The Heart Surgery Forum #2003-60520
6 (3), 2003

Online address: www.hsforum.com/vol6/issue3/2003-60520.html

Improving Neurologic Outcome in Off-Pump Surgery: The "No Touch" Technique

(#2003-60520 . . . January 28, 2003)

Marzia Leacche, MD, Michel Carrier, MD, Denis Bouchard, MD, Michel Pellerin, MD, Louis P. Perrault, MD, PhD, Pierre Pagé, MD, Yves Hebert, MD, Raymond Cartier, MD

Department of Cardiac Surgery and Research Center, Montreal Heart Institute, Montreal, Quebec, Canada

ABSTRACT

Background: As patients referred for cardiac surgery include increasingly older individuals, the prevalence of comorbid factors, such as previous cerebrovascular disease, carotid disease, aortic atherosclerosis, and reoperations, is on the rise. Avoiding manipulation of the ascending aorta in this high-risk subgroup may become a necessity to perform safe coronary artery bypass grafting (CABG) surgery.

Methods: We retrospectively reviewed our database of 640 off-pump CABG patients and identified 84 patients in whom we adopted the "no touch" technique (NTT). Revascularization was carried out with single or bilateral internal thoracic arteries (ITA) and by connecting additional coronary grafts (saphenous vein, radial artery) in a T or Y configuration. The right gastroepiploic artery was used as a conduit in 2 patients. The brachiocephalic artery was used as an alternative inflow site in 3 patients (reoperation).

Results: Age, sex, risk factors, functional class, and history of congestive heart failure were comparable in the two groups. In the NTT group, the frequencies were higher for severe atherosclerosis of the aorta (13% versus 0%; $P = .00$), carotid disease (25% versus 16%; $P = .02$), and history of previous cerebrovascular accidents (17% versus 8%; $P = .04$). Complete revascularization was achieved in 96% of the patients in the off-pump CABG group, compared with 90% in the NTT group ($P = .17$). No differences in the prevalence of postoperative low cardiac output syndrome, intra-aortic balloon pump use, perioperative myocardial infarction, or operative mortality at 30 days were observed between the two groups. In the NTT group, weak trends toward a lower incidence of postoperative delirium (8% versus 15%; $P = .12$), a lower incidence of stroke (0% versus 1%; $P = .85$), and a shorter intensive care unit stay ($P = .07$) were observed. Hospital stay was also shorter in the NTT group ($P = .04$).

Conclusion: Avoiding aortic manipulations in patients with severe atherosclerosis of the aorta, carotid disease, and a previous history of cerebrovascular accidents is technically feasible and is associated with a low risk of mortality and good short-term results. Adopting this practice may reduce the incidence of stroke and improve early outcome in this subset of patients.

Submitted January 22, 2003; accepted January 28, 2003.

Address correspondence and reprint requests to: Raymond Cartier, MD, Research Center, Montreal Heart Institute, 5000 Belanger St E, Montreal, Quebec, H1T 1C8, Canada; 514-376-3330 ext 3715; fax: 514-376-4766 (e-mail: rc2910@aol.com).

INTRODUCTION

By decreasing the systemic inflammatory response normally associated with extracorporeal circulation, off-pump coronary artery bypass (OPCAB) surgery may reduce the adverse effects that normally affect organ systems during conventional coronary artery bypass grafting (CABG) surgery [Kirklin 1983, Butler 1993]. However, the better physiologic conditions provided with OPCAB surgery have not yet been accompanied by the expected benefits of improvements in perioperative neurologic outcome. Currently, the frequencies of cerebrovascular accidents for OPCAB and conventional CABG surgery are reported to be not statistically different [Iaco 1999, Arom 2000].

Although there are numerous causes of stroke following coronary artery surgery, stroke is usually due to embolic dislodgement of aortic atherosclerotic plaques, aerial and platelet aggregate emboli related to cardiopulmonary bypass (CPB), and surgical manipulations of the ascending aorta. Aortic side-bite clamping and cross-clamping have been identified as significant sources of emboli resulting in adverse neurologic outcomes [van der Linden 1991, Bal-El 1992, Clark 1995, Barbut 1997]. Similar manipulations are still necessary during OPCAB surgery to construct proximal anastomoses, but the differences in manipulation may be responsible for the modest advantages observed with OPCAB over conventional surgery with regard to neurologic outcomes. The purpose of this study was to determine if avoiding aortic manipulation during OPCAB surgery (the "no touch" technique [NTT]) can reduce the incidence of neurologic complications while providing safe and efficient coronary artery revascularization.

MATERIALS AND METHODS

We retrospectively reviewed our database of 640 patients who had undergone systematic OPCAB surgery during the period between September 1996 and June 2001 and identified 84 patients in whom the NTT had been employed.

Definitions

The following definitions were adopted for the purpose of this study. Previous cerebrovascular disease (CVD) was defined as a history of stroke or transient ischemic attacks (TIA). Internal carotid disease was diagnosed on the grounds of carotid bruits found during the physical examination or duplex findings (stenosis >80% surface area). Peripheral vascular disease was defined as a previous vascular surgical procedure (aortic or peripheral) or an absence of peripheral pulses with or without associated claudication, and renal insufficiency was defined as a serum creatinine level >140 mM. Incomplete revascularization was defined as the technical impossibility of grafting one coronary artery of >1.25 mm in diameter with a stenosis >50% or any coronary territory that could not be bypassed because of small and diffuse vessel disease. Perioperative myocardial infarction was documented by the presence of a new Q wave on the electrocardiogram or a maximal serum creatine kinase MB isoenzyme level of >100 IU/L. Low cardiac output syndrome was defined as a cardiac index of less than 2 L/min requiring inotropic support for more than 24 hours or an intra-aortic balloon pump, renal failure was defined as a postoperative increase in the creatinine level of >50 mM, and operative mortality was defined as any death occurring within 30 days of surgery.

Ascending Aortic Disease

Three methods were used for the assessment of the ascending aorta. Chest radiography and coronary angiography were used to detect the presence of aortic calcifications, along with gentle intraoperative digital palpation of the aorta by the surgeon. In accordance with the grading criteria of Mills and Everson [Mills 1991], the degree of aortic disease was graded as none, mild (areas free of aortic disease easily identified), moderate (disease moderately extensive with adequate disease-free areas found), or severe (circumferential disease of the aorta and no areas free of disease). Intraoperative epicardial echocardiography was not systematically used during the period of this study.

Neurologic Complications

Postoperative delirium was diagnosed by a psychiatrist at our institution in accordance with the criteria outlined in the *Diagnostic and Statistical Manual of Mental Disorders Revised Third Edition* [Aldea 1997]. Stroke was defined as the development of a new focal neurologic deficit confirmed by clinical findings and computed tomographic scan; a stroke was defined as intraoperative if it was present when the patient awoke and as postoperative if it occurred after a normal postoperative period. TIA was defined as the onset of a neurologic deficit lasting less than 24 hours and associated with a normal computed tomographic cerebral scan. The severity of stroke was graded according to the stroke severity outcome scale [Reed 1988].

Surgical Technique and Strategies

OPCAB surgery was performed through a median sternotomy with the patient under general anesthesia. The left and right internal thoracic arteries (ITAs) were usually harvested as pedicles, although lately we have adopted skeletonization as a routine harvesting technique. This modification has permitted the harvesting of longer conduits and has allowed a better flexibility for constructing composite and sequential grafts. After systemic heparinization was carried out with an initial dose of 1 mg/kg body weight, the activated clotting time was maintained at >300 seconds, and the ITAs were divided and clipped distally and then covered with gauze moistened with a 1 mg/mL verapamil solution. When it was requested, the radial artery was simultaneously harvested from the nondominant arm during ITA harvesting and preserved in the verapamil solution. Preoperative assessment of the palmar arch was done with the Allen test and with Doppler ultrasonography in questionable cases. Occasionally, the heart rate was maintained when necessary below 80 beats/min by the administration of intravenous boluses of metoprolol tartrate. Coronary immobilization was achieved with a mechanical stabilizer (CorVasc; CoroNéo, Montreal, Quebec, Canada), and silicone rubber slings attached to a blunted needle (Quest Medical, Allen, TX, USA) were used for isolating and occluding the coronary artery at the arteriotomy site. The left anterior descending artery, the right coronary artery, and the posterior descending artery were approached with minimal mobilization. Access to the obtuse marginal arteries was achieved with Trendelenburg positioning, rightward table rotation (30°), and heart verticalization via the placement of 4 deep pericardial sutures at the base of the heart between the left superior pulmonary vein and the inferior vena cava. An occluded right territory was revascularized first to provide collateral flow to the left territory during subsequent anastomoses. When an anastomosis was constructed in the presence of left main disease in cases of the nondominant right coronary artery, an intracoronary shunt was employed to ensure an adequate perfusion of the distal territory. Proximal bypass anastomoses were carried out in a unique side-bite clamping period to minimize aortic trauma. Distal coronary artery anastomoses were performed with 7-0 or 8-0 polypropylene sutures. All grafts were immediately verified with continuous wave Doppler ultrasonography. Unsatisfactory anastomoses were immediately refashioned.

The surgical technique was modified in cases of extensive calcifications of the ascending aorta, patent aortic saphenous grafts from prior operations, or comorbid predisposing factors to perioperative stroke, such as significant carotid disease, previous CVD, or advanced age (>80 years). The NTT was adopted with single or double ITA grafts to which additional grafts (radial artery, or saphenous veins, or free ITA) were connected in a Y or preferably a T configuration [Royse 1999, APA 1994]. End-to-side anastomoses between ITA grafts were always performed with 8-0 polypropylene sutures. Occasionally, arterial revascularization was completed by the use of the gastroepiploic artery. The presence of obesity, previous abdominal surgery, and gastroesophageal reflux were contraindications to the use of the gastroepiploic artery. Occasionally, the brachiocephalic artery was selected as an alternative inflow site. A careful inspection was always carried out to detect any evidence of severe atherosclerosis (Table 1).

ST-segment trends and invasive monitoring were used to detect myocardial ischemia and cardiovascular instability. Intravenous perfusion of nitroglycerin or phenylephrine was employed when required. At the end of the procedure, half of the heparin dose was neutralized with protamine sulfate.

Table 1. Conduit Arrangements in the "No Touch" Group*

Conduit Graft	No. of Grafts
LITA	19 (24%)
LITA RA	3 (3.5%)
LITA SVG	2 (2.5%)
BITA	31 (38.7%)
BITA RA	6 (7.6%)
BITA SVG	11 (14%)
RITA RA	2 (1%)
RITA SVG	4 (1%)
GEA	2 (2.5%)
SEQ	12 (15%)
Tector	11 (13.7%)
Y grafts	16 (20%)
IA	3 (3.5%)

*LITA indicates left internal thoracic artery graft; RA, radial artery graft; SVG, saphenous vein graft; BITA, bilateral internal thoracic artery graft; RITA, right internal thoracic artery graft; GEA, gastroepiploic artery graft; SEQ, sequential graft; IA, innominate artery graft.

Statistical Analysis

The data are expressed as the mean ± SD. For statistical analysis, the Student *t* test was used for the analysis of continuous variables, and the Fisher exact test was used for categorical variables. Multivariate analysis with the logistic regression model was used to perform risk-adjusted analyses and to eliminate potential confounding effects (SPSS version 10.0 for Windows; SPSS, Chicago, IL, USA). A *P* value <.05 was considered statistically significant.

Table 2. Preoperative Data*

Preoperative Data	No Touch (n = 84)	Off-Pump (n = 556)	*P*
Age, y	62 ± 13	64 ± 10	.11
Sex ratio (M/F)	5.14	3.55	.29
Diabetes	18%	25%	.20
Hypertension	46%	47%	.98
Dyslipidemia	79%	69%	.09
Smoking	43%	32%	.09
Prior myocardial infarction	35%	44%	.18
Myocardial infarction <30 d	11%	16%	.37
Prior CABG	13%	7%	.19
LCA disease >50%	30%	30%	.90
Territories involved			
One	31%	6.20%	.000
Two	38%	21.80%	.005
Three	31%	71.60%	.000
Peripheral vascular disease	13%	18.90%	.08
Prior CVD	17%	8.4%	.04
Carotid disease	25.10%	16.35%	.02
LVEF	57 ± 12	54 ± 12	.49
Unstable angina	55%	68%	.03
CCS	2.73 ± 1.79	3.5 ± 0.7	1
Pulmonary disease	14%	11%	.53
Renal insufficiency	2.5%	1.6%	.96
Congestive heart failure	10%	9%	.95
Use IABP	4%	7%	.42

*Data are presented as the mean ± SD where appropriate. CABG indicates coronary artery bypass grafting; LCA, left coronary artery; CVD, cerebrovascular disease; LVEF, left ventricular ejection fraction; CCS, Canadian Cardiovascular Society angina classification; IABP, intra-aortic balloon pump.

RESULTS

Demographics

Patient demographics and preoperative characteristics are displayed in Table 2. There were no significant differences in age, sex, and risk factors between the two groups. However, the frequencies of previous CVD (17% versus 8%; *P* = .04) and carotid atherosclerosis (25% versus 16%; *P* = .02) were higher in the NTT group. Nevertheless, a lower incidence of triple-vessel disease (31% versus 72%; *P* = .000) was noted in this group.

Operative Data

A complete revascularization was achieved more frequently in the OPCAB group, although the difference did not reach statistical significance. On average, fewer grafts per patient were completed in the NTT group (Table 3). A comparison of the grafted territories for the two groups is displayed in the Figure. Grafting of the posterior descending artery (18% versus 42%; *P* = .000) and the obtuse marginal artery territory (proximal obtuse marginal artery, 36% versus 62% [*P* = .054]; distal obtuse marginal artery, 18% versus 42% [*P* = .000]) was more frequent in the OPCAB patients. However, the ratios of the number of grafts to the territory in which they were performed were comparable for the two groups. The prevalence of severe atherosclerosis of the ascending aorta (13% versus 0%; *P* = .000) was higher in NTT patients. The ischemic period was also shorter in the NTT group.

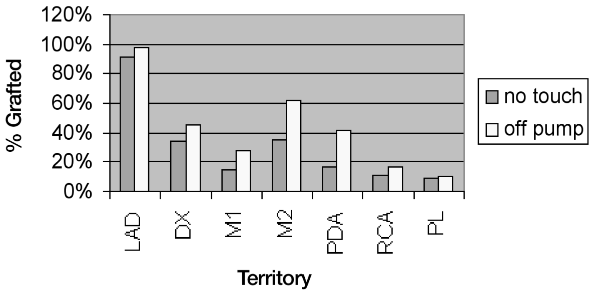
Postoperative Outcome

The operative mortality rate (30 days) was comparable for both cohorts (1.6% for the NTT group and 1.7% for the OPCAB group). The prevalence of postoperative delirium (8% and 15%; *P* = .12), the frequency of blood transfusions (16% versus 28%; *P* = .03), the length of intensive care unit

Table 3. Perioperative Data*

Perioperative Data	No Touch (n = 84)	Off-Pump (n = 556)	*P*
Bypasses/patient, n	2.13 ± 0.97	3.14 ± 0.80	.00
Incomplete revascularization	10%	5.40%	.17
Grafts/territory, n	1.11 ± 0.26	1.19 ± 0.29	.09
Global ischemia, min	23 ± 10	30 ± 11	.000
Severe atherosclerosis ascending aorta	13%	0%	.000

*Data are presented as the mean ± SD where appropriate.



Differences in grafted territories between the no-touch group and the off-pump group. LAD indicates left anterior descending artery; DX, diagonal arteries; M1 and M2, marginal arteries; PDA, posterior descending artery; RCA, right coronary artery; PL, posterior lateral artery.

(ICU) stay (51 hours versus 74 hours; P = .07), the length of hospital stay (5 days versus 6.8 days; P = .04), and the frequency of atrial fibrillation (18% versus 29%, $p < 0.05$) were all lower in the NTT group. No differences in the frequencies of perioperative myocardial infarction, low cardiac output syndrome, perioperative stroke (0% versus 1%; P = .14), and the use of intra-aortic balloon pump were detected (Table 4). The characteristics of the 4 patients in the OPCAB group who experienced strokes are summarized in Table 5.

Risk-Adjusted Analysis

To control potential confounding effects, we used multiple logistic regression analysis to evaluate the influence of NTT on the occurrence of postoperative delirium, prolonged ICU stay (>48 hours), prolonged in-hospital stay (>7 days), atrial fibrillation, and blood transfusion need. Results were adjusted for differences in age, sex, left ventricular function, and discordant preoperative characteristics between the two groups. Results are shown in Table 6. Age was a significant independent risk factor for all postoperative events studied. Female sex was a risk factor for prolonged ICU stay and blood product need, whereas male patients had a higher propensity for postoperative atrial fibrillation. Peripheral vascular disease and a previous medical history of cerebrovascular accident and TIA were significantly associated with an increased incidence of prolonged in-hospital stay and of postoperative atrial fibrillation, respectively. A decreased left ventricular ejection fraction contributed to prolonging the lengths of ICU and in-hospital stays and was associated with the triggering of atrial fibrillation. The presence of unstable angina prior to surgery was significantly associated with a prolonged ICU stay. The severity of the coronary disease and a history of prior cardiac surgery were associated with an increased frequency of blood product transfusion need. Interestingly, no independent effect was seen from the use or nonuse of the NTT.

COMMENTS

Atheroembolism originating from the ascending aorta has been documented as an important cause of mortality and morbidity after coronary artery bypass surgery [Roach 1996]. In a postmortem study of 221 patients who had undergone cardiac surgery, Blauth and colleagues [Blauth 1992] identified direct correlations between the incidence of atheroembolic events and the severity of ascending aorta atherosclerosis, the patient's age, and the presence of peripheral vascular disease. Most (98%) of these patients who evidenced atheroembolism had severe atherosclerosis of the aorta. Numerous strategies have been proposed to avoid manipulations of the severely atherosclerotic aorta to decrease the occurrence of intraoperative embolism. Digital palpation of the aorta prior to aortic cannulation is mandatory to identify any signs of disease. Alternative sites of cannulation, such as the aortic arch or the femoral artery, may be required as well [Suma 1989, Mills 1991, Wareing 1992]. Unfortunately, both techniques can predispose the patient to systemic and cerebral embolization [Tobler 1988]. Retrograde perfusion through the femoral artery is associated with more neurologic complications than aortic arch antegrade cannulation [Gaudino 2000]. In the presence of an unclampable aorta (10 of 80 patients in the NTT group), our strategy of avoiding any manipulation of the aorta was successful, because no strokes or TIAs were observed. The use of the brachiocephalic artery as alternative inflow site for proximal anastomosis may also be problematic, because the prevalence of atherosclerotic disease has been reported to be as high as 30% [Jones 1989]. In the current series, we used this technique preferentially in 2 patients who underwent reoperative coronary surgery. Placement of the side-bite clamp was not feasible because of the presence of a prior patent graft, not because of the presence of a severely calcified aorta. For the reasons mentioned above, in most patients we prefer to use the left and right ITAs, which are connected to additional grafts in a T or a Y configuration (Table 1). Some investigators have raised the concern of insufficient arterial flow in cases of extensive coronary disease [Wendler 1999]. In the 26 patients in whom these configurations were constructed, no instances

Table 4. Postoperative Data*

Postoperative Data	No Touch (n = 84)	Off-Pump (n = 556)	*P*
Perioperative myocardial infarction	1.3%	1.8%	.56
Low cardiac output syndrome	1%	1.3%	.61
Atrial fibrillation	18%	29%	.05
Stroke	0%	1%	.85
Transient ischemic attack	0%	0.5%	.73
Reoperation for bleeding	3.8%	3.6%	.97
Blood transfusion	16%	28%	.03
Renal failure	2%	2.4%	.83
Inotropic support >24 h	19%	18%	.20
Intra-aortic balloon pump	0%	0.80%	.95
Intubation time, h	21 ± 32	22 ± 49	.86
Intensive care unit stay, h	52 ± 42	74 ± 110	.07
Delirium	9%	18%	.12
Postoperative hospital stay, d	5.4 ± 2.6	6.8 ± 6.1	.04
30-Day death	1.6%	1.7%	.83

*Data are presented as the mean ± SD where appropriate.

Table 5. Clinical Characteristics of Patients Who Experienced Stroke (OPCAB Group)*

Patient No.	Age, y	CVA	PVD	CD	AD	LVEF	AF	OS	T	SS	SL
1	72	+	+	+	+	65%		0	PO	3	MCA
2	69	–	–	+	+	72%		2	IO	11	VBA
3	62	–	+	–	–	38%	+	5	PO	3	PCA
4	56	–	–	–	–	23%	+	5	PO	5	VBA

*CVA indicates previous cerebrovascular accident; PVD, peripheral vascular disease; CD, carotid disease; AD, aortic disease; LVEF, left ventricular ejection fraction; AF, atrial fibrillation; OS, postoperative day of onset of symptoms; T, timing; SS, stroke severity score; SL, stroke location; PO, postoperative; MCA, middle cerebral artery; IO, intraoperative; VBA, vertebrobasilar artery; PCA, posterior cerebral artery.

of perioperative ischemia or low output syndrome were encountered, suggesting that myocardial perfusion was adequate. However, some preventive measures were applied. The perioperative use of nitroglycerin derivatives was started intraoperatively and maintained for 24 hours. Gurne and colleagues [Gurne 1995] have shown that the baseline blood flow in the main stem of the left ITA 1 week after the operation varies between 72 ± 34 mL/min (left ITA and radial artery) and 76.13 ± 34 mL/min (left ITA and right ITA) in the Y graft, both values being higher than the flow rates reported for single ITA grafts (30-40 mL/min) [Shimizu 2000]. This result reflects the augmented need implemented by the 2 grafts. Thus, the functional capacity of the ITA depends mostly on the severity of the proximal stenosis of the native coronary artery [Ricotta 1995]. These graft configurations are useful for avoiding the manipulation of the aorta in the presence of multiple preoperative risk factors strongly associated with stroke, such as significant carotid artery disease, previous stroke, redo heart surgery, and increased age [McKhann 1997, Cartier 2000]. Even though a history of prior CVD was less frequent in OPCAB patients, the prevalence of perioperative strokes was comparable (NTT, 0%; OPCAB, 1%). When the patients' characteristics were considered, those patients who experienced strokes had a 50% incidence of carotid disease, which has been recognized to increase the perioperative risk of stroke or TIA by 3.9-fold [Das 2000]. The debate about the management of these high-risk patients remains open. Combined approaches, such as concurrent carotid artery endarterectomy during or before CABG as well as CABG alone, have been proposed. Discordant data have been reported in the literature regarding the risk of stroke and mortality from these various adopted strategies [Ricotta 1995, Horst 1999, Das 2000]. Only a prospective, randomized trial will eventually resolve this issue. Two patients in the current series experienced stroke with no predisposing factor other than postoperative atrial fibrillation. The incidence of atrial fibrillation in OPCAB patients has been reported to be comparable with the incidence reported for CABG surgery with CPB [Matthew 1996, Davis 2000]. However, the incidence with the current NTT series appears to be considerably lower (18%; P = .05), even though the risk-adjusted analysis has shown that atrial fibrillation was mainly associated with age, sex, and left ventricular function, rather than with the technique itself. Nevertheless, in the NTT group the aortic fat pad, which extends between the aorta and the pulmonary artery and onto the surface of the ascending aorta, was not isolated for aortic manipulation. Interestingly, the human aortic fat pad has been reported to contain neurogenic tissue [Davis 2000]. These investigators reported that preserving the aortic fat pad can significantly reduce the incidence of atrial fibrillation associated with OPCAB surgery (fat pad

Table 6. Risk-Adjusted Multiple Logistic Regression Analysis of Confounding Effects other than the "No Touch" Technique*

	Delirium, *P* (OR)	ICU Stay >48 h, *P* (OR)	Hospital Stay >7 d, *P* (OR)	Transfusion, *P* (OR)	AF, *P* (OR)
Age	**.02 (1.03)**	**.09 (1.01)**	**.001 (1.05)**	**.001 (1.1)**	**.001 (1.05)**
Sex	.79 (1.08)	**.01 (0.59)**	.03 (0.61)	**.001 (0.44)**	**.01 (1.84)**
PVD	.21 (1.50)	.87 (1.04)	**.01 (1.94)**	.09 (1.53)	.75 (1.09)
CVD	.36 (1.34)	.30 (1.29)	.55 (0.84)	.41 (1.25)	.47 (1.21)
CVA/TIA	.46 (0.71)	.08 (1.78)	.55 (1.23)	.45 (1.30)	.07 (0.52)
LVEF	.32 (0.40)	**.01 (0.19)**	**.03 (0.19)**	.17 (0.34)	**.02 (0.18)**
UA	.79 (1.07)	.07 (1.40)	.60 (1.13)	.68 (1.1)	.47 (0.86)
Territories involved	.49 (0.86)	.34 (1.16)	.49 (1.14)	**.02 (1.63)**	.19 (1.27)
Redo surgery	.69 (1.17)	.62 (1.16)	.66 (1.16)	**.04 (1.97)**	.09 (0.52)
NTT	.19 (0.54)	.28 (0.74)	.33 (1.7)	.86 (0.94)	.83 (0.93)

*Entries in boldface signify a statistically significant result. OR indicates odds ratio; ICU, intensive care unit; AF, atrial fibrillation; PVD, peripheral vascular disease; CVD, cerebrovascular disease; CVA/TIA, cerebrovascular accident and transient ischemic attack; LVEF, left ventricular ejection fraction; UA, unstable angina; NTT, "no touch" technique.

not removed, 3.5%; removed, 21.1%) or CPB surgery (fat pad not removed, 10.3%; removed, 20.4%).

Stroke is not the only adverse effect of coronary artery bypass surgery on the central neurologic system. Postoperative delirium has been reported to occur in 10% to 30% of patients undergoing operations with CPB. Rolfson and colleagues [Rolfson 1999b] in reporting the results of a series of 72 patients suggested that patients who experienced such complications were older, were more likely to have a previous history of stroke (8-fold increase in risk), and had undergone a longer duration of CPB (double the risk after 38 minutes and triple the risk after 60 minutes). This last risk factor has been suspected to result in a higher incidence of perioperative microembolic events [Brown 2000]. This relationship has been clearly demonstrated by Bowles and colleagues [Bowles 2001]. They found in a study of patients who died shortly after CPB (36 patients) that there was compelling evidence of lipid microembolism with an incremental load of close to 90% for every additional hour of CPB. Off-pump surgery can reduce the number of microemboli but cannot eliminate all of them [Rolfson 1999a]. Microembolic events are still being reported during OPCAB surgery, mainly in relation to the side-bite clamping of the aorta used during the construction of the proximal anastomosis [Tector 1994]. As a result, the occurrence of postoperative delirium in the current series of OPCAB patients (18%) was lower than in other reported series of standard CABG surgery (28%-32%) [Rolfson 1999b] but was considerably more reduced in the NTT series (8%). It is likely that the combined lower incidences of postoperative delirium and atrial fibrillation contributed to the shorter ICU and hospital stays observed in the NTT population. However, the risk analysis confirmed that age, sex, and ventricular function were the factors responsible for ICU stay beyond 48 hours, whereas patient age was the main factor associated with postoperative atrial fibrillation.

The current study has some obvious limitations. It is likely that certain cases of atherosclerotic disease of the ascending aorta were undetected, because epiaortic ultrasonography was not routinely used. Many of these plaques are not calcified, and such plaques are predisposed to embolization once they are manipulated. Preoperative chest radiography, angiography, and perioperative inspection and palpation underestimate the frequency of this pathology. However, this aortic manifestation was more likely to be present in NTT patients because of the more extensive vascular disease found in this group. Other limitations are the small number of patients of the current NTT cohort, which decreases the power of the statistical analysis. Further validation studies including larger number of patients will be necessary to confirm these preliminary results.

In conclusion, as patients referred for CABG continues include increasingly older individuals, the benefit of a complete successful revascularization can be concealed by the occurrence of stroke, a devastating complication for both the patient and the patient's family. In cases of severe atherosclerotic disease of the aorta or the presence of concomitant risk factors for stroke, such as advanced age, previous CVD, peripheral vascular disease, or carotid disease, the NTT is a safe and efficient alternative that can contribute to decreasing perioperative neurologic morbidity. This technique should be part of the armamentarium of modern cardiac surgery.

REFERENCES

Aldea GS, Lilly K, Gaudiani JM, et al. 1997. Heparin-bonded circuits improve clinical outcomes in emergency coronary artery bypass grafting. J Card Surg 12:389-97.

[APA] American Psychiatric Association. 1994. Diagnostic and statistical manual of mental disorders: DSM-IV. 4th ed. Washington, DC: American Psychiatric Association. p 123-33.

Arom KV, Flavin T, Emery RW, Kshettry VR, Janey PA, Petersen RJ. 2000. Safety and efficacy of off-pump coronary artery bypass grafting. Ann Thorac Surg 69:704-10.

Bal-El Y, Goor DA. 1992. Clamping of the atherosclerotic ascending aorta during coronary artery bypass operations: its cost in stroke. J Thorac Cardiovasc Surg 102:469-74.

Barbut D, Yao FF, Lo YW, et al. 1997. Determination of size of aortic emboli and embolic load during coronary artery bypass. Ann Thorac Surg 63:1262-7.

Blauth CI, Cosgrove DM, Webb BW, et al. 1992. Atheroembolism from the ascending aorta. J Thorac Cardiovasc Surg 103:1104-12.

Bowles BJ, Lee JD, Dang CR, et al. 2001. Coronary artery bypass performed without the use of cardiopulmonary bypass is associated with reduced cerebral microemboli and improved clinical results. Chest 119:25-30.

Brown WR, Moody DM, Challa VR, Stump DA, Hammon JW. 2000. Longer duration of cardiopulmonary bypass is associated with greater numbers of cerebral microemboli. Stroke 31:707-13.

Butler J, Rocker GM, Westaby S. 1993. Inflammatory response to cardiopulmonary bypass. Ann Thorac Surg 55:552-8.

Cartier R, Brann S, Dagenais F, Martineau R, Couturier A. 2000. Systematic off-pump coronary artery revascularization in multivessel disease: experience of three hundred cases. J Thorac Cardiovasc Surg 119:221-9.

Clark RE, Brillman J, Davis DA, Lovell MR, Price TR, Magovern GJ. 1995. Microemboli during coronary artery bypass grafting: genesis and effect on outcome. J Thorac Cardiovasc Surg 109:249-57.

Das SK, Brown TD, Pepper J. 2000. Continuing controversy in the management of concomitant coronary and carotid disease: an overview. Int J Cardiol 74:47-65.

Davis Z, Jacobs K, Bonilla J, Anderson RR, Thomas C, Forst W. 2000. Retaining the aortic fat pad during cardiac surgery decreases postoperative atrial fibrillation. Heart Surg Forum 3:108-12.

Gaudino M, Glieca F, Alessandrini F, et al. 2000. The unclampable ascending aorta in coronary artery bypass patients. Circulation 102:1497-502.

Gurne O, Chenu P, Polidori C, et al. 1995. Functional evaluation of the internal mammary artery bypass grafts in the early and late postoperative periods. J Am Coll Cardiol 25:1120-8.

Horst M, Geissler HJ, Mehlhorn U, et al. 1999. Simultaneous carotid and coronary artery surgery: indications and perioperative outcome. J Thorac Cardiovasc Surg 47:328-32.

Iaco AL, Contini M, Teodori G, et al. 1999. Off or on bypass: what is the safety threshold? Ann Thorac Surg 68:1486-9.

Jones EL, Lattouf OM, Weintraub WS. 1989. Catastrophic consequences of internal mammary artery hypoperfusion. J Thorac Cardiovasc Surg 97:2402-5.

Kirklin JK, Westaby S, Blackstone EH, Kirklin JW, Chenowith DE, Pacifico AD. 1983. Complement and the damaging effects of cardiopulmonary bypass. J Thorac Cardiovasc Surg 86:845-57.

Matthew JP, Parks R, Savino JS, et al. 1996. Atrial fibrillation following coronary artery bypass graft surgery. JAMA 276:300-6.

McKhann GM, Goldsborough MA, Borowicz LM Jr, et al. 1997. Predictors of stroke risk in coronary artery bypass patients. Ann Thorac Surg 63:516-21.

Mills NL, Everson CT. 1991. Atherosclerosis of the ascending aorta and coronary artery bypass. J Thorac Cardiovasc Surg 102:546-53.

Price DL, Harris J. 1970. Cholesterol emboli in cerebral arteries as a complication of retrograde aortic perfusion during cardiac surgery. Neurology 20:1209-14.

Reed GL III, Dinger DE, Picard EH, DeSanctis RW. 1988. Stroke following coronary artery bypass surgery. N Engl J Med 319:1246-50.

Ricotta JJ, Faggioli GL, Castilone A, Hasset JM. 1995. Risk factors for stroke after cardiac surgery: Buffalo Cardiac-Cerebral Study Group. J Vasc Surg 21:359-64.

Roach GW, Kanchuger M, Mangano CM, et al. 1996. Adverse cerebral outcomes after coronary bypass surgery. N Engl J Med 335:1857-63.

Rolfson DB, McElhaney JE, Jhangri GS, Rockwood K. 1999. Validity of the confusion assessment method in detecting postoperative delirium in the elderly. Int Psychogeriatr 11:431-8.

Rolfson DB, McElhaney JE, Rockwood K, et al. 1999. Incidence and risk factors for delirium and other adverse outcomes in older adults after coronary artery bypass graft surgery. Can J Cardiol 15:771-6.

Royse AG, Royse CF, Raman JS. 1999. Exclusive Y graft operation for multivessel coronary revascularization. Ann Thorac Surg 68:1612-8.

Shimizu T, Hirayama T, Suesada H, Ikeda K, Ito S, Ishimaru S. 2000. Effect of flow competition on internal thoracic artery graft: postoperative velocimetric and angiographic study. J Thorac Cardiovasc Surg 120:459-65.

Suma H. 1989. Coronary artery bypass grafting in patients with calcified ascending aorta: aortic no-touch technique. Ann Thorac Surg 48:728-30.

Tector AJ, Amundsen S, Shmahl TM, Kress DC, Peter M. 1994. Total revascularization with T grafts. Ann Thorac Surg 57:33-8.

Tobler HG, Edwards JE. 1988. Frequency and location of atherosclerotic plaques in the ascending aorta. J Thorac Cardiovasc Surg 96:304-6.

van der Linden J, Casimir-Ahn H. 1991. When do cerebral emboli appear during open heart operations? A transcranial Doppler study. Ann Thorac Surg 51:237-41.

Wareing TH, Davila-Roman VG, Barzillai B, Murphy SF, Kouchoukos NT. 1992. Management of the severely atherosclerotic ascending aorta during cardiac operations. J Thorac Cardiovasc Surg 103:453-62.

Wendler O, Hennen B, Markwirth T, et al. 1999. Grafts with the right internal thoracic artery to the left internal thoracic artery vs. the left internal thoracic artery and radial artery: flow dynamics in the left thoracic artery main stem. J Thorac Cardiovasc Surg 118:841-8.