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The Impact of Coronary Artery Bypass Grafting Surgical Technique on Stroke in Young and Elderly Patients

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ABSTRACT

Background: Today, the elderly represent a large and rapidly growing segment of society and are being referred in increasing numbers for coronary artery bypass grafting (CABG) surgery. Stroke is a major complication of CABG surgery. The risk of stroke after CABG can be managed successfully, especially in high-risk patients, by choosing an adequate and appropriate surgical technique.

Methods: We evaluated 890 consecutive patients who underwent isolated CABG surgery by the same team between June 2006 and July 2008. The patients were divided by age into 2 groups. Group I consisted of 480 patients <65 years of age, and group II comprised 410 patients >65 years of age. Each group was then divided into 4 subgroups according to the surgical technique used: double-clamp technique (DCT), single-clamp technique (SCT), off-pump, and on-pump cross-clamp off. Preoperative risk factors for stroke and all clinical data were collected for the patients.

Results: In group I, 192 (40%) of the patients were female, and 288 (60%) were male. In group II, 170 (41.5%) were female, and 240 (58.5%) were male. Five patients in each group experienced stroke, with an incidence of 1.04% in group I (4 men and 1 woman) and 1.21% in group II (3 men and 2 women). The stroke rates of the 2 age groups were not significantly different (P = .802). Three of the 480 patients in group I died, with only 1 (33.3%) of the deaths related to stroke. In group II, however, 2 (50%) of the 4 deaths were related to stroke. The incidences of stroke-associated mortality in the 2 age groups were not significantly different (P = 1.0).

Conclusion: Although off-pump and on-pump cross-clamp off techniques were performed for some of the patients, DCT and SCT were used for the majority of the patients. We detected no statistically significant difference between these 2 groups of patients in the impact of applying DCT and SCT on the stroke rate. We conclude that this result was due to the different surgical techniques performed on a minority of the patients (82 patients).

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INTRODUCTION

Patients who undergo myocardial revascularization procedures are still at risk for major complications, despite recent advances in cardiac surgical techniques. Stroke is a major complication of coronary artery bypass grafting (CABG) surgery. The mechanisms that contribute to a poor neurologic outcome have been well documented. Cerebral embolization with macro- and microemboli has been shown to be the most common mechanism, which is related to cardiopulmonary bypass (CPB). Atherosclerotic disease of the ascending aorta has been thought to contribute significantly to the release of emboli during aortic manipulation and clamp application during CABG [Aranki 1994]. Salerno [1982] described a technique in which the distal and proximal anastomoses were constructed during a single period of total aortic occlusion in order to decrease the risk of emboli during aortic manipulation. On the other hand, CPB can also induce other physiological dysfunctions, including air/fat embolism, hemodynamic fluctuations, cerebral hyperthermia, and systemic inflammatory reactions, that can also contribute to neurologic damage [Gardner 1985; Loop 1988; Hammon 1997].

Today, the elderly are a large and rapidly growing segment of society and are increasingly referred for CABG surgery [Jones 1983]. Percutaneous intervention has been chosen as a treatment option in a large proportion of such patients, and the surgical option has been reserved as a treatment option in older patients, for whom the rates of perioperative mortality and morbidity are higher [Cosgrove 1984; Weintraub 1991].

Our goal in this prospective study was to test the hypothesis of whether the use of the preferred surgical technique for the age group decreases the incidence of stroke rates in patients who undergo CABG.

PATIENTS AND METHODS

In this prospective study, we included 890 consecutive patients who underwent isolated CABG surgery by the same team between June 2006 and July 2008. The patients were divided by age into 2 groups. Group I included 480 patients <65 years of age, and group II included 410 patients >65 years of age. Each of the groups was also divided into 4 subgroups according to the surgical technique: double-clamp

Table 1. Demographic Data*

Characteristic	Group I (n = 480)	Group II (n = 410)	*P*†
Sex, n			
Female	192 (40%)	170 (41.5%)	.658
Male	288 (60%)	240 (58.5%)	
Body surface area, m^2	1.8 ± 0.3	1.9 ± 0.3	.008‡
Ejection fraction, n			
Good (>50%)	192 (40%)	160 (39%)	.366
Moderate (30%-50%)	182 (38%)	144 (35%)	
Poor (<30%)	106 (22%)	107 (26%)	
History of hypertension, n	269 (56%)	279 (68%)	.001
History of smoking, n	269 (56%)	279 (68%)	.001
History of diabetes, n	168 (35%)	156 (38%)	.346
History of atrial fibrillation, n	10 (2%)	12 (3%)	.419
History of stroke or TIA, n	5 (1%)	12 (3%)	.041
Previous myocardial infarction, n	34 (7%)	41 (10%)	.118
Peripheral vascular disease, n	38 (8%)	49 (12%)	.043
Renal failure (Cr >200 µmol/L), n	10 (2%)	21 (5%)	.014
EuroSCORE (median)	3	5	.001§
Diseased coronary vessels, n			
1	54 (11.3%)	40 (9.8%)	.768
2	175 (36.5%)	151 (36.8%)	
≥3	251 (52.2%)	219 (53.4%)	

*TIA indicates transient ischemic attack; Cr, creatinine.
†Results are χ^2 tests except where indicated.
‡Student *t* test.
§Mann-Whitney *U* test.

technique (DCT), single-clamp technique (SCT), off-pump, and on-pump cross-clamp off. After examining the preoperative reports for the operations, we collected all clinical data. Table 1 summarizes the demographic characteristics of the patients.

Before undergoing CABG surgery, all patients underwent a carotid duplex ultrasound examination, which detects most cases of carotid artery disease. The presence of plaques was noted, and the reduction in the carotid artery lumen cross-sectional area was calculated. We were more concerned when plaques grow to the point at which they cause blockage of 60% to 70% or more. If plaques caused symptoms such as transient ischemic attacks (TIAs), patients with symptoms and stenosis of greater than 60% to 70% underwent carotid angiography. Concomitant carotid endarterectomy and CABG were preferred treatment options for these patients, and they were excluded from this study.

Postoperative stroke was defined as any new major (type II) neurologic deficit presenting in the hospital that was a focal or global dysfunction of presumed vascular origin and lasted more than 24 hours [Trehan 2000]. TIA was defined as a focal cerebral dysfunction of presumed vascular origin that resolved completely within 24 hours; however, TIAs were not included in this analysis. The diagnosis of stroke was made by a neurologist and confirmed in most patients by postoperative computed tomography evaluation or magnetic resonance imaging.

Surgical Strategy

The choice of the 4 different surgical techniques (DCT, SCT, off-pump, on-pump cross-clamp off) was based on the preoperative and intraoperative data. Only 2 methods were used to diagnose aortic pathology: (1) a preoperative chest radiograph to detect any aortic calcification, and (2) intraoperative gentle digital palpation of the ascending aorta by the surgeon. In the presence of extensive atherosclerosis of the ascending aorta or the aortic arch, the CABG technique was tailored to each patient to avoid atheroembolism.

If a chest radiograph and/or digital palpation detected diffuse aortic calcification, cross-clamping was not used; however, if intraoperative digital palpation revealed a suitable area, partial cross-clamping was applied (22 patients in group I and 20 patients in group II).

When diffuse atheroma of the aorta was present, patients suitable for off-pump CABG underwent this procedure (30 patients in group I and 25 patients in group II). If a patient was not suitable for off-pump CABG, a femoral artery was cannulated, and the patient underwent on-pump CABG without aortic cross-clamping (10 patients in group I and 17 patients in group II). Distal anastomoses were done sequentially to decrease the number of proximal anastomoses. In addition, the proximal anastomosis was done as a T or Y graft (Figure 1).

Operative Techniques

Tables 2 and 3 summarize the operative techniques used in the patients.

On-Pump CABG with Aortic Cross-Clamping. A median sternotomy was followed by harvesting of the internal mammary artery when indicated in patients who underwent DCT and SCT procedures. Radial artery and saphenous vein grafts were harvested during internal mammary artery harvesting. The aorta was gently palpated before cannulation. The aorta was cannulated at the distal part of ascending aorta, just before the innominate artery. If localized aortic thickening was present and a suitable site for the cross-clamp could be found, SCT was preferred; Otherwise, DCT was preferred for proximal anastomoses. The cannula for antegrade cardioplegia was located at the most suitable site of the ascending aorta for a proximal anastomosis. CPB was started after 2-stage venous cannulation. Antegrade blood cardioplegia and moderate systemic hypothermia (32°C) were used for myocardial protection. Proximal anastomoses were established at the most suitable site when the SCT was used for proximal anastomoses. The lateral clamp was applied once for all proximal anastomoses in patients for whom the DCT was preferred.

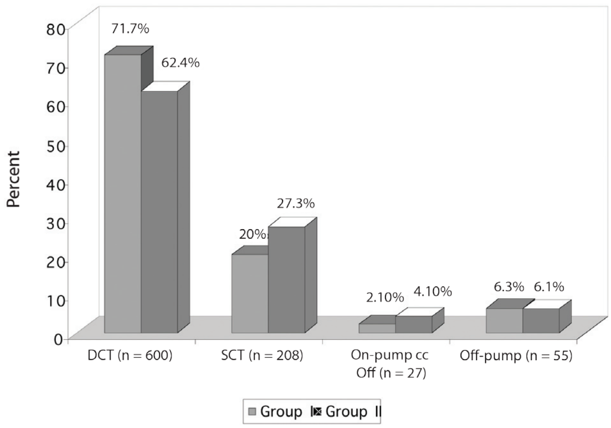

Figure 1. The distributions of patients according to surgical technique. DCT indicates double-clamp technique; SCT, single-clamp technique; CC, cross-clamp.

Off-Pump CABG. In the off-pump subgroup, revascularization was performed on the beating heart with stabilization (Octopus 3; Medtronic, Minneapolis, MN, USA) of the target coronary arteries. If the ascending aorta was suitable, a partial clamp was preferred for proximal anastomoses (22 patients in group I, 20 patients in group II). In cases of suspected aortic disease, vein or radial grafts were anastomosed as T grafts to the internal mammary artery or the innominate artery (8 patients in group I, 5 patients in group II).

On-Pump CABG Cross-Clamp Off. When a patient had a diffusely atherosclerotic aorta and was not suitable for off-pump CABG, a femoral artery was cannulated, and CPB was started after 2-stage venous cannulation. Complete myocardial revascularization was provided by the Octopus 3 stabilization device without aortic cross-clamping. Proximal anastomoses were made as T or Y grafts.

Statistical Analysis

The Statistical Package for the Social Sciences (Version 15.0; SPSS, Chicago, IL, USA) was used for statistical analyses. Results for continuous variables are expressed as the mean ± SD, and those for categorical variables are expressed as percentages. The Student t test was used for continuous variables, and the χ^2 or Fisher exact test was used for categorical variables. All P values <.05 were considered statistically significant.

RESULTS

Preoperative and Operative Details

Table 1 summarizes the preoperative demographics of the study groups.

In this prospective study, the same surgical team evaluated 890 cases between June 2006 and July 2008 in the cardiovascular surgery departments of Bursa Acıbadem Hospital and Izmit Anadolu Health Center Hospital. Group I consisted of 480 patients <65 years of age, and group II comprised 410 patients >65 years of age. In group I, 192 (40%) of the patients were female, and 288 (60%) were male. In group II, 170 (41.5%) were female, and 240 (58.5%) were male. Five patients in each group experienced stroke, with an incidence of 1.04% in group I (4 men and 1 woman) and 1.21% in group II (3 men and 2 women). The stroke rates of the 2 age groups were not significantly different (P = .802; Figure 2). Table 3 summarizes the relationship of stroke incidence with surgical technique.

The age groups were not significantly different with respect to the sex of the patients (P > .05). Body surface area was significantly higher in group II (P < .01), but the age groups were not different with respect to ejection fraction (P > .05). The incidences of histories of hypertension and smoking were both significantly higher in group II (P < .01 for both). The incidences of diabetes mellitus and atrial fibrillation in the 2 age groups were not significantly different (P > .05), whereas the incidence of a history of stroke or TIA was significantly higher in group II (P < .01). The age groups were not significantly different with respect to the incidence of a previous myocardial infarction (P > .05), but the incidences of peripheral vascular disease and renal failure were higher in group II (P < .05 for both). EuroSCORE values were significantly higher in group II (P < .01).

The numbers of distal anastomoses were significantly higher in group II in patients who underwent operations with the DCT and those who underwent the on-pump cross-clamp off technique (P < .05, and P < .01, respectively). Cross-clamp times in both age groups were significantly shorter (P < .01) in patients who underwent operation with the DCT than in those who underwent operation with the SCT. The different operation techniques did not influence CPB times (P > .05).

Three of the 480 patients in group I died, with only 1 (33.3%) of the deaths related to stroke. In group II, however, 2 (50%) of the 4 deaths were related to stroke. The incidences

Table 2. Surgical Maneuvers*

	Group I (n = 480)			Group II (n = 410)		
	On-Pump (n = 450), n	Off-Pump (n = 30), n	P	On-Pump (n = 385), n	Off-Pump (n = 25), n	P
Partial clamp on	DCT, 344 (76.4%)	22 (73.3%)	.585	DCT, 256 (66.5%)	20 (80%)	.015
Partial clamp off	SCT, 96 (21.3%)	8 (26.7%)		SCT, 112 (29.1%)	5 (20%)	
On-pump cross-clamp off	10 (2.2%)	—		17 (4.4%)	—	

*P values are for χ^2 tests.

Table 3. On-Pump Intraoperative Variables*

	Group I, On-Pump (n = 480)				Group II, On-Pump (n = 410)			
	DCT (n = 366)	No CC (n = 10)	SCT (n = 104)	*P*	DCT (n = 276)	No CC (n = 17)	SCT (n = 117)	*P*
Aorta cannulation, n†	344 (93.9%)	—	96 (92.3%)	.585	256 (92.7%)	—	112 (95.7%)	.298
Femoral artery cannulation, n†	—	10 (100%)	—	—	—	17 (100%)	—	—
No. of distal anastomoses‡	3.4 ± 0.9	2.6 ± 0.7	3.8 ± 0.8	.001	3.6 ± 0.8	2.8 ± 0.7	3.8 ± 0.8	.006
CC time, min§	48 ± 19	—	78 ± 22	.001	50 ± 25	—	80 ± 26	.001
CPB time, min‡	106 ± 45	141 ± 65	110 ± 47	.122	120 ± 51	150 ± 63	119 ± 53	.118

*DCT indicates double-clamp technique; CC, cross-clamp; SCT, single-clamp technique; CPB, cardiopulmonary bypass.

†χ^2 test.

‡Data are presented as the mean ± SD. One-way analysis of variance, post hoc Tukey HSD test.

§Data are presented as the mean ± SD. Student t test.

of stroke-associated mortality in the 2 age groups were not significantly different (*P* = 1.0; Table 5).

In group I, the operation procedures had significantly different numbers of distal anastomoses (*P* < .01). A post hoc Tukey HSD test performed to understand this difference revealed that the number of distal anastomoses in on-pump cross-clamp off cases was significantly lower than the numbers of distal anastomoses performed in DCT cases and in SCT cases (*P* = .012, and *P* = .004, respectively). The number of distal anastomoses was significantly higher in SCT patients than in DCT patients. In group I, the incidences of stroke in the DCT and SCT subgroups were not significantly different (*P* = 1.00).

In group II, the operation procedures had significantly different numbers of distal anastomoses (*P* < .01). A post hoc Tukey HSD test revealed that the number of distal anastomoses in on-pump cross-clamp off cases was significantly lower than the numbers of distal anastomoses in DCT cases and in SCT cases (*P* = .012, and *P* = .009, respectively). The number of distal anastomoses was significantly higher in SCT patients than in DCT patients (*P* = .044). In group II, the incidences of stroke in the DCT and SCT subgroups were not significantly different (*P* > .05). These results are summarized in Table 4.

COMMENT

Stroke is a serious, potentially devastating complication following coronary surgery and seriously modifies the short- and long-term prognoses of cardiac surgery. Cerebral microemboli generated during CABG with CPB can be implicated in postoperative neurologic impairment. The dislodgement of material after vascular injury caused by surgical manipulation has been recognized as a major cause of stroke after open heart surgery.

Also well documented are other preoperative risk factors, including hypertension, an older age, and concomitant carotid artery disease [John 2000; Stamou 2001]. Cerebral embolization of macro- and microemboli has been shown to be the most common mechanism and is related to the use of CPB. Atherosclerotic disease of the ascending aorta has been thought to contribute significantly to the release of emboli during aortic manipulation and clamp application during CABG. Air/fat embolism, hemodynamic fluctuation, cerebral hyperthermia, and systemic inflammatory reaction are other physiological dysfunctions elicited by CPB that can contribute to neurologic damage [Barbut 1994; Grega 2003]. Therefore, avoiding aortic manipulation decreases the incidence of adverse neurologic outcomes. Aranki and colleagues [1994] reported that SCT patients had more favorable outcomes, such as fewer strokes. On the other hand, Musumeci and colleagues [1998] reported that the SCT was not as effective as intermittent ischemic arrest for preventing myocardial ischemia and neurologic problems, despite more aortic manipulation. These investigators reported that the major risk factors during CABG with CPB were preoperative risk factors, such as previous stroke and carotid artery disease. When patients with these preoperative risk factors were excluded, the neurologic outcomes after CABG for patients older and younger than 65 years were the same.

Kim and colleagues [2001] concluded that use of an SCT does not prevent stroke. Grega et al [2003] found stroke rates of 1.1% in SCT patients and 2.9% in DCT patients; avoiding a second clamp decreases the risk of aortic emboli [Barbut 1994; Kim 2001]. Use of an SCT increases the cross-clamp time and leads to opening of a closed system, which can increase the risk of cerebral air emboli [Kim

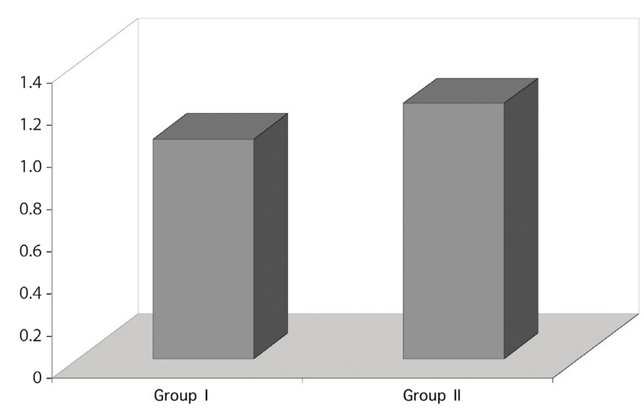

Figure 2. The distributions of stroke rates by age group.

Table 4. Relationship between Surgical Maneuver and Stroke*

	Partial Clamp On, n	Partial Clamp Off, n	On-Pump CC Off, n	*P*
Group I on-pump (n = 450)				
Stroke (+)	DCT, 3 (0.9%)	SCT, 1 (1.0%)	1 (10%)	.025
Stroke (−)	DCT, 341 (99.1%)	SCT, 95 (99.0%)	9 (90%)	
Group I off-pump (n = 30)				
Stroke (+)	0	0	–	–
Stroke (−)	22 (100%)	8 (100%)	–	
Group II on-pump (n = 385)				
Stroke (+)	DCT, 3 (1.2%)	SCT, 1 (0.9%)	0	.884
Stroke (−)	DCT, 253 (98.8%)	SCT, 111 (99.1%)	17 (100%)	
Group II off-pump (n = 25)				
Stroke (+)	1 (5.0%)	0	–	1.00
Stroke (−)	20 (95.0%)	5 (100%)	–	

**P* values are for χ^2 tests. CC indicates cross-clamp; DCT, double-clamp technique; SCT, single-clamp technique.

2001]. The open aorta may also complicate the venting of the left ventricle by gravity or suction. Some surgeons have argued that the DCT abolishes the effect of extending the cross-clamp time on myocardial protection. On the other hand, surgeons advocating use of the SCT argue that it causes a more uniform distribution of cardioplegia and more effective reperfusion after removal of the aortic clamp [Aranki 1994; Kim 2001]. However, surgeons advocating the DCT state that this myocardial-protection technique has no effect, because a short ischemia time and immediate internal mammary artery perfusion are also possible with the DCT. The total incidences of stroke in our study were 1.7% for the SCT and 2% for the DCT. There was also no difference between the SCT and the DCT in the incidence of stroke for higher-risk patients older than 65 years (0.3% in SCT patients and 1.2% in DCT patients) [Kim 2001]. Therefore, the SCT is not a key factor for cerebral protection during CABG surgery. The prevention of stroke after CABG requires a multifactorial approach. Because the site of embolization is related not only to the side clamp but also to cross-clamp usage, CPB flow, aortic cannulation, and the aortic punch. The origin of embolization may be the left atrium in patients with atrial fibrillation. All of these potential sites of embolization are independent of the side clamp [Kim 2001]. The frequency of cerebral ischemia related to carotid artery disease and intracranial thrombosis is also not related to side-clamp use.

Diegeler and coworkers [2000] demonstrated a significant difference between conventional and off-pump CABG with respect to microemboli and postoperative neurophysiological dysfunction. We preferred the SCT technique, not the DCT, in patients with carotid artery disease and peripheral artery disease; however, we have tried to decrease the ischemic time during the DCT as much as possible to achieve better myocardial protection. The incidence of stroke was 1.04% in group I and 1.21% in group II, a difference that was not significantly different.

Even though the off-pump and the on-pump cross-clamp off techniques were performed for some of the patients, the DCT and the SCT were used in the majority of the patients. In our study, neither group I nor group II showed any significant difference between the DCT and the SCT with respect to the stroke rate. We concluded that this result was due to the different surgical techniques performed for the minority of the patients (82 patients).

A recent longitudinal study reported the incidence of neurocognitive disease after CABG to be 53% at discharge, 36% at 6 weeks after the operation, and 24% at 6 months [Newman 2001]. The risk factors that have been described were an older age, an apolipoprotein E4 genotype [Tardiff 1997], the rate of rewarming after hypothermic CPB [Grigore 2002], and postoperative hyperthermia [Grocott 2002]. Cerebral embo-

Table 5. Evaluation of Postoperative Measurements by Age Group

	Group I (n = 480)	Group II (n = 410)	*P**
Myocardial infarction, n	4 (0.9%)	2 (0.5%)	.688†
Stroke, n	5 (1.04%)	5 (1.21%)	.802
Renal failure (acute), n	1 (0.2%)	4 (1.0%)	.187†
Reexploration for bleeding, n	4(0.8%)	6 (1.5%)	.374
Atrial fibrillation, n	57 (11.9%)	45 (11.0%)	.675
Prolonged inotrope use, n	39 (8.1%)	52 (12.7%)	.025
Intensive care unit stay, d‡	1 (1-14)	1 (1-18)	.765§
Length of stay, d‡	5 (4-35)	5 (4-63)	.812§
Hospital 30-d mortality, n	3 (0.6%)	4 (1.0%)	.709

**P* values are for χ^2 tests except where indicated.
†Fisher exact test.
‡Data are presented as the median (range).
§Mann-Whitney *U* test.

lization with macro- and microemboli has been shown to be one of the most common factors for neurocognitive disease [Stump 1996; Braekken 1998]. Although focal macroemboli are considered a major etiologic factor for stroke after cardiac surgery, neurocognitive disease probably reflects a more diffuse cerebral injury involving different pathophysiological mechanisms and risk factors [Harrison 1995]. Possible mechanisms include cerebral microemboli, global cerebral hypoperfusion, cerebral and systemic inflammatory responses, cerebral edema formation, and hyperthermia-related cerebral damage [Grocott 2002; Bar-Yosef 2004].

Salazar and colleagues [2001] reported a stroke rate of 3.2% in patients who underwent isolated CABG. Zingone et al [2006] reported that epiaortic scanning might be helpful for decreasing stroke rates after manipulation of the aorta and aortic cannulation. Previous stroke is also a major risk factor for stroke after CABG [Almassi 1999]. Filsoufi and colleagues [2008] found 4 independent predictors of postoperative stroke after CABG: extensive aortic calcification, congestive heart failure, previous cerebrovascular accident, and female sex. The total incidence of stroke was 1.6% in their study, and the mortality rate for patients with stroke was 10 times higher than in patients without stroke [Filsoufi 2008].

In our study, there were 3 deaths among the 480 patients younger than 65 years of age, and one (33.3%) of these deaths was related to stroke. There were 4 deaths in the 410 patients older than 65 years, and 2 (50%) of these deaths were related to stroke. The 2 groups were not significantly different with respect to stroke-related mortality ($P = .576$). McKhann and colleagues [2006] have suggested that watershed stroke is associated with a higher mortality rate than embolic stroke.

Cerebral microembolization during CPB has been reported to occur primarily during aortic cannulation, setting of the cross-clamp, or removal of the clamp [Barbut 1994; Goto 2003]. It is very difficult to determine the actual site of embolization during CPB [Goto 2003]. Transcranial Doppler ultrasonography is a useful technique for quantifying and detecting the source of microemboli during CPB [Clark 1995]. In the present study, the incidences of hypertension, smoking, previous stroke, TIA, and peripheral arterial disease were significantly higher in group II than in group I, but the 2 age groups were not significantly different with respect to the incidences of carotid artery disease and the numbers of diseased vessels.

Extensive atherosclerosis of the aortic arch and carotid artery disease are associated with a high incidence of stroke [Cosgrove 1983; Brener 1987]. Faggioli and associates [1990] suggested that prophylactic carotid endarterectomy in patients with high-grade or bilateral disease may reduce the incidence of perioperative stroke. In our search for the most suitable technique to use for myocardial revascularization, however, we found no significant differences between methods with respect to the incidence of stroke, despite the multifactorial etiology of this adverse outcome.

Trehan et al [2000] found incidences of significant carotid stenosis (>70%) and nonsignificant stenosis of 2.88% and 7.08%, respectively. These investigators also reported that the highest incidence of atheroma was in the distal aortic arch, followed by the proximal aortic arch. The lowest incidence was in the ascending aorta. Their results were similar with those of Sternby [1968], who studied 1486 postmortem examinations. Sternby reported that atherosclerotic disease was mostly seen at the aortic arch and the descending aorta. Ricotta and colleagues [1995] demonstrated that significant carotid artery stenosis was present in 11.3% of asymptomatic patients older than 60 years. In the present study, the incidences of significant carotid artery stenosis were 7% in group I and 9% in group II. These patients were excluded from the study. Demopoulos et al [1995], however, reported a 20% incidence of carotid artery stenosis greater than 50%. The rates of stroke after CABG in patients with symptomatic and asymptomatic carotid artery disease were reported to be as high as 17% in different studies [Brener 1987; Hertzer 1989]. Therefore, with respect to the incidence of stroke, there were no significant differences between surgical techniques in patients with carotid artery disease.

In conclusion, the typically poor postoperative course of patients who develop stroke after CABG underlines the need for timely recognition, prevention, and modification of the factors that predispose to stroke. Each surgical technique has its advantages and disadvantages. Therefore, insisting that the same surgical technique be applied to all patients who undergo CABG is inappropriate and inadequate. The risk of stroke after CABG surgery can be successfully managed, especially in high-risk patients, by choosing an adequate and appropriate surgical technique.

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