Comparison of Off-pump and On-pump Coronary Artery Bypass Grafting in Midterm Results

Objective: **Off-pump coronary artery bypass grafting (OPCAB) has become a procedure of choice for surgical treatment of coronary artery disease. Although early advantages of OPCAB were confirmed in comparison with conventional on-pump coronary artery bypass grafting (CABG), late cardiac complications are still controversial. We examined midterm results of OPCAB compared with standard CABG.** *Methods:* **Between July 1997 and April 2002, 736 consecutive patients who underwent isolated CABG were retrospectively reviewed. The OPCAB group (Group I) comprised 357 patients (49%), and the on-pump CABG group (Group II) 379 patients (51%). Their preoperative, intraoperative, and follow-up data were analyzed.** *Results:* **The mean number of distal anastomoses and the early graft patency were not greatly different between the two groups. The actuarial survival rate at 3 years was not significantly different between Group I (98.3%) and Group II (98.2%) (p=0.71). The frequency of cardiac events was 4.2%/patient-year in Group I and 2.6%/patient-year in Group II (p=0.12). The actuarial event free rates were not different between the two groups (p=0.61). The cardiac event free rates at 3 years were significantly (p=0.011) higher in patients with complete revascularization (96.7%) than without complete revascularization in Group I (69.2%) and in Group II (92.7% versus 85.9%, p=0.026).** *Conclusions:* **Midterm clinical outcome in OPCAB is as good as conventional on-pump CABG. Incomplete revascularization caused cardiac events more frequently than complete revascularization both in OPCAB and on-pump CABG in the intermediate follow-up. (Jpn J Thorac Cardiovasc Surg 2004; 52: 240–246)**

Key words: coronary artery bypass grafting, minimally invasive cardiac surgery

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Off-pump coronary artery bypass grafting (OPCAB) has become a procedure of choice in patients with operative risk factors for cardiopulmonary bypass (CPB). The frequency of OPCAB has increased gradually[1] because CPB induces a systemic inflammatory response and other adverse consequences. Improved stabilizers and other instruments have also accelerated the increase of OPCAB.

The advantages of OPCAB were reduction in operation time, bleeding, hospitalization, transfusion, and early morbidity. Although early graft patency of OPCAB is comparable with conventional coronary artery bypass grafting (CABG) with CPB, the difference in the cardiac event free rate between OPCAB and conventional on-pump CABG is still controversial. The lower number of grafts and quality of anastomosis may affect those long-term outcomes.

In the present study, we retrospectively examined the morbidity after discharge associated with CABG and assessed the efficacy of OPCAB, compared with conventional on-pump CABG.

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Subjects and Methods

Between July 1997 and April 2002, 736 consecutive patients who underwent isolated CABG in our institution were retrospectively reviewed.. The OPCAB group (Group I) comprised 357 patients (49%), and the on-pump CABG group (Group II) 379 (51%). Preoperative demographic data are summarized in Table I. The

Table I. *Baseline characteristics*

Variables	*Group I (n=357)*	*Group II (n=379)*	*p value*
Clinical characteristics			
Age, mean (SD) (year)	66.6 (8.8)	64.6 (8.8)	0.013
Male, %	83.2	86.3	0.24
Angiographic profile			
Left main disease, %	25.2	24.2	0.77
One-vessel disease, %	4.5	1.6	0.02
Two-vessel disease, %	14.6	17.7	0.25
Three-vessel disease, %	55.7	56.5	0.84
Cardiac profile			
Unstable angina, %	22.7	28.5	0.07
Acute myocardial infarction, %	5.3	4.0	0.38
Previous myocardial infarction, %	28.9	24.0	0.14
Poor ejection fraction (<30%), %	3.4	3.7	0.81
Redo surgery, %	2.5	5.8	0.03
Emergency surgery, %	8.4	9.0	0.78
Preoperative IABP, %	2.2	4.5	0.09
Comorbidity			
Hypertension, %	65.0	68.1	0.37
Diabetes, %	46.2	47.0	0.84
Hyperlipidemia, %	54.9	49.3	0.13
Cerebral vascular disease, %	18.8	11.6	0.0067
Chronic renal failure, %	9.0	3.2	0.0009
Dialysis, %	3.4	1.6	0.12
Chronic pulmonary obstructive disease, %	2.0	2.9	0.41

IABP, Intra-aortic balloon pumping.

mean age at operation was significantly older in Group I (66.6±8.8 years) than in Group II (64.6±8.8 years) (p=0.013). OPCAB was performed more frequently in patients with cerebral vascular disease and chronic renal failure. Redo CABG was more frequently performed with cardiopulmonary bypass. About 2 weeks after the operation, 670 patients (91%) underwent coronary and graft angiography.

Follow-up data were compiled by April 30, 2002. The data of patients followed up in our out-patient clinic were obtained from their records. The data of other patients were obtained by primarily questionnaires and telephone interviews. The follow-up was completed in 100% of the patients. The interval from the operation was 1.0±0.8 years in Group I, and 3.2± 1.0 years in Group II (p<0.0001). In the early series, patients with single vessel disease and who needed less distal anastomoses were assigned for OPCAB (Group I). During this period, OPCAB has gradually increased and replaced on-pump CABG (Fig. 1). The occurrence of new cardiac events after discharge, such as admission for congestive heart failure and tachyarrhythmia, refractory angina requiring angioplasty or redo CABG, acute myocardial infarction, or cardiac death was conducted. Late coronary angiography was performed for patients with recurrent ischemic events on symptoms.[2]

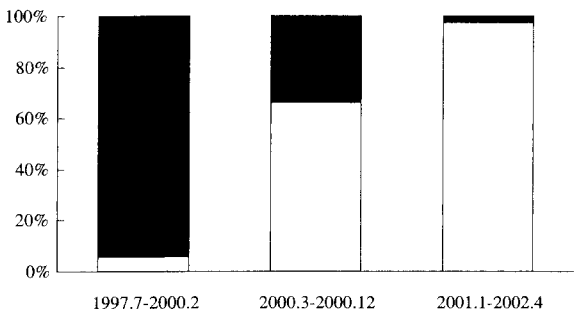

Fig. 1. Percentage for patients with OPCAB or on-pump CABG. OPCAB has gradually increased and replaced on-pump CABG.
□ Group I, ■ Group II.

Complete revascularization was defined as the revascularization of at least one bypass in each of the three major coronary artery systems diseased, and not being necessary to bypass every stenotic vessels, regardless of the number involved.[3-10]

Table II. *Intraoperative characteristics*

Variables	*Group I (n=357)*	*Group II (n=379)*	*p value*
Number of distal anastomoses,			
mean (SD)	3.1 (1.0)	3.2 (1.0)	0.074
Arterial graft bypass, %	93.2	58.3	<0.0001
Grafted vessel, %			
LAD	99.7	100	0.98
Dx	36.7	34.6	0.14
HL or OM	29.1	46.4	<0.0001
PL	57.1	54.1	0.45
4AV	23.5	17.2	0.04
PDA	49.3	49.9	0.94
RCA	8.1	17.4	0.0003
Early graft patency,%	96.9	97.1	0.80
Complete revascularization, %	73.4	77.8	0.17

LAD, Left anterior descending artery; *Dx*, diagonal branch; *HL*, high lateral branch; *OM*, obtuse marginal branch; *PL*, posterolateral branch; *AV*, atrioventricular artery; *PDA*, posterior descending artery; *RCA*, right coronary artery.

Operative technique. Conventional CABG was performed with CPB using an ascending aortic perfusion cannula and single venous cannula. Myocardial protection was achieved with antegrade and retrograde tepid blood cardioplegic arrest under aortic cross-clamping. OPCAB was performed through a median sternotomy. The details of the procedure were previously described.[11] Partial clamping of the ascending aorta was performed for the proximal anastomosis in 27 patients (7.6%). In 330 patients (92.4%), OPCAB was performed by the aorta "no-touch" technique with a combination of in situ and composite grafting.

Statistical analysis. Values are presented as means ±standard deviations. Continuous variables were compared by the Wilcoxon rank sum test and discrete variables were analyzed using Fisher's exact test. Probability of survival or event free rate was calculated by the Kaplan-Meier life-table method and differences were analyzed by Mantel-Cox. Differences were considered statistically significant at $p<0.05$.

Results

The mean number of distal anastomoses was 3.1± 1.0 in Group I, and 3.2±1.0 in Group II (p= 0.074). The arterial grafts were more frequently used in Group I (93.2% of all grafts) than in Group II (58.3%) (p<0.0001). Anastomosis was more frequently performed for the atrioventricular artery (AV) in Group I (p=0.04), and for the high lateral branch (HL) or the obtuse marginal branch (OM) and the right coronary artery (RCA) in Group II (p<0.0001, 0.0003, respectively). The early graft patency was not significantly different between the two groups (96.9% in Group I and 97.1% in Group II, p=0.80) (Table II).

The incidence and causes of early and late events are listed in Table III. The actuarial survival rate at 3 years in Group I (98.3±0.8%) was not significantly different from that in Group II (98.2±0.7%) (p=0.71) (Fig. 2). The incidence of hospital deaths in Group I (1.4%) was not significantly different from that in Group II (1.3%) (p=0.92). The late mortality was 5 patients (1.4%) in Group I and 3 (0.8%) in Group II. Cardiac events occurred in 15 patients (4.2%) in Group I and 32 (8.4%) in Group II (Table III). The frequency of cardiac events after discharge was 4.2±1.1%/patient-year in Group I and 2.6±0.5%/patient-year in Group II (p=0.12). The actuarial event free rates were not significantly different between the two groups (p=0.61) (Fig. 3).

Complete revascularzation was performed in 73.4% in Group I. The actuarial survival rate at 3 years saw a minimal difference between patients with complete and incomplete revascularization (99.1±0.7% versus 96.3 ±2.1%, p=0.10) (Fig. 4). The cardiac event free rate at 3 years was significantly (p=0.011) higher in patients who received complete revascularization (96.7±1.5%) than in patients who did not (69.2±16.0%) in Group I (Fig. 5). Similarly in Group II, 77.8% patients received complete revascularization. The actuarial survival rate

Table III. *Midterm clinical outcome*

Outcome	*Group I (n=357)*	*Group II (n=379)*	*p value*
Death (total)	10 (2.8%)	8 (2.1%)	
hospital death	5 (1.4%) cerebral bleeding 1 pneumonia 1 mediastinitis 1 sepsis 1 AMI 1	5 (1.3%) low output syndrome 3 VSP 1 respiratory insufficiency 1	0.92
late death	5 (1.4%) cerebral infarction 1 gastric cancer 2 AMI 1 heart failure after AVR 1	3 (0.8%) ARDS 1 mediastinitis 1 cholecystic cancer 1	
Cardiac event (total)	15 (4.2%)	32 (8.4%)	
linearized rate	4.2±1.1%/pt-yr	2.6±0.5%/pt-yr	0.12
congestive heart failure	7 (2.0%)	13 (3.4%)	
reintervention	4 (1.1%)	13 (3.4%)	
cardiac death	3 (0.8%)	4 (1.1%)	
arrhythmia (VT)	1 (0.3%)	2 (0.5%)	
Non-cardiac event			
stroke	4 (1.1%)	10 (2.6%)	
linearized rate	1.1±0.6%/pt-yr	0.8±0.3%/pt-yr	0.62

VSP, Ventricular septal perforation; *AMI,* acute myocardial infarction; *ARDS,* adult respiratory distress syndrome; *AVR,* aortic valve replacement; *VT,* ventricular tachycardia.

at 3 years was similar in patients with complete and incomplete revascularization (98.6±0.7% versus 96.4 ±2.0%, p=0.18) (Fig. 6). The cardiac event free rate at 3 years who received complete revascularization was superior (92.7±1.6%) to patients who did not (85.9± 4.0%, p=0.026) (Fig. 7).

Discussion

OPCAB has become more common since the late 1990s after establishment of the deep pericardial suture technique and introduction of stabilizers.[12] The major advantages of OPCAB were reduction in operation time, blood loss, hospitalization, and transfusion.[1,13] Arom et al.[14] reported better early clinical results of OPCAB than standard CABG. After adjustment with the STS database model, they found that operative outcomes were better in the OPCAB group than in the conventional CABG group if the predicted risk was high. BHACAS studies, which were randomized controlled trials assessing the effects of cardiopulmonary bypass, showed significant reductions in early mortality and morbidity by OPCAB.[15] In our experiences, OPCAB contributed reduction of ventilation time, ICU stay, hospital stay, blood loss, requirement for transfusion, and in-hospital morbidity.[16] However, only a few long-term studies comparing OPCAB to on-pump CABG are available though short-term results were encouraging. In this study we examined midterm results of OPCAB and conventional on-pump CABG.

It was suggested that the reduction of early morbidity with OPCAB surgery might be at the expense of long-term results. Cooley et al.[17] reported that OPCAB with difficulty of access and exposure, especially when grafting vessels on the lateral or inferior wall, might compromise the quality of the anastomosis and result in the greater occurrence of late cardiac complications. Gundry et al.[18] performed a 7-year follow-up study comparing CABG with and without CPB. These results showed a similar incidence of cardiac and noncardiac deaths. The patients who had OPCAB needed repeat intervention with a percutaneous coronary intervention (PCI) or repeat CABG double those who had on-pump CABG. However, these results were performed before the introduction of stabilizers. Subramanian et al.[19] and Poirier et al.[20] compared OPCAB with or without myocardial stabilization and showed coronary artery anastomosis had a lower degree of

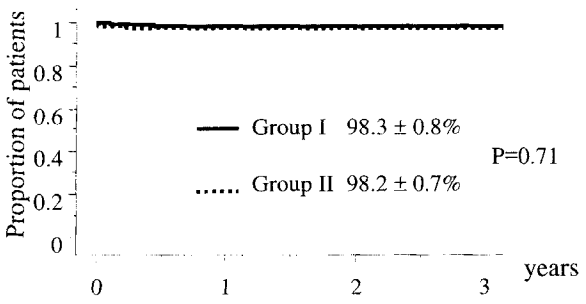

Fig. 2. Actuarial survival curve. Group I (98.3±0.8%) was not significantly different from that in Group II (98.2±0.7%) (p=0.71).

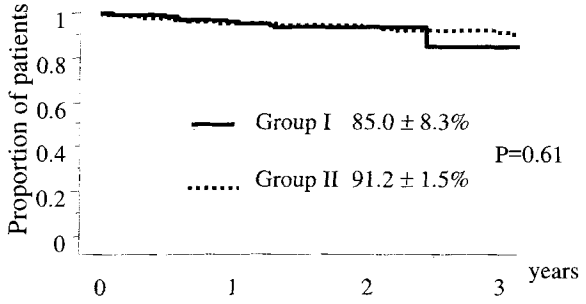

Fig. 3. Actuarial cardiac event free rate curve. The actuarial event free rates were not significantly different between the two groups (p=0.61).

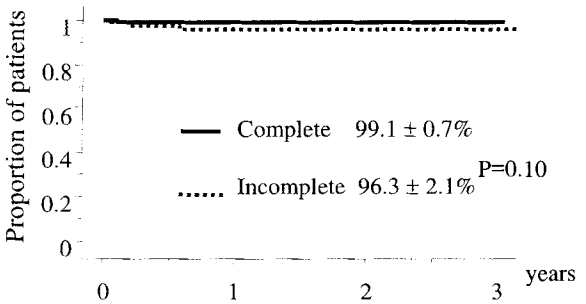

Fig. 4. Actuarial survival curve of patients with complete or incomplete revascularization in Group I. The actuarial survival rate at 3 years was not significantly different between patients who had complete and who had incomplete revascularization (99.1±0.7% versus 96.3±2.1%, p=0.10).

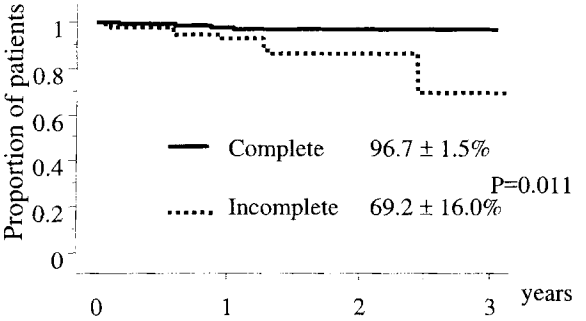

Fig. 5. Actuarial cardiac event free rate curve of patients with complete or incomplete revascularization in Group I. The cardiac event free rate at 3 years was significantly (p=0.011) higher in patients who received complete revascularization (96.7±1.5%) than in patients who did not (69.2±16.0%).

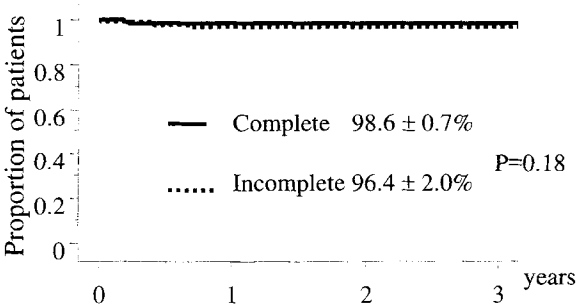

Fig. 6. Actuarial survival curve of patients with complete or incomplete revascularization in Group II. The actuarial survival rate at 3 years was similar in patients who had complete and incomplete revascularization (98.6±0.7% versus 96.4±2.0%, p=0.18).

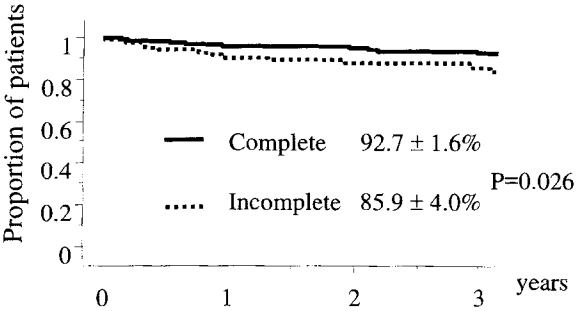

Fig. 7. Actuarial cardiac event free rate curve of patients with complete or incomplete revascularization in Group II. The cardiac event free rate at 3 years who received complete revascularization was superior (92.7±1.6%) to patients who did not (85.9 ±4.0%, p=0.026).

stenosis when mechanical stabilizers were used. In Gundry's results after OPCAB, PCI was performed in grafted vessels three times the one in ungrafted vessels.[18] This might have been caused by not only immature skills and lower quality of graft anastomoses but also by difficulty of access to the lateral and posterior coronary branches. In BHACAS studies, OPCAB and on-pump CABG groups recorded a similar low rate of cardiac-related events.[15] In the present study, we used both stabilizers and intracoronary shunts. Therefore, the cardiac event free and survival rate up to 3 years in the OPCAB group was as good as those in the on-pump CABG group.

Amano et al.[21] reported the event free rate of OPCAB patients was less favorable than on-pump CABG patients. Their mean number of distal anastomoses in OPCAB was 1.9 and 3.6 in the on-pump CABG group. They concluded that the observed long-term cardiac events might be related to incomplete revascularization. Several studies have dealt with the importance of complete revascularization in on-pump CABG. Those studies showed improved long-term results with fewer cardiac events in complete revascularization compared with incomplete revascularization,[3-5] though the definition of complete revascularization varied. Vander Salm et al.[22] evaluated the importance of complete revascularization by their definition. By the traditional definition, complete revascularization means the state where at least one vessel is grafted in each of the three major coronary artery systems, and bypass grafting every stenotic vessels is not necessary, regardless of the number of stenosed coronary branches, on which our present study was based. The rate of complete revascularization was relatively low, but it was similar to other studies[23,24] using the same definition, in which the rate of complete revascularization was about 70%. The main cause of incomplete revascularization was the surgeon's decision that the target vessel was too small. Our preoperative plan for grafting, in which we exclude the obviously ungraftable branches, was accomplished at 98%. In another study, the patients who underwent isolated left internal thoracic artery (LITA) to left anterior descending artery (LAD) grafting were followed up for 25 years.[24] In that study, in the late consequence of incomplete revascularization, survival rate and freedom from re-intervention were not improved. Isolated LITA to LAD grafting was not sufficient for patients with RCA, Cx, and left main trunk (LMT) lesions. The importance of complete revascularization should be recognized, and appropriate vessel requiring grafts should be ascertained. In the present study, complete revascularization for better prognoses was confirmed not only in the on-pump CABG group but also in the OPCAB group.

The present study had several limitations. Patients were not randomly assigned to the OPCAB group and the conventional CABG group. This was a retrospective study of patients operated during the period of our initial experience with OPCAB. Although it was reported that a shift from routine use of cardiopulmonary bypass to OPCAB was possible without an apparent increase in morbidity or change in technique,[25] the pattern of graft material has also changed by using artery grafts. The mean follow-up time was shorter in OPCAB groups in the present study. For precise evaluation, more than 5 years of follow-up will be required, and to remove these biases, randomized prospective studies of OPCAB is necessary to confirm the present preliminary results.

In conclusion, midterm results of OPCAB were satisfactory. Although OPCAB is technically demanding, progression of the OPCAB technique contributed to the high quality of anastomosis and increased the number of anastomotic sites. Complete revascularization is key for better long-term results in OPCAB.

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