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Early and Midterm Outcome of Redo Coronary Artery Bypass Grafting: On-Pump versus Off-Pump Bypass

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Background: Redo coronary artery bypass grafting (CABG) is still associated with increased morbidity and mortality as compared to the first-time operation. Further, the application of the off-pump technique to redo CABG is limited due to technical difficulties. The aim of this retrospective study was to analyze early and midterm results after redo CABG and compare the outcome of redo on-pump and off-pump CABG. ***Methods:*** From June 1996 to October 2011, elective redo CABG was performed in 32 patients. Mean age was 64.8 years (on pump 64.3 years vs. off pump 65.5 years; p=0.658), and 21 patients were male. Among these patients, 14 (43.8%) underwent on-pump CABG, and 18 (56.2%) underwent off-pump CABG. ***Results:*** Internal thoracic artery was used in 22 patients (68.8%), and total arterial revascularization was achieved in 17 patients (53.1%). The average number of distal anastomoses was 2.13, and the rate of incomplete revascularization was 43.8%. The rate of total arterial revascularization was higher in the off-pump group (14.3% vs. 83.3%, $p<0.001$), and the use of saphenous vein graft was more in the on-pump group (78.6% vs. 16.7%, $p<0.001$). Overall hospital mortality was 3.1% (n=1) and was comparable in both groups (on pump 7.1% vs. off pump 0%; p=0.249). Postoperative complications occurred in 9 patients (64.2%), and the rate of complications was high in the on-pump group without statistical significance (64.2% vs. 33.3%, p=0.082). The mean follow-up duration was 5.4 years, and overall survival at 10 years was 86.0%±10.5%. There was no significant difference in the 10-year survival rate between the two groups (79.6% vs. 100%, p=0.225). ***Conclusion:*** Redo CABG can be safely performed with acceptable mortality. Redo off-pump coronary artery bypass is feasible with low mortality and morbidity, comparable target vessel bypass grafting, and long-term survival. The off-pump technique might be considered a safe option for redo CABG in high-risk patients.

Key words: 1. Reoperation
2. Coronary artery bypass
3. Coronary artery bypass, off-pump

INTRODUCTION

The use of reoperative coronary artery bypass grafting (CABG) steadily increased during the two decades of 1980 and 1990. Since the early 2000s, however, the prevalence of redo CABG has reached a plateau as the time interval between the first operation and the reoperation has lengthened. This was mainly due to the higher patency of saphenous vein grafts owing to the routine postoperative use of aspirin and statins and wide use of left internal thoracic artery (ITA) [1]. In various studies, perioperative mortality of redo CABG remains markedly high, ranging from 3.4% to 12.5%, compared

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Table 1. Baseline characteristics (n=32)

Patient characteristic	Value
Age (yr)	64.8±7.5
Sex (female)	11 (34.4)
Smoking	10 (31.3)
Hypertension	22 (68.8)
Diabetes mellitus	12 (37.5)
Overweight (body mass index＞25 kg/m^2)	17 (53.1)
Dyslipidemia	9 (28.1)
History of stroke	4 (12.5)
Chronic kidney disease	2 (6.8)
Peripheral arterial occlusive disease	4 (12.5)
left ventricular ejection fraction＜35%	5 (14.3)
Left main disease	6 (18.6)
3-Vessel disease	27 (84.3)
Prior percutaneous transluminal coronary angioplasty with stent	12 (37.5)
New York Heart Association functional class	1.9±0.8
Euroscore	7.8±2.2
Logistic Euroscore	11.2±7.9

Values are presented as mean±standard deviation or number (%).

with that of the first-time CABG [1-12]. To overcome the technical difficulty and to lower the mortality rate of redo CABG, surgical techniques have evolved such as minimizing the dissection before bypass, routine use of femoral vessels for cannulation, use of antegrade and retrograde blood cardioplegia, and performance of all vascular anastomoses under a single aortic cross clamp. This has led to a slight improvement in the surgical outcome in on-pump CABG, but the suboptimal mortality and morbidity rates still remain a challenge.

Complex difficulties of reoperative CABG lead to a poorer outcome than those of first-time CABG. The patients undergoing redo CABG are older with more comorbidity, left ventricular dysfunction, and myocardial infarction. Redo CABG poses problems on the approach for re-entry, potential for cardiac and conduit injury during dissection, availability of conduit, management of patent grafts, myocardial protection, and use of blood products [2]. To overcome the aforementioned problems and difficulties, off-pump CABG could be an alternative method. Clarifying the feasibility of the off-pump technique in redo CABG seems to be important. Therefore, the aim of this retrospective study was to analyze early and midterm results after redo CABG and compare the outcome of redoing the procedure on pump and off pump.

METHODS

1) Patients' characteristics

From June 1996 to October 2011, elective redo CABG was performed in 32 patients. The mean duration from the first CABG to redo CABG was 12.2±8.4 years. The mean age of the patients was 64.8±7.5 years (on pump 64.3±8.1 years vs. off pump 65.5±7.2 years; p=0.658), and 21 patients (65.6%) were male. Among these patients, 14 (43.8%) underwent on-pump CABG and 18 (56.2%) underwent off-pump CABG. In Severance Cardiovascular Hospital, on-pump CABG had been performed as the standard procedure for redo CABG until 2001. Since 2002, off-pump CABG has been performed as the first choice. Six patients (6.8%) had chronic kidney disease, and 5 patients (14.3%) had significant left ventricular dysfunction (left ventricular ejection fraction＜35%). The patient demographics are listed in Table 1. The reasons for redo CABG included previous graft failure in 26 patients (81.2%) and progressed native coronary artery disease in 6 patients (18.7%).

The patients who underwent on-pump CABG and off-pump CABG had similar demographics and preoperative cardiac function. There was no significant difference in the preoperative risk factors except the presence of peripheral artery obstructive disease (on pump 0% vs. off pump 24.3%; p ＜0.001) between the two groups (Table 2). The mean follow-up duration was 6.1±5.1 years in the on-pump group and 3.8±2.8 years in the off-pump group (Fig. 1).

2) Operative technique

(1) Off-pump technique: All operations were performed via a full mid-sternotomy incision under normothermia. Standard intraoperative monitoring methods including Swan-Ganz catheterization and transesophageal echocardiogram were used. The choice of the grafts to be used was made individually based on the location of the diseased vessel, previous grafting, and the surgeon's preference. The ITA was harvested in a semi-skeletonized fashion. The non-dominant side radial artery was harvested with a Harmonic scalpel

Table 2. Comparison of preoperative characteristics between on-pump and off-pump

Characteristic	On pump (n=14)	Off pump (n=18)	p-value
Age (yr)	64.3±8.1	65.5±7.2	0.658
Sex (female)	5 (35.7)	6 (33.3)	0.888
Smoking	5 (35.7)	5 (27.8)	0.187
Hypertension	12 (85.7)	10 (55.6)	0.068
Diabetes mellitus	4 (28.6)	8 (44.4)	0.358
Overweight (body mass index＞25 kg/m^2)	6 (42.8)	11 (61.1)	0.321
Dyslipidemia	4 (28.6)	5 (27.8)	0.960
History of stroke	1 (7.1)	3 (16.7)	0.419
Chronic kidney disease	1 (7.1)	1 (5.6)	0.854
Peripheral arterial occlusive disease	0	4 (24.3)	＜0.001
Left ventricular ejection fraction＜35%	3 (21.4)	2 (11.1)	0.443
Left main disease	3 (21.4)	3 (16.7)	0.732
3-Vessel disease	12 (85.7)	15 (83.3)	0.655
Prior percutaneous transluminal coronary angioplasty with stent	4 (28.6)	8 (44.4)	0.384
New York Heart Association functional class	2.1±0.5	1.7±0.7	0.095
Euroscore	8.5±2.4	7.4±2.0	0.173
Logistic Euroscore	14.0±10.6	9.4±5.2	0.126

Values are presented as mean±standard deviation or number (%).

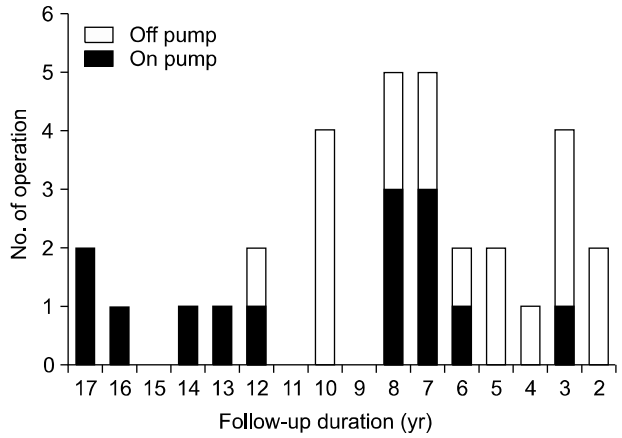

Fig. 1. The mean follow-up duration was 6.1±5.1 years in on-pump group and 3.8±2.8 years in off-pump group.

(Ethicon Endosurgery, Cincinnati, OH, USA) as a pedicle. In case of using ITA, heparin and papaverine were injected through ITA. Intravenous calcium channel blocker was used to prevent vasospasm of the radial artery. Anticoagulation was achieved with 100 U/kg of intravenous heparin to maintain the activated clotting time at more than 300 seconds. For cardiac stabilization and displacement, Octopus tissue stabilizer (Medtronic Inc., Minneapolis, MN, USA) was used during the anastomosis. Intracoronary shunt was used for left anterior descending artery (LAD) anastomosis and the proximal snaring technique for the other vessels.

(2) On-pump technique: Standard cardiopulmonary bypass using cannulation on ascending aorta and right atrium were established under moderate systemic hypothermia. Transesophageal echocardiography was used to evaluate postoperative cardiac function and existence of significant atheroma on ascending aorta. The aorta was cross clamped, and myocardial protection was achieved with intermittent antegrade, or simultaneous antegrade and retrograde infusion of blood cardioplegia. The ITA was harvested in a semi-skeletonized fashion. In case of using the saphenous vein graft, distal anastomosis was made at first, and the ITA was anastomosed last during rewarming.

3) Data collection and analysis

Preoperative and perioperative data were collected prospectively at Severance Cardiovascular Hospital in the cardiac research database. We compared the overall and annual mortality and morbidity of all the patients, and according to the surgical techniques. Patient follow-up was performed by patient interview in an outpatient clinic or by telephone. Perioperative myocardial infarction was defined as a significant increase in creatine kinase (CK)-MB with the appear-

ance of a new Q-wave or S-T segment elevation of more than 2 mm on the electrocardiogram. Complete revascularization was defined when the number of revascularized vessels was the same or greater than the number of diseased vessels.

For statistical analysis, continuous variables were expressed as mean±standard deviation. For comparison of two variables, the Student t-test and the chi-square test were used. A significant level of 0.05 was used throughout the tests. For survival, the Kaplan-Meier method was used, and the differences were assessed with the log-rank test. Statistical analyses were performed using the SPSS ver. 12.0 software package (SPSS Inc., Chicago, IL, USA).

RESULTS

1) Operative data

One of the patients underwent concomitant mitral valve annuloplasty, and the rest underwent isolated redo CABG. ITA was used in 15 patients (48.9%) in the first operation. For redo CABG, ITA was used in 22 patients (68.8%): 12 left ITAs, 10 right ITAs, and 1 using both of them. The incidence of composite Y graft and aorta grafts was similar, and total arterial revascularization was achieved in 17 patients (53.1%). Incomplete revascularization occurred in 14 patients (43.8%), and the causes of incomplete revascularization were small native coronary arteries that were not suitable for target vessels in 9 patients and the inability to expose the target vessel in 4 patients.

The average number of distal anastomoses was 2.13±0.9. The types of grafts used and the composition of grafts are described in Tables 3, 4. Comparing the on-pump group and off-pump groups, we found that the number of distal anastomoses and the types of grafts used were similar. The rate of total arterial revascularization was higher in the off-pump group (14.3% vs. 83.3%, $p<0.001$); therefore, saphenous vein grafts were less frequently used in this group (78.6% vs. 16.7%, $p<0.001$). Operation time was significantly longer in the on-pump group (on pump 437.9±93.6 minutes vs. off pump 327.7±57.1 minutes, $p<0.001$) (Table 5). Cardiopulmonary bypass time of the on-pump group was 168.3±68.5 minutes, and the aortic cross-clamping time was 121.3±66.3 minutes.

Table 3. Types of grafts

Variable	On pump (n=14)	Off pump (n=18)	p-value
Left internal thoracic artery	5 (35.7)	7 (38.9)	0.854
Right internal thoracic artery	4 (28.6)	7 (38.9)	0.542
Radial artery	7 (50.0)	13 (72.2)	0.198
Saphenous vein	11 (78.6)	3 (16.7)	<0.001
Gastroepiploic artery	0	2 (11.1)	0.198
Bilateral internal thoracic arteries	0	1 (5.6)	0.370

Values are presented as number (%).

2) Postoperative outcome

There was one in-hospital death. The patient underwent on-pump CABG with concomitant valve surgery and died from the acute respiratory distress syndrome. The overall hospital mortality was 3.1% (n=1) and was comparable in both groups (on pump 7.1% vs. off pump 0%, p=0.249). Postoperative complications occurred in 12 patients, and the rate of complications was higher in the on-pump group without stat-

Table 4. Composition of grafts

Configuration	On pump (n=14)	Off pump (n=18)
ITA only	0	5 (LITA-1, RITA-3, bilateral ITA-1)
LITA+aorta	3	2
LITA+Y composite	2 (RA-2)	3 (RA-2, SVG-1)
RITA+aorta	2	1
RITA+Y composite	2 (RA)	2 (RA)
Aorta only	5 (SVG-3, both-2)	4 (RA-2, SVG-0, both-2)
GEA only (GEA-right postero-descending artery)		1

ITA, internal thoracic artery; LITA, left internal thoracic artery; RITA, right internal thoracic artery; RA, radial artery; SVG, saphenous vein graft; GEA, gastroepiploic artery.

Table 5. Operative and postoperative data

Variable	On pump (n=14)	Off pump (n=18)	p-value
Anastomoses/patient	2.36±0.9	1.94±0.9	0.224
Total arterial revascularization	2 (14.3)	15 (83.3)	<0.001
Incomplete revascularization	8 (57.1)	6 (33.3)	0.178
Operation time (min)	437.9±93.6	327.7±57.1	<0.001
Intensive care unit stay (day)	5.5±7.9	2.7±1.0	0.356
Hospital stay (day)	17.1±9.5	12.5±6.9	0.129

Values are presented as mean±standard deviation or number (%).

Table 6. Mortality and complications

Variable	On pump (n=14)	Off pump (n=18)	p-value
30 day mortality	1 (7.1)	0	0.249
Perioperative myocardial infarction	1 (7.1)	0	0.249
Atrial fibrillation/flutter	2 (14.3)	0	0.098
Low cardiac output syndrome	1 (7.1)	0	0.249
Mediastinitis	0	2 (11.1)	0.198
Cerebrovascular accident	1 (7.1)	0	0.249
Respiratory failure	2 (14.3)	0	0.098
Renal failure	1 (7.1)	2 (11.1)	0.490
Gastrointestinal bleeding	0	2 (11.1)	0.198
All complication	9 (64.2)	6 (33.3)	0.082

Values are presented as mean±standard deviation or number (%).

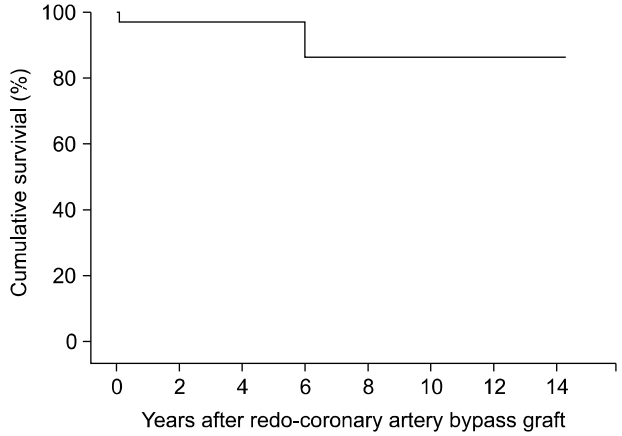

Fig. 2. Kaplan-Meier estimated survival curve shows overall survival at 10-year rate of 86.1%±10.5%.

istical significance (64.2% vs. 33.3%, p=0.082) (Table 6). The length of the intensive care unit stay and the hospital stay did not differ between the on-pump and off-pump group (Table 5).

The mean follow-up duration was 5.4±4.1 years, and overall survival at 10 years was 86.0%±10.5%. Kaplan-Meier estimated survival at 5 and 10 years was 92.9%±6.9% and 79.61%±13.6% in the on-pump group, and 100% and 100% in off-pump group, respectively, and there was no significant difference in the 10-year survival rate in both groups (p=0.225) (Figs. 2, 3).

DISCUSSION

Reoperative coronary artery bypass grafting has been known to be a firm predictor of increased mortality and morbidity in previous studies [13]. Reoperation per se carries additional risks including the issues of the second sternotomy and mediastinal dissection, and technical difficulties. In addition, comparatively higher age and impaired left ventricular function of the patients have been contributive [1]. Early mortality of reoperative CABG has been reported in a wide range from 1.8% to 16.7% [14]. Our study demonstrated

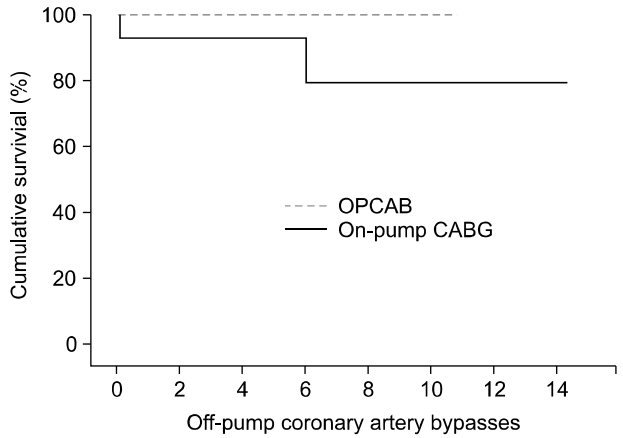

Fig. 3. Kaplan-Meier estimated survival at 5 and 10 years were 92.9%±6.9%, and 79.6.1%±13.6% in on-pump group, and 100% and 100% in off-pump group, and there was no significant difference in 10-year survival rate in both groups (p=0.225). CABG, coronary artery bypass graft.

30-day mortality of 3.1%, which is acceptable as compared to previous studies.

Mack [8] performed 86 redo off-pump coronary artery bypasses (OPCABs) among 87 patients who were planned on redo CABG on an 'intention to treat' basis. Only one patient had converted to on-pump CABG. Mishra and associates [9] performed 332 redo OPCABs among 538 patients, and the patients who underwent on-pump CABG had worse hemodynamic status, increased urgency, and worse quality of distal coronary target vessels. In contrast, Vohra et al. [3] did not consider small targets and intramyocardial vessels as contra-indications to the off-pump technique. Contrasting views on the feasibility of redo OPCAB are similar to those of the first-time OPCAB in the earlier days between the mid-1980s and the late 1990s. To clarify the feasibility of redo OPCAB, a comparison between the off-pump technique and the on-pump technique regarding the following issues is beneficial because the on-pump technique is the mainstay of redo CABG.

1) Completeness of revascularization

The ultimate goal of coronary bypass grafting is complete revascularization irrespective of the techniques used. Complete revascularization is associated with better long-term survival than incomplete revascularization. However, the definition of complete revascularization differs by surgeon or institution. In redo CABG, there is wide variation on the definition of complete revascularization giving consideration to particular issues such as senile vein grafts. This leads to the controversy on the optimal revascularization and diverse emphasis on complete revascularization [15-17]. The complete revascularization rate after redo OPCAB is lower than that of first-time CABG. There are few reports on the complete revascularization rate after redo CABG. Di Mauro et al. [1] reported a lower complete revascularization rate in redo CABG patients using either on-pump or off-pump techniques (on pump 59.8% and off pump 40.2%) as compared to first-time CABG (93.3% vs. 85.4%). The patients with incomplete revascularization showed higher incidence of cardiac-related death, acute myocardial infarction, and cardiac events. Tugtekin et al. [12] reported a lower complete revascularization rate of 48.6% after off-pump CABG compared with 86.9% after on-pump CABG in reoperation. On the other hand, Mishra et al. [9] reported a rather high rate of complete revascularization after redo OPCAB (75%). Some others have reported similar complete revascularization rate of on-pump and off-pump techniques by propensity score matching [3,6]. In our study, the incomplete revascularization rate was higher in the on-pump group than in the off-pump group, although there was no statistically significant difference. In conclusion, the complete revascularization rate after redo OPCAB seems to be comparable with that of on-pump redo CABG and is largely affected by myocardial function and the surgeon's experience.

2) Operative morbidity and mortality

Schutz et al. [6] reported preferable results for redo OPCAB in terms of platelet transfusion and the length of intensive care unit stay by comparing 20 patients from each group. There was no hospital death in either group. Trehan et al. [10] showed a mortality rate of 4% in redo OPCAB patients, and the others reported a mortality rate of 2.9% after redo OPCAB and 3.8% after redo on-pump CABG although there was no statistical significance [12]. Mishra et al. [9] showed a mortality rate of 3.3% after redo OPCAB and 5.5% after redo on-pump CABG without any significant difference. However, in terms of the length of ventilator care and in-

otropic use, the off-pump technique showed superior outcomes. Vohra et al. [3] also reported a lower mortality rate in patients undergoing redo OPCAB but did not reach the statistical difference (off pump 2.3% and on pump 6.9%). Stamou et al. [7] reported a significantly lower mortality rate in the off-pump group than in the on-pump group (1% vs. 10%, p=0.03), and even better outcomes in terms of postoperative transfusion, incidence of atrial fibrillation, duration of ventilator care, and length of hospital stay. Di Mauro et al. [1] suggested the use of the off-pump technique in reoperative patients because the off-pump technique was associated with lower postoperative CK-MB level. The higher CK-MB level after CABG is known to have association with poor 5-year survival. As a result, the off-pump technique is associated with similar or rather lower operative mortality rate and morbidities, which was also demonstrated in our study.

3) Long-term survival

There is a lack of long-term data comparing two techniques in reoperative CABG. Vohra et al. [3] reported a 5-year survival rate of 95% after redo OPCAB and 87% after redo on-pump CABG (p=0.17), when the others reported 88.6% in the off-pump group and 83.8% in the on-pump group [12]. Even though the data are limited, the long-term survival rates after redo CABG using the two techniques are similar to that of first-time CABG.

In redo cases, the off-pump technique showed acceptable outcomes compared with the on-pump technique with similar graft patency, 5-year survival rate, and lower morbidity and mortality rates. However, the complete revascularization rate of redo OPCAB was lower than that of redo on-pump CABG as in the case of first-time CABG. This can be overcome by using various surgical approaches. In the case of multi-vessel disease, for example, a hybrid technique can be considered when the lesion is located too posterior to approach or to visualize via a mid-sternotomy incision. Devices to avoid aortic clamping during proximal anastomosis can be used in some cases such as dense adhesion around the aorta or severe atherosclerosis. Furthermore, minimally invasive direct coronary artery bypass via antero-lateral thoracotomy can be the optimal surgical strategy when the lesion is confined to the LAD territory. In a circumflex system, the descending aorta can be used as the proximal anastomosis site under a postero-lateral thoracotomy incision.

4) Limitation of the study

This study is limited by its retrospective nature. The limitation of the present study includes a small number of patients, retrograde single-institution methodology, and different follow-up period and operation time of two groups.

5) Conclusions

In conclusion, redo CABG can be safely performed with acceptable mortality. The off-pump technique in the redo cases is feasible with low mortality and morbidity, and comparable target vessel bypass grafting, and long-term survival. The off-pump technique might be considered a safe option for redo CABG in high-risk patients in highly experienced centers. A large-population study with a longer follow-up duration is needed to clarify the safety and effectiveness of off-pump redo CABG.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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