biased the favorable incidence of PS toward the no-touch group; however, the overall incidence of atrial fibrillation in patients who developed a stroke was relatively low (16%) and cannot completely explain the difference in stroke rates.

Operative approach may be an additional source of bias. A total of 402 patients in the no-touch group underwent minimally invasive single vessel left internal thoracic artery–left anterior descending bypass without sternotomy. Although this subgroup could have conceivably biased

the study results, the findings were unchanged even after controlling for the nonsternotomy approach in the multivariable model.

CONCLUSIONS

The present study shows that any degree of aortic manipulation is likely to increase the risk of PS regardless of the severity of aortic atherosclerotic disease. Although it is clear that a no-touch technique may not be appropriate for all patients, these data suggest that avoiding aortic manipulation may minimize the incidence of stroke after CABG.

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EDITORIAL COMMENTARY

Don't touch that aorta!

John W. Hammon, MD

See related article on pages 175-80.

In this issue of the *Journal of Thoracic and Cardiovascular Surgery*, a multidisciplinary research group from Emory University present important information regarding surgical technical maneuvers to reduce the incidence of stroke in the perioperative period after coronary artery bypass operations (CABG).¹ They discuss stroke rates in 12,079 patients divided into 3 groups with different methods of aortic manipulation. The authors should be congratulated for their extensive data collection and rigorous analysis.

In the group with no aortic manipulation (no-touch technique), the stroke incidence was 0.06%, significantly different from the group with aortic clamping (1.5%). The ratio of observed to expected stroke rate increased from 0.48 in the no-touch group, to 0.61 in the clamless facilitating device (CFD) group, and 0.95 in the clamp

group. This was true whether or not cardiopulmonary bypass was used for the procedure. So is this publication another ho-hum retrospective study on postoperative stroke after CABG or an important news flash with information to significantly improve outcomes?

I would say that there are some of both in this article. It would be ideal to have a multicenter randomized study of the 3 techniques measured here but in this era of increased scrutiny of outcomes, this study would be almost impossible to perform because few centers have surgeons who are comfortable with all 3 techniques. One reason for the reluctance to perform off-pump coronary artery bypass (OPCAB) is that published prospective studies reporting on perioperative stroke incidence are underpowered to show differences in technique because stroke is such a rare event after CABG.^{2,3} If the incidence is so low, why get so concerned about stroke after CABG?

Thoracic surgeons are striving to offer safe and effective treatment to patients with severe coronary artery atherosclerosis. Several recent risk-adjusted randomized trials have demonstrated superior long-term cardiac subsystem results with CABG compared with an alternative catheter-based procedure, percutaneous coronary intervention (PCI).⁴ Unfortunately, the periprocedure stroke rate for PCI was less than 1% compared with 1% to 2% for CABG.^{5,6} Because stroke is such a devastating complication of an otherwise successful CABG operation, this finding has been used by some clinicians as a reason to push patients toward PCI. In

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