



## STROKE AFTER ON-PUMP AND OFF-PUMP CORONARY SURGERY: INCIDENCE, PREDICTORS AND OUTCOME

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### Abstract

**Background:** The stroke remains a devastating complication after cardiac surgical procedures despite advances in perioperative monitoring and management. The purpose of the present study was to investigate the incidence, predictors and outcome of stroke after on-pump and off-pump coronary artery bypass grafting (CABG).

**Methods:** From January 1999 to June 2005, 703 consecutive patients aged  $\geq 60$  underwent isolated coronary artery bypass surgery in our institution. Before 2002, the myocardial revascularization was performed off-pump at the discretion of the operating surgeon. After this period, our strategy was to plan starting the CABG without the cardiopulmonary bypass (CPB) in patients over 60 years. In accordance with our off-pump CABG (OPCAB) policy, our inclusion criterion was the age over 60 years. On-pump CABG (ONCAB) was performed in 289 (41.1%) patients and OPCAB in 414 (58.9%) patients. Perioperative neurological events were diagnosed by neurologists and were defined as any new neurological deficit during the postoperative period.

**Results:** The incidence of stroke was 2.6% ( $n = 18$ ) and significantly higher in ONCAB group compared with OPCAB patients (5.9% and 0.25%, respectively;  $p = 0.001$ ). Multivariable logistic regression analysis revealed four independent predictors of postoperative stroke: cardiopulmonary bypass ( $p = 0.001$ ; odds ratio (OR) 30.76), preoperative atrial fibrillation ( $p = 0.023$ ; OR 7.52), peripheral vascular disease ( $p = 0.024$ ; OR 4.28) and left main stenosis ( $p = 0.026$ ; OR 3.24).

The in-hospital mortality (4.8% and 1.2%, respectively;  $p = 0.004$ ), renal failure (4.5% and 1.9%, respectively;  $p = 0.039$ ), wound infection (11.8% and 7%, respectively;  $p = 0.022$ ), acute cardiac failure (3.5% and 0.5%, respectively;  $p = 0.005$ ), need for intra-aortic balloon pump (2.8% and 0%, respectively;  $p = 0.001$ ) and prolonged intensive care unit stay (20.4% vs 9.2%, respectively;  $p = 0.001$ ), ventilation time (11.4% vs 5.1%, respectively;  $p = 0.002$ ) and length of hospital stay (23.5% vs 16.7%, respectively;  $p = 0.026$ ) were all significantly greater in the ONCAB population.

**Conclusions:** The stroke is a devastating complication of coronary surgery. In this study OPCAB, compared with ONCAB surgery reduced neurologic and clinical morbidity, mortality, as well as hospital stay.

**Keywords:** postoperative stroke, coronary surgery, postoperative complications after CABG, on-pump and off-pump CABG, predictors of stroke

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### Introduction

The stroke remains a devastating complication after cardiac surgical procedures despite advances in perioperative monitoring and management. Stroke was a common complication after CABG in the 1960s (5% to 9%) [Furlan A.J. et al., 1992]. Despite the improvement in surgical techniques and cardioplegic agents, along with the introduction of membrane oxygenators and in-line filtration, there is a persistent stroke rate associated with CABG ranging from 1% to 5% [Gilman S., 1965]. The mortality in patients experiencing a postoperative stroke was 25.6% as opposed to a mortality rate of 2.4% in patients who did not have a postoperative stroke (1997 Society of Thoracic Surgeons National Database). John R. et al. reported that patients with a stroke had an in-hospital mortality of 24.8% and a mean hospitalization of 27.9 days compared with 2.0% mortality and a mean hospitalization of 9.1 days for the non-stroke patients [John R. et al., 2000]. Edmunds L.H. (2003) reported an average patient stay of 11 days in the intensive care unit, 25 days at the hospital, which caused at least an additional \$23,300 in-hospital boarding charges, and a cost of 5 to 10 times the in-hospital charge for rehabilitative and outpatient support [Edmunds L.H., 2003]. A number of risk factors for the development of stroke in patients undergoing CABG have been identified [Frye R.L. et al., 1992; Lynn G.M. et al., 1992; Riccotta J.J. et al., 1995; Roach G.W. et al., 1996; Redmond J.M. et al., 1996; Bucerius J. et al., 2003]. The purpose of the present study was to investigate the incidence, predictors and outcome of stroke after on-pump and off-pump CABG.

### Methods

**Patients.** From January 1999 to June 2005, 703 consecutive patients of age 60 and older underwent OPCAB surgery in our institution. ONCAB was performed in 289 (41.1%) patients and OPCAB in 414 (58.9%) patients.

Our experience in OPCAB surgery began in 1999. Before January 2002, we performed

OPCAB procedures without any categorical preferences. However, an internal evaluation of stroke rates after CABG with CPB determined that the incidence of postoperative cerebrovascular accident (CVA) was higher in patients of 60 years and older. After that, our surgical strategy for this category of patients was to start the operation with a plan to perform it without CPB (Fig.1). The exceptions were patients under 60 with atherosclerosis of aorta and previous CVA, who were also operated OPCAB. Given the small number of these patients, they were not included in the study. During the period of study, we performed OPCAB approximately in 30% of all procedures of isolated myocardial revascularization. Written informed consent was obtained from all patients involved in the study. For several years, all patients in our Center are operated after obtaining of the written consent. At the time, when we started our data collection, we did not have an established IRB at the Center. However, approval to conduct the study and access the data was obtained from the Medical Board of the hospital prior to initiation of the study. The preoperative variables are shown in Table 1.

**Definitions.** Postoperative neurological events were diagnosed by neurologists and were defined as any new neurological deficit during the 3 days of postoperative period.

Prolonged ventilation time was determined under mechanical ventilation support over 24 hours, the prolonged intensive care unit stay in case of 72 hours and the prolonged in-hospital stay - over 16 days of hospitalization. Other perioperative variables and complications were defined in accordance with Society of Thoracic Surgeons database definitions.

**Surgical technique.** All operations were performed through a median sternotomy.

**Off-pump CABG.** After the pericardium was opened, pericardial sutures were placed to facilitate pericardial retraction for cardiac elevation

Table 1.

Variable	Preoperative variables		p-value
	On-pump group (n = 289)	Off-pump group (n = 414)	
Age (years)	65.2 ± 4.0	66.7 ± 4.0	0.001*
Female	19% (n=55)	18.1% (n=75)	0.768
BMI	28.8 ± 4.2	28.7 ± 4,5	0.926
EuroScore	4.7 ± 2.2	4.7 ± 2.3	0.987
Impaired left ventricular function	60.2% (n=174)	50.0% (n=207)	0.008*
Urgent and emergent surgery	47.8% (n=138)	41.3% (n=171)	0.090
History of MI	61.2% (n=177)	52.4% (n=217)	0.006*
Acute MI	11.1% (n=32)	14.5% (n=60)	0.358
Unstable angina	31.5% (n=91)	22.9% (n=95)	0.003*
COPD	4.5% (n=13)	7% (n=29)	0.255
PVD	8.5% (n=60)	6.2% (n=18)	0.080
CVA	2.4% (n=7)	11.1% (n=46)	0.001*
Diabetes mellitus	26.3% (n=76)	21.2% (n=88)	0.053
Heart failure	8.3% (n=24)	7.5% (n=31)	0.550
Arrhythmia	15.2% (n=44)	20.5% (n=85)	0.108
Hypertension	76.8% (n=222)	86.2% (n=357)	0.019*
Left main stenosis	13.8% (n=57)	16.6% (n=48)	0.191
Renal dysfunction	29.4% (n=85)	20% (n=83)	0.005*
Renal failure	1.7% (n=5)	0.7% (n=3)	0.119

BMI = body mass index; COPD = chronic obstructive pulmonary disease; CPB = cardiopulmonary bypass; CVA = cerebrovascular accident; PVD = peripheral vascular disease; MI = myocardial infarction; \* - p-value <0.05.

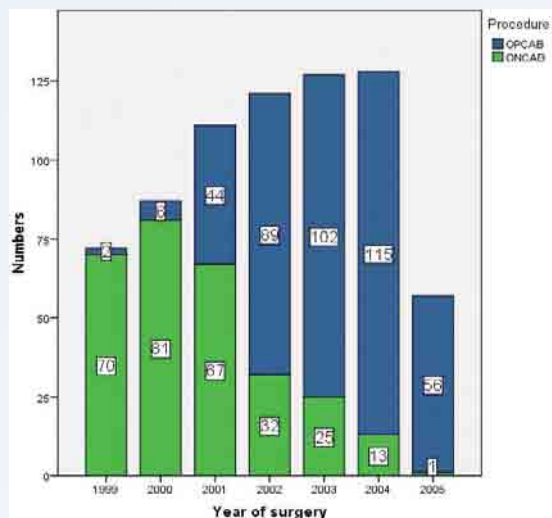


Figure 1. Comparative growth of off-pump coronary artery bypass grafting over 7 years (1999 until June 2005).

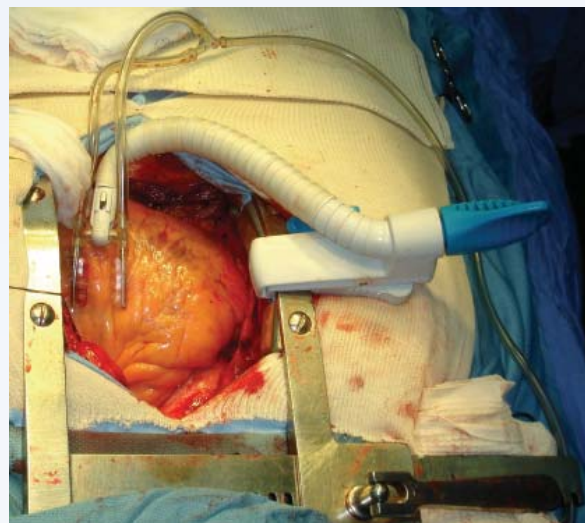


Figure 2. Mechanical vacuum-stabilizer Octopus.

and exposure. Single dose heparin (350U/kg) was administered. To reduce the amplitude of ventricular wall movement, a suction-type mechanical stabilizer (Octopus, Medtronic, Minneapolis, MN) was used (Fig. 2). The distal anastomoses were usually constructed before proximal anastomoses using a continuous technique with 7-0 or 8-0 polypropylene sutures. Internal vascular control was achieved with intracoronary shunt (FloCoil Shunt, CardioThoracic Systems Inc., Cupertino, CA) or bulldog clamp. In general, the left internal thoracic artery was implanted first. A Blower/Mister using carbon dioxide gas (flow rate: 3-5 L/min) or a micro-sucker system was also used to obtain a bloodless surgical field. The proximal anastomosis on the ascending aorta was constructed by means of a partial occlusion clamp with 6-0 polypropylene continuous sutures and at a controlled systolic pressure of 60-70 mm Hg. If significant aortic calcification precluded safe clamp placement, proximal anastomoses were made to the side of the internal thoracic artery or rarely on the right subclavian artery. At the end of the procedure, protamine was administered and the chest was closed.

*On-pump CABG.* The patients were heparinized with an initial dose of 350 U/kg of heparin and periodically supplemented with additional doses to maintain an activated clotting time of more than 400 seconds. Conventional CABG was performed with standard cannulation for CPB - ascending aortic and dual-stage cannulation of the right atrium, moderate systemic hypothermia, and intermittent ischemic fibrillatory arrest. Distal anastomoses were performed with or without the aortic cross clamp. All proximal anastomoses were performed with the aid of an aortic side-biting clamp in place. At the end of the procedure, heparin was reversed with protamine.

*Statistics.* Data were obtained retrospectively from our surgical database and patients' medical histories. The data were statistically analyzed using SPSS 11.5 software (SPSS Inc, Chicago, IL)

and Stata version 7.0 for Windows (Stata Corporation). Results for continuous variables are expressed as mean  $\pm$  standard deviation. Parametric data were compared using Pearson's Chi-square test or Fisher's exact test as appropriate. Distributions of continuous data were observed and t-tests or Mann-Whitney tests were performed accordingly for comparison of groups. Logistic regression analysis was used to determine important independent predictors of stroke and conversion. Finally, in order to examine the independent effect of an individual variable while controlling for the others, multiple logistic regression analyses were conducted using stepwise selection method. We tested our model's discrimination via the receiver operating characteristic (ROC) curve and assessed the calibration of the prediction model (Lemeshow- Hosmer goodness of fit statistics). All data were analyzed retrospectively.

### Results

The significant differences in preoperative patient characteristics for different surgical procedures were as follows (Table 1): OPCAB patients were significantly older ( $65.2 \pm 4.0$  and  $66.7 \pm 4.0$ , respectively;  $p = 0.001$ ), more likely to be hypertensive (76.8% and 86.2%, respectively;  $p = 0.019$ ) and to have previous strokes or transient ischemic attacks (2.4% and 11.1%, respectively,  $p = 0.001$ ), whereas incidence of unstable angina (31.5% and 22.9%, respectively;  $p = 0.003$ ), previous MI (61.2% and 52.4%, respectively;  $p = 0.006$ ), impaired ventricular function (60.2% and 50%, respectively;  $p = 0.008$ ) and renal dysfunction (29.4% and 20%, respectively;  $p = 0.005$ ). The mean age of Group 2 patients was significantly higher ( $65.2 \pm 4.0$  and  $66.7 \pm 4.0$ , respectively;  $p = 0.001$ ).

The overall incidence of stroke was 2.6% ( $n = 18$ ). The incidence of stroke was significantly higher in ONCAB group compared with OPCAB patients (5.9% and 0.25%, respectively,  $p = 0.001$ ).

Tab.2 shows that the clinical outcome of ONCAB patients was significantly worse compared with

OPCAB patients. The postoperative renal failure (4.5% and 1.9%, respectively;  $p = 0.039$ ), wound infection (11.8% and 7%, respectively;  $p = 0.022$ ), acute cardiac failure (3.5% and 0.5%, respectively;  $p = 0.005$ ), need for intraaortic balloon pump (2.8% and 0%, respectively;  $p = 0.001$ ) and prolonged intensive care unit stay (20.4% vs 9.2%, respectively;  $p = 0.001$ ), prolonged ventilation time (11.4% vs 5.1%, respectively;  $p = 0.002$ ) and prolonged length of hospital stay (23.5% vs 16.7%, respectively;  $p = 0.026$ ) were all significantly greater in the ONCAB population.

In-hospital mortality for the overall study population was 2.7% ( $n = 19$ ). ONCAB patients had threefold increase of in-hospital mortality compared with OPCAB patients (4.8% and 1.2%, respectively;  $p = 0.004$ ).

Univariable analysis revealed that 6 of 26 included variables had a significant association with postoperative stroke (Table 3).

Multivariable logistic regression analysis revealed four independent predictors of postoperative stroke: cardiopulmonary bypass ( $p = 0.001$ ; OR 30.76), preoperative atrial fibrillation ( $p = 0.023$ ;

Table 2.

Clinical outcome of ONCAB and OPCAB patients

Outcome	ONCAB group (n = 289)	OPCAB group (n = 414)	p-value
In-hospital mortality	4.8% (n = 14)	1.2% (n = 5)	0.004*
Respiratory complications	12.4% (n = 36)	13.1% (n = 54)	0.908
Gastrointestinal complications	3.7% (n = 8)	2.4% (n = 10)	0.633
Atrial fibrillation	29.8% (n = 86)	38.2% (n = 158)	0.069
Renal failure	4.5% (n = 13)	1.9% (n = 8)	0.039*
Wound infection	11.8% (n = 34)	7% (n = 29)	0.022*
Reexploration	2.8% (n = 8)	2.7% (n = 11)	0.813
Bleeding	2.1% (n = 6)	2.2% (n = 9)	0.524
Perioperative MI	0.3% (n = 1)	0% (n = 0)	0.411
Acute heart failure	3.5% (n = 10)	0.5% (n = 2)	0.005*
Inotropic agents used	29.4% (n = 85)	16.9% (n = 70)	0.064
Open chest	2.1% (n = 6)	0.5% (n = 2)	0.069
IABP	2.8% (n = 8)	0% (n = 0)	0.001*
Prolonged ventilation	11.4% (n = 33)	5.1% (n = 21)	0.002*
Prolonged ICU stay	20.4% (n = 59)	9.2% (n = 38)	0.001*
Prolonged length of stay	23.5% (n = 68)	16.7% (n = 69)	0.026*

IABP = intraaortic balloon pump; ICU = intensive care unit; MI = myocardial infarction; \* -  $p$ -value  $< 0.05$ .

OR 7.52), peripheral vascular disease ( $p = 0.024$ ; OR 4.28) and left main stenosis ( $p = 0.026$ ; OR 3.24) (Table 4).

The final model demonstrated strong discriminatory ability (area under ROC curve – 0.85) (Fig. 3). The Lemeshow-Hosmer goodness-of-fit statistic was not statistically significant ( $p = 0.48$ ), indicating that there was no statistically significant departure from a perfect fit.

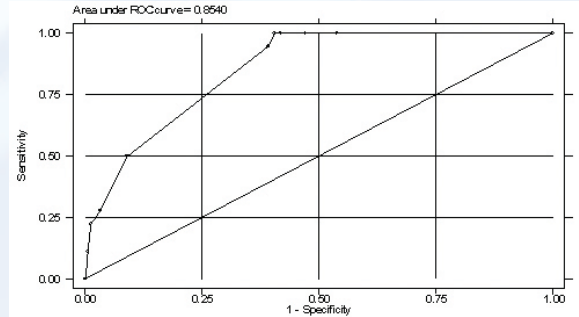


Figure 3. Area under ROC curve

Table 3.

Univariable logistic regression analysis			
Variables	OR	p-value	CI 95%
Age	1.06	0.271	0.95 - 1.17
Gender (female)	0.87	0.841	0.25 - 3.08
Urgent and emergent surgery	1.51	0.504	0.45 - 4.99
Unstable angina	2.03	0.142	0.78 - 5.23
Acute MI	1.21	0.759	0.34 - 4.29
Previous MI	1.17	0.739	0.45 - 3.07
Heart failure	2.32	0.193	0.65 - 8.29
Impaired left ventricular function	1.21	0.728	0.42 - 3.34
COPD	1.81	0.465	1.34 - 6.48
CVA	1.38	0.672	0.31 - 6.18
PVD	2.81	0.076	0.89 - 8.84
Hypertension	1.03	0.981	0.88 - 1.45
Diabetes mellitus	2.52	0.055	0.97 - 6.51
Left main stenosis	3.45	0.012*	1.30 - 9.12
Previous cardiac surgery	1.34	0.881	1.25 - 4.47
Postoperative renal failure	2.27	0.126	0.79 - 6.54
Preoperative atrial fibrillation	4.14	0.071	0.88 - 19.39
Postoperative atrial fibrillation	0.43	0.191	0.12 - 1.51
Calcified aorta	2.43	0.078	0.90 - 6.56
BMI	0.99	0.997	0.88 - 1.12
Conversion to CPB	24.29	0.026*	1.45 - 405.11
CPB used	25.81	0.002*	3.41 - 195.06
EuroSCORE	1.05	0.017*	1.01 - 1.09
Duration of surgery	1.40	0.019*	1.05 - 1.85
Partial aortic clamp used	2.38	0.250	0.54 - 10.47
Number of partial aortic clamps	1.75	0.020*	1.09 - 2.83

BMI = body mass index; CI = confidence interval; COPD = chronic obstructive pulmonary disease; CPB = cardiopulmonary bypass; CVA = cerebrovascular accident; OR = odds ratio; PVD = peripheral vascular disease; MI = myocardial infarction; \* -  $p$ -value  $< 0.05$ .

Patients with stroke had a significantly higher incidence of prolonged intensive care unit stay (94.4% vs 11.7%, respectively;  $p = 0.001$ ), prolonged ventilation time (61.1% vs 6.3%, respectively;  $p = 0.001$ ) and prolonged length of hospital stay (72.2% vs 18.1%, respectively;  $p = 0.001$ ). Patients with stroke had also postoperative respiratory complications (55.6% and 11.7%, respec-

tively;  $p = 0.001$ ), renal failure (22.2% and 2.5%, respectively;  $p = 0.001$ ), gastrointestinal complications (16.7% and 2.2%, respectively;  $p = 0.001$ ), need for inotropic agents (44.4% and 21.5%, respectively;  $p = 0.026$ ). Patients with stroke had also a significantly higher incidence of in-hospital mortality compared with patients without stroke (44.4% vs 1.6%;  $p = 0.001$ ) (Table 5).

Table 4.

## Multivariable logistic regression analysis

Independent predictors	OR	p-value	CI 95%
CPB	30.76	0.001	3.96 - 238.83
Preoperative atrial fibrillation	7.52	0.023	1.32 - 42.79
PVD	4.28	0.024	1.21 - 15.15
Left main stenosis	3.24	0.026	1.15 - 9.14

CPB = cardiopulmonary bypass; PVD = peripheral vascular disease.

Table 5.

## Clinical outcome of patients with and without stroke

Outcome	Stroke group (n = 18)	Non-stroke group (n = 685)	p-value
In-hospital mortality	44.4% (n = 8)	1.6% (n = 11)	0.001*
Respiratory complications	55.6% (n = 10)	11.7% (n = 80)	0.001*
Renal failure	22.2% (n = 4)	2.5% (n = 17)	0.001*
Wound infection	11.1% (n = 2)	8.9% (n = 61)	0.746
Atrial fibrillation	16.7% (n = 3)	29.5% (n = 202)	0.179
Perioperative MI	0% (n = 0)	0.1% (n = 1)	0.871
Gastrointestinal complications	16.7% (n = 3)	2.2% (n = 15)	0.001*
Reexploration	5.6% (n = 1)	2.6% (n = 18)	0.450
Bleeding	0% (n = 0)	2.2% (n = 15)	0.524
Acute heart failure	5.6% (n = 1)	1.6% (n = 11)	0.202
Inotropic agents used	44.4% (n = 8)	21.5% (n = 147)	0.026*
Open chest	0% (n = 0)	1.2% (n = 8)	0.645
IABP	0% (n = 0)	1.2% (n = 8)	0.645
RBC transfusion	55.6% (n = 10)	56.2% (n = 385)	0.196
Prolonged ventilation	61.1% (n = 11)	6.3% (n = 43)	0.001*
Prolonged ICU stay	94.4% (n = 17)	11.7% (n = 80)	0.001*
Prolonged length of stay	72.2% (n = 13)	18.1% (n = 124)	0.001*

IABP = intraaortic balloon pump; ICU = intensive care unit; MI = myocardial infarction; RBC = red blood cell; \* - p-value <0,05.

**Discussion:** Off-pump CABG has gained popularity because of many clinical and economic benefits in comparison with conventional CABG [Angelini G.D. et al., 2002; Puskas J.D. et al., 2004; Fukui T. et al., 2005]. Neurologic complications after cardiac surgical procedures remain a relatively common problem despite improvements in anesthetic and surgical techniques, as well as in perioperative monitoring and management [Buceri J. et al., 2003].

One of the findings of our study was the protective effect against stroke achieved while performing surgery on the beating heart and without CPB. The overall incidence of stroke in our study was 2.6% (n = 18). The incidence of stroke was significantly higher in ONCAB group compared with OPCAB patients (5.9% and 0.25%, respectively). This is in accordance with reports [Cleveland J.C. et al., 2001, Reston J.T. et al., 2003; Racz M.J. et al., 2004] which demonstrated a significant reduction of neurological complications when surgery was performed off-pump. Several previous studies have also demonstrated that permanent neurologic deficits occur in as many as 6% of patients undergoing cardiac surgery [Gardner T.J. et al., 1985; Roach G.W. et al., 1996; Redmond J.M. et al., 1996; Iaco A.L. et al., 1999; Salazar J.D. et al., 2001; Hogue C.W. et al., 2001]. In our opinion, the lower incidence of perioperative stroke within the OPCAB group can be explained by the avoidance of aortic cannulation and subsequent decreased risk of embolization.

Our data also suggests that off-pump CABG reduces in-hospital mortality and morbidity (renal failure 4.5% and 1.9%, respectively; wound infection 11.8% and 7%, respectively; acute cardiac failure 3.5% and 0.5%, respectively; need for intraaortic balloon pump 2.8% and 0%, respectively and prolonged intensive care unit stay 20.4% vs 9.2%, respectively; ventilation time 11.4% vs 5.1%, respectively; length of hospital stay 23.5% vs 16.7%, respectively, compared to conventional CABG). Although our data showed

a decrease length of stay with the off-pump CABG group, actual hospital resource use, but overall cost savings were not calculated in the present study. In-hospital mortality for the overall study cohort was 2.7% (n = 19). ONCAB patients had threefold increase of in-hospital mortality compared with OPCAB patients (4.8% and 1.2%, respectively).

Multiple logistic regression analysis identified the following risk factors to be independent for the development of a postoperative stroke: CPB, preoperative atrial fibrillation, peripheral vascular disease, and left main stenosis.

Our analysis revealed that CPB was the strongest predictor of stroke with an OR of 30.76. Beating heart techniques presumably lower the risk of stroke by minimizing emboli production, particularly those caused by disruption of atheromatous plaques during cannulation, crossclamping, and manipulation of the ascending aorta [Murkin J.M. et al., 1999; Stump D.A. et al., 2001].

Indeed, the chronic atrial fibrillation is a hazard for thromboembolic perioperative stroke. Intraoperative surgical manipulation or spontaneous resumption of sinus rhythm early in the postoperative period may be associated with embolism of a left atrial clot. Chugh S.S. et al. reported that preoperative atrial fibrillation associated with a four-fold to fivefold increase in postoperative risk for stroke [Chugh S.S. et al., 2001]. Preoperative atrial fibrillation was also an independent predictor of stroke in our analysis (OR: 7.52).

Previously published studies speculated that patients with peripheral vascular disease are high-risk group for atherosclerotic embolizations [Bentsen N. et al., 1975; Roach G.W. et al., 1996; Stamou S.C. et al., 2001; Borger M.A. et al., 2001]. Peripheral vascular disease and left main stenosis were two other independent predictors of stroke in our analysis (OR 4.28 and 3.24, respectively). These risk factors are both markers of atherosclerosis. It is important to emphasize that the asso-

ciations observed between predictor variables and stroke are not necessarily causal, and that significant predictors may simply be acting as proxy markers for other factors that were not documented in the database.

We found that patients with stroke had a significantly higher incidence of prolonged intensive care unit stay, ventilation time, and length of hospital stay. These patients had also higher incidence of postoperative respiratory complications, renal failure, gastrointestinal complications, need for inotropes. Stroke patients had a markedly higher mortality rate (44.4% vs 1.6%). These findings have been previously reported by several other investigators [*Stamou S.C. et al., 2001; Borger M.A. et al., 2001*].

The present study has several important limitations. It is a retrospective study with relatively

small sample size. Patient selection for off-pump surgery, differences in surgical technique, experience of surgical team performing on-pump and off-pump procedures over the years, and other differences between the on-pump and off-pump patients are important variables that certainly differed between these two groups.

In summary, the stroke is a devastating complication of coronary artery bypass surgery. The incidence of stroke was significantly higher in ONCAB group compared with OPCAB patients. Identification of predictors of stroke is important for understanding the pathogenesis of stroke and for developing possible preventative strategies. The increased use of beating heart CABG may be one such preventative strategy given its association with a significantly lower risk of stroke.

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