Trends in aortic clamp use during coronary artery bypass surgery: Effect of aortic clamping strategies on neurologic outcomes

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Objective: The purpose of the present study was to determine the effect of different clamping strategies during coronary artery bypass grafting on the incidence of postoperative stroke.

Methods: In the present case-control study, all patients at Emory hospitals from 2002 to 2009 with postoperative stroke after isolated coronary artery bypass grafting (n = 141) were matched 1:4 to a contemporaneous cohort of patients without postoperative stroke (n = 565). The patients were matched according to the Society of Thoracic Surgeons' predicted risk of postoperative stroke score, which is based on 26 variables. The patients who received on-pump and off-pump coronary artery bypass grafting were matched separately. Multiple logistic regression analysis with adjusted odds ratios was performed to identify the operative variables associated with postoperative stroke.

Results: Among the on-pump cohort, the single crossclamp technique was associated with a decreased risk of stroke compared with the double clamp (crossclamp plus partial clamp) technique (odds ratio, 0.385; $P = .044$). Within the on-pump cohort, no significant difference was seen in the incidence of stroke according to clamp use. Epiaortic ultrasound of the ascending aorta increased from 45.3% in 2002 to 89.4% in 2009. From 2002 to 2009, clamp use decreased from 97.7% of cases to 72.7%.

Conclusions: During on-pump coronary artery bypass grafting, the use of a single crossclamp compared with the double clamp technique decreased the risk of postoperative stroke. The use of any aortic clamp decreased and epiaortic ultrasound use increased from 2002 to 2009, indicating a change in the operative technique and surgeon awareness of the potential complications associated with manipulation of the aorta. (J Thorac Cardiovasc Surg 2014;147:652-7)

Coronary artery bypass grafting (CABG) is the most commonly performed operation by cardiothoracic surgeons. Postoperative stroke is a rare but major cause of morbidity and mortality in patients undergoing CABG. Several operative techniques have been used in attempts to minimize the detrimental morbidity and mortality associated with postoperative stroke. Because increased ascending aortic manipulation has been proposed as the primary mechanism of postoperative cerebral atheroembolism, the focus has concentrated on innovative techniques to minimize manipulation of the ascending aorta.

Postoperative stroke occurs in approximately 2% of CABG cases.[1,2] Survival among CABG patients at both 1 and 5 years has been significantly reduced in patients who have had a postoperative stroke compared with those who have not.[3] Furthermore, postoperative stroke is also a major source of increased healthcare costs. Compared with those without a postoperative stroke, an additional $19,000 in hospital costs have been attributed to patients with a postoperative stroke.[4] Moreover, in patients with a postoperative stroke and 2 or more complications, more than $58,000 in additional hospital costs has been reported.[4]

Most CABG procedures in the United States are performed with cardiopulmonary bypass support. Two different clamping strategies have been used for the construction of the proximal aortocoronary anastomoses: single clamping or double clamping. With off-pump coronary artery bypass (OPCAB), a partial clamp is frequently used for construction of the proximal anastomoses. However, a clampless approach is possible with facilitating devices (Heartstring; Maquet Cardiovascular, San Jose, Calif) or anastomotic connectors. These devices can be selectively deployed on relatively disease-free portions of the aorta to minimize the risk of atheroembolism. Therefore, the purpose of the present study was to test the hypothesis that aortic clamping was associated with an increased risk of stroke. Furthermore, we wanted to determine the effect of the

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Abbreviations and Acronyms
CABG = coronary artery bypass grafting
ONCAB = on-pump coronary artery bypass
OPCAB = off-pump coronary artery bypass
PROPS = predicted risk of postoperative stroke
STS = Society of Thoracic Surgeons

different clamping strategies used for performing proximal anastomoses on the incidence of postoperative stroke.

METHODS

Patients

The Emory University's institutional Society of Thoracic Surgeons (STS) Adult Cardiac Database was queried for all patients (cases) with postoperative stroke after isolated, primary CABG. The control patients were selected from the entire cohort without postoperative stroke. All consecutive patients from January 1, 2002 to December 31, 2009 were included in the database query.

Design

The present study was a retrospective, single-center, case-control study. A case-control study design was chosen because the operative details of the aortic clamping methods are not currently available in the STS database. The operative reports were reviewed and detailed data collected about the surgical strategy, including an on-pump or off-pump approach, details about the aortic clamping methods, and the extent of aortic atherosclerosis measured using epiaortic ultrasound. These data were then merged with the STS database to produce the complete data set. The institutional review board at Emory University, in compliance with the Health Insurance Portability and Accountability Act regulations and the Declaration of Helsinki, approved the present study. The institutional review board waived the need for individual patient consent.

Exclusions

Patients undergoing concomitant cardiac operations, redosternotomy, or emergency CABG were excluded from the study.

Matching Algorithm

A predicted risk of postoperative stroke (PROPS) score, as part of the STS database, is calculated using 26 preoperative variables believed to be associated with an increased risk of postoperative stroke. The PROPS score has been identified as a reliable predictor of postoperative stroke by Shroyer and colleagues.[5] The control patients were matched to the patients in a 1:4 ratio using the PROPS score and whether the patient underwent ONCAB or OPCAB. Because the effect of an on- versus off-pump strategy on the incidence of postoperative stroke was not the goal of the present study, the use of CABG was used as part of the matching algorithm. The ONCAB control patients were matched to the ONCAB patients and the OPCAB control patients to the OPCAB patients. An optimal matching algorithm was used that was designed to identify the best cutpoint for a continuous variable.[6] The optimal matching algorithm was used as a SAS macro that defined a distance measure between the patients and control patients according to the PROPS score. The control patient chosen for each case patient was the one closest to the patient in terms of the distance measure produced by the optimal matching algorithm. This algorithm sequentially matched each patient with stroke with the potential nonstroke control patients by calculating the multivariate distance between the patients using the 26 variables that constitute the PROPS. The algorithm chooses the set of matches that minimizes the sum of the multivariate distances across all possible sets of matches.

Surgical Technique

For the entire cohort, the overall effect of any aortic clamping was examined for the entire cohort. For the ONCAB patients, the 2 most common clamping strategies were the single crossclamp and double crossclamp techniques. Another on-pump CABG strategy used by the surgeons included on-pump beating heart CABG. In the present cohort, 25 patients underwent on-pump beating heart CABG; 15 of these had the proximal anastomoses performed with a partial occluding clamp and 10 with a Heartstring device. Only 1 CABG was performed under cold fibrillatory arrest. For all other on-pump cases, either a single clamp or double clamp technique was used.

For patients undergoing OPCAB, the strategies examined in the present study were the use of a partial-occluding clamp, the use of clampless facilitating devices, and the "no-touch" technique, which involves the use of in situ arterial grafts (no aortocoronary proximal anastomoses). A "no-touch" aortic technique was used in 45 OPCAB patients.

Epiaortic Ultrasound

At Emory University, all patients currently undergoing cardiac operations routinely have the aorta evaluated using epiaortic ultrasound. It has been gradually adopted since its implementation in 2002 for patients in whom a clamp is being considered, making it the current standard of care within our institution. It is the test of choice for identifying atherosclerotic lesions within the aorta, and it is superior to transesophageal echocardiography and palpation alone.[7-9] Preoperative imaging with computed tomography is another option. Before the aorta is manipulated, patients undergo an epiaortic ultrasound examination to grade the amount of atherosclerotic disease within the ascending aorta according to the thickness and presence of mobile atheroma. The aorta is graded from 1 to 5: 1, normal (<2 mm thickness); 2, minimal disease (2-3 mm); 3, moderate disease (3-5 mm); 4, severe disease (>5 mm); and 5, the presence of mobile plaque within any portion of the ascending aorta.

Outcome

The incidence of postoperative stroke was the primary outcome of the present study. Stroke was defined as a new, focal, permanent neurologic deficit found on clinical examination diagnosed by an attending neurologist and confirmed with either brain computed tomography or magnetic resonance imaging. The clinical and radiologic examinations were used to differentiate stroke from transient ischemic attack or postoperative delirium.

Statistical Analysis

A conditional logistic regression analysis was performed to evaluate the effect of clamp versus no-clamp on the occurrence of postoperative stroke, controlling for matching factors (PROPS and pump) and epiaortic grade. The epiaortic grade was controlled for as both an ordinal (1, 2, 3, 4, and 5) and a dichotomous (1-2 vs 3-5) variable in the regression analysis. The analysis was also performed without controlling for epiaortic grade, because its use was not ubiquitous until recently. In addition, the effect of different clamping or nonclamping strategies within the ONCAB and OPCAB patients and control patients was evaluated using conditional logistic regression analysis. In the original model, which studied the association of any clamping strategy with postoperative stroke incidence, the potential preoperative confounding variables were controlled for by the matching algorithm for the PROPS score (Table 1). The effect of cardiopulmonary bypass, or an on-pump technique, as a potential confounder was also controlled for in the matching strategy, because the patients were matched separately to the control patients according to whether an on- or off-pump strategy was used. To determine whether the year of surgery