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Off-Pump versus On-Pump Coronary Artery Bypass: Can OPCAB Reduce Neurologic Injury?

Dr. Schmitz

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C. Schmitz,[1] S. Weinreich,[1] R. Schneider,[1] D. Schneider,[1] I. Speth,[1]
C. Schulze-Rauschenbach,[1] C. Pohl,[2] A. Welz[1]

Departments of [1]Cardiac Surgery and [2]Neurology, University of Bonn, Bonn, Germany

ABSTRACT

Objective: Coronary artery bypass grafting (CABG) with cardiopulmonary bypass is still the gold standard for surgical myocardial revascularization. Despite advances in techniques and technologies, documented evidence indicates that cardiopulmonary bypass remains the major source of intraoperative brain injury. This study was set up to test whether off-pump coronary artery bypass (OPCAB) is superior to CABG regarding postoperative neurologic outcome or neurocognitive function.

Methods: Between January 1999 and June 2001, 251 patients scheduled for coronary revascularization were divided into 2 groups, CABG (control) and OPCAB. All patients underwent an extensive neurologic and neurocognitive battery of tests preoperatively and postoperatively at 48 hours, 7 days, and 3 months following surgery.

Results: There were no statistically significant differences between the 2 groups regarding the preoperative or intraoperative data. The means for patient age, number of grafts, and number of central anastomoses were, respectively, 65.4 years (CABG) and 64.6 years (OPCAB), 3.0 (CABG) and 2.2 (OPCAB), and 2.0 (CABG) and 1.2 (OPCAB). The occurrence of stroke was 2.3% (CABG) and 0% (OPCAB).

Conclusion: Neurologic complications and postoperative neurocognitive dysfunction remain major concerns in coronary artery surgery. Besides the occurrence of stroke, which dramatically reduces the success of the heart operation, the importance of neurocognitive disorders for postoperative quality of life is not yet well defined. OPCAB significantly improves postoperative neurocognitive function, which may in turn improve the postoperative quality of life.

INTRODUCTION

Although remarkable advances have been made in coronary artery surgery in the past decade, complications due to neurologic injury continue to have a devastating impact on the overall outcome. The reported incidence of neurologic complications after coronary artery surgery is between 3% and 7%, the percentage depending mainly on the study design [Newman 1996, Roach 1996]. Despite advances in technologies and techniques, the incidence has been remarkable stable during the past 2 decades.

Although the causes for perioperative stroke may be multifactorial, embolization of atherosclerotic material from the ascending aorta has been identified as the most common pathogenetic mechanism [Barbut 1996a]. In coronary artery surgery, displacement of atherosclerotic plaques from the aorta may occur as a result of various maneuvers, such as aortic palpation, cannulation, and the use of cross- and partial side-biting clamps [Barbut 1996b].

A major problem in assessing the efficacy of a new method aiming to decrease neurologic damage during coronary artery surgery is the low incidence of stroke. Looking at large numbers of enrolled study cases is the best way to address this issue. For this reason, we started a program in January 1999 in Bonn to assess neurologic injury during cardiac surgery. For 3 years we built up a database of more than 600 patients who underwent different cardiac surgical procedures and techniques.

PATIENTS AND METHODS

From October 1998 to July 2001, more than 600 patients were entered prospectively into the database. One hundred seventy-six patients underwent standard coronary artery bypass grafting with cardiopulmonary bypass (CABG), and 75 patients underwent off-pump coronary artery bypass on the beating heart (OPCAB). Both groups of patients were evaluated with standard neurologic assessments and a subset of each group received extensive neurologic, neurocognitive, and neuropsychologic testing. The remaining patients were not included in this analysis due to combination valve/CABG procedures or the use of an intraaortic filter system.

CABG patients received standard surgery per the normal protocols and procedures of our center. These protocols include cardiopulmonary bypass using aortic and single 2-stage venous cannulas, a target flow rate of 2.4 L/m^2 per minute, and a core body temperature of 32°C to 34°C. Myocardial protection is achieved with Buckberg's cold blood cardioplegia or Bretschneider's cardioplegia. Central anastomoses are sewn with the assistance of a partial clamp after the removal of the aortic cross-clamp.

Different mechanical stabilizers were applied for OPCAB patients. In most cases, the left internal mammary artery was

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Address correspondence and reprint requests to: Christoph Schmitz, MD, Klinik und Poliklinik für Herzchirurgie, Herzzentrum Universität Bonn, Sigmund-Freud-Strasse 25, 53105 Bonn, Germany; 49-02-28-2-87-41-93; fax: 49-02-28-2-87-90-00-41-93 (e-mail: Christoph.Schmitz@ukb.uni-bonn.de).

Table 1. Neuropsychologic and Neurocognitive Test Protocol*

Neuropsychologic Testing	Main Cognitive Domain	Preoperative	Postoperative, 3 mo
CI Test of Cerebral Insufficiency	Frontal lobe	✓	✓
Digit Span Test (version A & B)	Short-term memory	✓	✓
Auditory Verbal Learning Test (A & B)	Verbal learning and retrieval	✓	✓
D2 Test of Selective Attention	Attention and vigilance	✓	✓
WFL Word Fluency Test (A & B)	Frontal Lobe	✓	✓
DCS Cerebral Vascular Insufficiency Test (A & B)	Spatial learning and retrieval	✓	✓
Token Test	Aphasia	✓	✓
Pegboard Test	Motor skills	✓	✓
MWWT (IQ) Verbal Intelligence Test	Cognition	✓	
Hospital Anxiety Depression Scale-D	Emotion	✓	✓
Maze Test/Trail-Making Test (3 levels)	Frontal lobe	✓	✓
SIP Quality of Life Test	Multifactorial	✓	✓

*DCS indicates Diagnostikum für Cerebralschäden; MWWT, Mehrfachwahl Wortschatztest; SIP, sickness impact profile.

anastomosed first. Then distal anastomoses were done in the following sequence: branches of the left anterior descending artery, branches of the left circumflex artery, and branches of the right coronary artery. Proximal anastomoses were usually performed last with a partial cross-clamp on the ascending aorta. Before the cross-clamp was applied, the arterial pressure was lowered to less than 80 mm Hg with either nitroglycerin or inflow occlusion.

The study design was controlled but was not randomized. Patients scheduled for nonemergent coronary artery surgery were eligible for inclusion in the study. Eighteen of the 75 CABG patients and 17 of the OPCAB patients underwent an additional neurocognitive and neuropsychologic battery of tests (Table 1). Patients with a carotid stenosis greater than 70%, an ejection fraction lower than 20%, and a native language other than German were excluded from the study.

All patients were given preoperative and postoperative neurologic examinations by trained staff of the University of Bonn. Postoperative examinations took place 48 hours after the operation and at discharge from our cardiac unit, usually 7 to 10 days after the operation. The examination consisted of the determination of neurologic status as well as assessments on the National Institutes of Health Stroke and Glasgow Coma scales. Patients were also seen 3 months after the operation.

Statistical Analysis

Preoperative, procedural, and postoperative data were submitted to a central database for analysis. Chi-square tests were used to analyze the risk factors. A Student t test was applied in the analysis of continuous variables, and the Fisher exact test was used for analyzing outcome variables. Differences between groups were considered statistically significant if the P value was less than .05.

RESULTS

There were no statistically significant differences between the 2 groups regarding preoperative patient data. These data are outlined in Table 2.

The mean ages were 65.4 years (CABG), and 64.6 years (OPCAB). The CABG group consisted of 75% males versus 69% in the OPCAB group. The incidences of prior myocardial infarction (44% versus 42%), prior transient ischemic attack or stroke (11% versus 14%), unstable angina (8% versus 14%), hypertension (65% versus 78%), and diabetes (19% versus 22%) were very similar for the 2 groups.

The mean numbers of grafts was 3.0 (CABG) and 2.2 (OPCAB), and the mean numbers of central anastomoses were 2.0 (CABG) and 1.2 (OPCAB).

Neurologic outcomes are shown in Table 3. Coma occurred in 0.6% of the patients in the CABG group and in 0% of the OPCAB group. Stroke and transient ischemic attack were both noted to be 2.3% in the CABG group and 0% in the OPCAB group. Delirium was found in 7.3% of CABG patients and in 2.7% of OPCAB patients. Mortality was 4.0% in the CABG group and 0% in the OPCAB group.

DISCUSSION

Neurologic complications and postoperative neurocognitive dysfunction remain a major concern in heart operations

Table 2. Preoperative Patient Data*

	CABG	OPCAB	*P*
Age, y	65.4 (176)	64.6 (75)	
Male sex	75% (131/176)	69% (52/75)	.74
Prior MI	42% (75/175)	44% (33/75)	.90
Prior TIA, stroke	14% (25/176)	11% (8/75)	.57
Unstable angina	14% (24/176)	8% (6/75)	.26
Hypertension	78% (138/176)	65% (49/75)	.40
Diabetes	22% (39/176)	19% (14/75)	.61

*Numbers in parentheses are numbers of patients. CABG indicates coronary artery bypass grafting with cardiopulmonary bypass; OPCAB, off-pump coronary artery bypass on the beating heart; MI, myocardial infarction; TIA, transient ischemic attack.

Table 3. Neurologic Outcomes*

	CABG	OPCAB	*P*
Coma	0.6% (1/176)	0% (0/75)	1.00
Stroke	2.3% (4/177)	0% (0/75)	.32
TIA	2.3% (4/177)	0% (0/75)	.32
Delirium	7.3% (13/177)	2.7% (2/75)	.24
Mortality	4.0% (7/177)	0% (0/74)	.20

*Numbers in parentheses are numbers of patients. Abbreviations are expanded in the footnote to Table 2.

with cardiopulmonary bypass [Engelman 1999]. Besides the occurrence of stroke, which dramatically reduces the success of the heart operation, the importance of neurocognitive disorders for postoperative quality of life is not yet well defined. However, Newman and coworkers confirmed the relatively high prevalence and persistence of cognitive decline after CABG and suggested that a pattern of early improvement was followed by a later decline predicted by the presence of an early postoperative cognitive decline [Newman 2001].

To reduce complications and trauma, minimally invasive technologies and techniques have been developed during the last decade [Mack 2000, Subramanian 2001]. Beating heart operations have received unparalleled attention, which has resulted in the development of sophisticated retractors, stabilizers, and heart positioners [Jansen 1998, Dullum 2000]. Some investigators have theorized that these advances should improve neurologic and neuropsychologic outcomes after cardiac surgery [Patel 2002].

Despite these efforts, neurologic injury remains a devastating and persistent surgical complication. Patients, families, surgeons, and the entire health care system bear a great burden each time a stroke occurs in cardiac surgery. A 1996 study by Roach and colleagues analyzed 2108 patients from 24 US centers [Roach 1996]. The investigators demonstrated that 6.1% of CABG patients experienced an adverse cerebral outcome, a far more common phenomenon than had been recognized previously. They further reported that these patients had 5 to 10 times the mortality rate, stayed 2 to 4 times longer in intensive care, and required 3 to 6 times more prolonged care, compared with patients without adverse cerebral events. Although a multifactorial etiology for this problem is recognized, aortic atheromatosis has repeatedly been reported as the greatest risk factor, and recent articles have highlighted the central role of arterial embolization in neurologic injury [Murkin 2001].

Previous studies using transesophageal echo and transcranial Doppler techniques demonstrated that embolization is associated with surgical manipulation of the heart and the ascending aorta during the operation [Barbut 1996a, Barbut 1996b]. The surgical periods associated with embolization are removal of the aortic cross-clamp, partial clamping, and cannulation. Although off-pump coronary artery surgery does not eliminate the use of a partial clamp, there is no need for aortic cannulation or the use of a cross-clamp. These changes should result in less arterial embolization and consequently produce a better cerebral outcome.

Preoperative patient data were similar for both groups with regard to documented risk factors for neurologic injury during cardiac surgery. The number of adverse neurologic events was very low in both groups, resulting in *P* values far from significance. However, the trend showing less neurologic injury in the OPCAB group is evident. This result emphasizes the need for even larger numbers of patients to be included in such analyses.

The authors acknowledge some limitations of the present study. The patients selected for either group were highly selected regarding the feasibility of doing the operation off-pump. This limitation of the design is the major drawback of most studies published in this field. It can be seen in the total number of grafts (2.2 in OPCAB versus 3.0 in CABG patients) as well as in the number of central anastomoses (1.2 versus 2.0). Finally, a randomized comparison of CABG and OPCAB patients would be desirable.

CONCLUSIONS

Preliminary clinical results indicate a possible trend toward a reduction in the incidence of adverse neurologic events in coronary patients who undergo surgery without cardiopulmonary bypass. This finding underlines the need to evaluate neurocognitive and neuropsychologic function more exhaustively. Support for this hypothesis requires increased patient numbers and continued study.

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