Original Article

Off-pump Redo Coronary Artery Bypass Grafting via Left Thoracotomy

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Objective: We evaluated the usefulness of off-pump coronary artery bypass grafting (CABG) via left thoracotomy (LT) in redo coronary revascularization.
Methods: Over the past 23 years, 21 patients (2.3%) underwent redo coronary revascularization in our hospital. The period between the first and the redo surgeries was 9.1±4.4 years. They were divided into two groups according to the method of surgical approach in the redo CABG: re-median sternotomy group (RMS group, n=12) and LT group (n=9).
Results: In the RMS group, five of 12 patients suffered prolonged postoperative respiratory failure with ventilatory support, and the RMS patients stayed in the hospital for a significantly longer period of time than the LT patients. Four patients (19.0%, 4/21), who were all in the RMS group, died during the hospitalization. In the LT group, there were no hospital deaths and no cases of respiratory failure.
Conclusion: Redo CABG via LT provided acceptable and satisfactory surgical results. As it is expected that the number of emergency reoperative surgical cases will increase, the LT approach may be useful for rapid exposure of the target coronary artery without causing significant myocardial damage. (Ann Thorac Cardiovasc Surg 2003; 9: 378–83)

Key words: off-pump coronary artery bypass grafting (CABG), redo CABG, left thoracotomy

Introduction

Coronary artery bypass grafting (CABG) has been performed in many angina patients, and the number of redo CABG cases due to vein graft disease or progression of native coronary artery stenosis has been increasing.[1-3] As 24 years have passed since the first coronary revascularization procedure was performed at our hospital, the number of reoperative CABG cases at our hospital has recently been increasing. There are still some problems with the redo CABG procedure, such as dissection of the adhesion while preserving patent grafts upon resternotomy.[2-5] To avoid these risks, off-pump CABG via left thoracotomy (LT) was performed in nine recent redo cases at our hospital. In this study, we evaluated the usefulness of the LT approach by comparing patients who underwent this approach with patients who underwent a redo operation by the resternotomy approach.

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Received March 19, 2003; accepted for publication June 1, 2003.
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Patients and Methods

Between January 1979 and December 2002, 894 patients underwent isolated CABG at our hospital. Among these patients, 21 patients (2.3%) underwent redo CABG, and were the subjects of the present study. Of the 21 patients, five were female and 16 were male, and their ages ranged from 39 to 84 years [65.6±10.9 years; mean ± standard deviation (SD)]. The period between the first CABG and the redo CABG ranged from 2 months to 14 years 10 months (9.1±4.4 years). The indications for redo operation were occlusion or severe stenosis of the grafts in 15 patients, and progression of native coronary artery stenosis in six patients. We divided the 21 patients into two

Table 1. Background characteristics of the redo CABG patients

Characteristics	RMS group (n=12)	LT group (n=9)	p value
Age (years)	65.2±13.3	66.0±7.5	
Gender			
Male	7 (58.3)	9 (100)	
Female	5 (41.7)	0	
Risk factor			
Hypertension	4 (33.3)	5 (55.6)	
Diabetes mellitus	4 (33.3)	4 (44.4)	
Hyperlipidemia	4 (44.4)	4 (44.4)	
CRF (HD)	0	2 (22.2)	
CVA	2 (16.7)	3 (33.3)	
OMI	8 (66.7)	6 (66.7)	
COPD	2 (16.7)	2 (22.2)	
No. of previous grafts	1.8±0.8	2.9±0.6*	0.02
Use of LITA in the first surgery	3 (25.0)	5 (55.6)	
No. of patent grafts	0.6±0.5	1.2±0.4*	0.04
Patent LAD grafts	3 (25.0)	5 (55.6)	
Reason for redo CABG			
Graft occlusion	8 (66.7)	7 (77.8)	
New lesion	4 (33.3)	2 (22.2)	
Interval (years)	9.7±4.1	8.2±4.8	
Pre redo CABG EF (%)	63.1±17.4	53.3±19.6	

RMS group, patients who underwent redo CABG through re-median sternotomy; LT group, patients who underwent redo CABG through left thoracotomy; CRF, chronic renal failure; HD, hemodialysis; CVA, cerebrovascular accident; OMI, old myocardial infarction; COPD, chronic obstructive pulmonary disease; LITA, left internal thoracic artery; LAD, left anterior descending artery; EF, ejection fraction.
Data are presented as number of cases (percentage). The value of each continuous variable are expressed as mean ± SD. * $p<0.05$

groups according to the surgical approach that was used in the redo CABG: re-median sternotomy group (RMS group, n=12) and LT group (n=9). Basically, patients requiring redo CABG after 1999 were operated on using the LT approach. Surgery on patients needing revascularization for the left anterior descending artery (LAD) alone or only the proximal right coronary artery (RCA) was performed through the RMS approach. To clarify the usefulness of the LT approach, perioperative clinical parameters were compared between the two groups. The clinical characteristics of the patients are summarized in Table 1.

This cohort involved the same surgeon using uniform techniques and with the same surgical team. Perioperative conditions were evaluated by retrospective review of each patient's hospital records, catheterization reports, cine angiograms, aortograms and computed tomographic scans. Data are presented as the number of cases with simple percentage. The data were analyzed by one-way analysis of variance, and unpaired observations were analyzed with the unpaired Student's t-test. All values are presented as means ± SD. Statistical significance was defined as a p value less than 0.05. Perioperative myocardial infarction was defined as the presence of a newly discovered Q-wave or an increase in myocardial enzyme (CK-MB) level exceeding 100 mg/dl. A cerebrovascular accident (CVA) was defined as any focal neurological deficit persisting longer than 24 hours. Respiratory failure was defined as intubation that was required for more than 48 hours and/or tracheotomy. Deep sternal infection (mediastinitis) was identified as instability of the sternum with positive wound culture necessitating an additional surgical procedure. Our indications for intra-aortic balloon pumping (IABP) were, generally speaking, a low output syndrome, namely patients requiring a lot of catecholamines for circulatory stability, and a serious arrhythmia after revascularization.

Operative technique

In the RMS group, 11 of the 12 patients underwent on-pump CABG. The patient in the RMS group who did not undergo on-pump CABG was elderly and had a history

Table 2. Distribution of anastomosis site in redo CABG in the RMS and LT patients

	RMS group (n=12)				LT group (n=9)			
	LAD	LCX	RCA	Total	LAD	LCX	RCA	Total
LITA	5 (22.7)	0	0	5 (22.7)	1 (5.3)	1 (5.3)	0	2 (10.5)
RITA	1 (4.5)	0	2 (9.1)	3 (13.6)	0	0	0	0
RGEA		3 (13.6)	3 (13.6)	6 (27.3)	0	1 (5.3)	3 (15.8)	4 (21.1)
RA	3 (13.6)	0	0	3 (13.6)	3 (15.8)	6 (31.6)	1 (5.3)	10 (52.6)*
SV	1 (4.5)	2 (9.1)	1 (4.5)	4 (18.2)	0	3 (15.8)	0	3 (15.8)
IEA	0	0	1 (4.5)	1 (4.5)	0	0	0	0
Total	10 (45.5)	5 (22.7)	7 (31.8)	22 (100)	4 (21.1)	11 (57.9)*	4 (21.1)	19 (100)

RMS group, patients who underwent redo CABG through re-median sternotomy; LT group, patients who underwent redo CABG through left thoracotomy; LITA, left internal thoracic artery; RITA, right internal thoracic artery; RGEA, right gastroepiploic artery; RA, radial artery; SV, saphenous vein; IEA, inferior artery; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery.
Data are presented as number of cases (percentage). * $p<0.05$

of right-side thoracoplasty for pulmonary tuberculosis. Cardiopulmonary bypass (CPB) and cold potassium crystalloid cardioplegia were performed in 11 RMS patients. Both distal and proximal anastomoses were completed during cardiac arrest with a single cross-clamping technique.

All nine patients in the LT group underwent off-pump CABG. In the LT group, the operative field was approached via LT through the fifth intercostal space, and upper median laparotomy was additionally performed in cases where the right gastroepiploic artery (RGEA) was used. We minimized dissection and exposure of the target coronary arteries to avoid myocardial injury. For coronary anastomosis, the target coronary artery was clamped by applying snares proximal and distal to the anastomotic sites using an Elastic A needle (Matsuda Ika Kogyo Co., Ltd., Tokyo, Japan). The Octopus II® stabilizer was applied to the prepared anastomotic site for precise anastomosis. With the dry anastomotic field which resulted from the snaring described above, coronary anastomosis with the radial artery (RA) or saphenous vein (SV) was completed with continuous suture of 7-0 polypropylene. The RA or SV was anastomosed to the left circumflex artery (LCX) system, and the RGEA was anastomosed to the RCA or the LCX system. Following anastomosis of the coronary side, proximal anastomosis was performed with the descending aorta by a single, running, continuous suture with 6-0 polypropylene. The used grafts and bypassed coronary segments in the patients of the two groups are summarized in Table 2.

Results

The preoperative characteristics of the patients in the RMS and LT groups did not significantly differ except for the number of previous grafts and patent grafts (Table 1). The patients in the LT group had a significantly larger number of previous grafts and patent grafts than those in the RMS group (p=0.02, p=0.04). The left internal thoracic artery (LITA) tended to have been used more frequently in the first surgery in the LT group than in the RMS group, and there was a high patency rate of grafts bypassed to the LAD in the LT group.

Table 3 summarizes the operative results of the redo CABG and the postoperative graft patency rate. There was no significant difference in the number of grafts between the two groups. The operative time was significantly shorter (p=0.02) and the volume of intraoperative bleeding was significantly smaller (p=0.04) in the LT group than in the RMS group. Postoperative complications occurred significantly more frequently among the RMS patients than among the LT patients (p=0.03). No significant difference was observed in the rate of complete revascularization between RMS group (9/12=75.0%) and LT groups (7/9=77.8%). There was no significant difference in the early postoperative graft patency rate between the RMS group (21/22=95.5%) and the LT group (18/19=94.7%). Although there was no significant difference in the preoperative cardiac function between the two groups, IABP was performed in a higher percentage of patients in the RMS group than in the LT group. Furthermore, five patients in the RMS group needed prolonged ventilatory support for respiratory failure, and the length of hospital stay was significantly longer in the RMS group than in the LT group (p=0.04). There were four hospital deaths, all of whom were in the RMS group. Three of the four patients died of sepsis and dissemi-

Table 3. Operative results of redo CABG

	RMS group (n=12)	LT group (n=9)	p value
Operative time (min)	492.6±118.3	335.0±88.3*	0.02
Cardiopulmonary support			
CPB (min)	129.1±38.8	–	
Ischemic time (min)	82.3±26.7	–	
Blood loss (ml)	3,450.9±1,953.1	1,340.0±454.6*	0.04
Number of grafts	2.3±1.0	2.1±1.1	
Complete revascularization	9 (75.0)	7 (77.8)	
Respiratory assist (hours)	46.9±39.7	16.0±5.4*	0.04
Mortality	4 (44.4)	0	
Early complications			
Respiratory failure	5 (41.7)	0*	
PMI	2 (16.7)	0	* 0.03
Use of IABP	4 (33.3)	1 (11.1)	
Mediastinitis	2 (16.7)	0	
Re-exploration for bleeding	2 (16.7)	0	
CVA	2 (16.7)	0	
Graft patency (%)	95.5 (21/22)	94.7 (18/19)	
Postoperative EF (%)	61.9±7.8	55.3±16.4	
Length of hospital stay (days)	54.0±23.2	31.0±10.1*	0.04

RMS group, patients who underwent redo CABG through re-median sternotomy; LT group, patients who underwent redo CABG through left thoracotomy; CPB, cardiopulmonary bypass; PMI, perioperative myocardial infarction; IABP, intra-aortic balloon pumping; CVA, cerebrovascular accident; EF, ejection fraction.
Data are presented as number of cases (percentage).
The values of each continuous variable are expressed as mean ± SD. * $p<0.05$

nated intravascular coagulopathy induced by intraoperative bleeding at the time of dissection of the adhesion. The remaining one patient, who was the only patient in the RMS group who underwent off-pump CABG, died of pneumonia. He was a 78-year-old patient who had respiratory insufficiency preoperatively because of a history of right-side thoracoplasty for pulmonary tuberculosis. No hospital deaths occurred in the LT group. Comparing the regions of coronary anastomosis, anastomosis to LCX branches was significantly more frequently performed in the LT group than in the RMS group (p=0.03) (Table 2). Although there was no significant difference, anastomosis to the LAD was less frequently performed in the LT group than in the RMS group. In five of nine patients in the LT group, the LITA was used in the first surgery and in two other patients the LITA was used in redo surgery. However, the LITA could not be used in another two patients because it was very small as revealed by preoperative angiography. Because the right internal thoracic artery (RITA) could not be used with the LT approach, the RA was used mostly for the arterial graft, naturally.

Discussion

Recently, the number of patients undergoing redo CABG has been increasing. Among the patients who underwent CABG, the percentage of patients who underwent redo CABG was reported to be 7% to 15.5%.[1,2] There are many problems in the operative technique of redo CABG compared with that of the first surgery including the method of approach to the operative field, dissection of heart adhesion, method of myocardial protection, method of CPB and preservation of patent grafts.[2-5] Consequently, the operative results of redo CABG are generally unsatisfactory. Especially, the indication for redo operation in patients with poor cardiac function should be determined carefully.[1] If off-pump CABG can be performed in the reoperation, many of the above-mentioned risk factors can be avoided. The off-pump technique has recently been utilized in many redo CABG patients with good results.[2,6] Off-pump CABG has the advantage of minimizing the dissection area, resulting in a small volume of bleeding because of unnecessary CPB and topical cooling. Miyaji et al.[7] reported that adhesion plays a role as a good stabilizer at the time of coronary anastomosis, and emphasized

that the adhesion should not be dissected unnecessarily. We also made efforts to reduce the operative damage by dissecting the adhesion only in the area surrounding the coronary artery, and this was considered to lead to reduction in the bleeding volume and shortening of the operative time. In cases where the previous graft that bypassed the target coronary artery became occluded, the target coronary artery could be easily identified because the occluded vessel was confirmed by palpitation.

The RMS approach is the standard method of redo CABG. However, in patients who undergo the RMS approach, many risks accompany dissection of the adhesion including injury to the myocardium, ascending aorta and patent grafts, and the usefulness of the LT approach as an alternative method was reported.[8-10] In the patients who underwent the RMS approach, it was necessary to dissect the adhesion between the left ventricle and pericardium in order to isolate the LCX branches even when CPB was not performed. Furthermore, if free grafts are used as the conduit, exposure of the ascending aorta is generally unavoidable for proximal anastomosis in the patients who undergo the RMS approach. Faro et al.[10] used the LT approach in nearly 10% of patients who underwent redo CABG. Problems with the LT approach compared with the RMS approach are a limited number of anastomosis sites and difficulty in performing the surgery using CPB. It is generally accepted that although it is easy to isolate the LCX branches and it is possible to perform anastomosis to the LAD via the LT approach, it is difficult to isolate the right coronary artery (RCA). However, in our experience, we could reach the posterior descending artery even by the LT approach. Moreover, when an upper abdominal median incision was made for preparation of the RGEA, the RCA (seg. 3) could be easily isolated upon the same incision. Anastomosis to the LCX branches was performed in a significantly smaller percentage of RMS patients than LT patients (Table 2); we consider that this was partially due to difficulty of dissection of the adhesion in the LCX area upon the RMS approach. Conversely, anastomosis to the LAD was performed in a larger number of patients in the RMS group than in the LT group, although there was no significant difference. However, one reason for this was that a higher percentage of patients in the LT group had patent LAD grafts (Table 1). Actually, revascularization to the LAD was performed in the previous operation or in the reoperation in all patients in the LT group. Furthermore, one advantage of using free grafts is that it is easy to approach the descending aorta for proximal anastomosis in the patients who undergo the LT procedure. The LT approach is especially useful in the patients with calcification of the ascending aorta.

Although the RITA could not be used in the LT group, the LITA could be easily prepared through the fifth anterior intercostal space upon the LT approach. Revascularization with only arterial grafts was possible by using the RGEA and right RA. The aorta non-touch technique is also possible by aggressively using composite grafts. At our hospital, 19 patients underwent their first CABG operation via the LT approach during the same period of this study. Thirteen of them underwent CABG with only arterial grafts. Moreover, the aorta non-touch technique could also be performed using composite grafts in six patients. However, in the patients who undergo the LT approach, anastomosis to the LCX branch is performed under the situation that the heart is rotated medially. If the graft is too long when a free graft is used, the graft often becomes compressed and crooked when the rotation of the heart is released. In the present study, one of the 19 grafts in the LT group became occluded, and it was the graft to the LCX (seg. 12) using the free RGEA graft. As the occluded graft became kinked after anastomosis, some fixation stitches were required to prevent kinking. Calafiore et al.[9] successfully anastomosed the proximal side of the RA to the left subclavian artery in a redo CABG via LT. Therefore, when a free graft is used as a bypass conduit, it is necessary to ensure that its length is appropriate and to choose a proximal anastomosis site that provides a good graft pathway to the coronary anastomosis site.

The hospital mortality rate in our study was 19.0% (4/21), and all four hospital deaths were in the RMS group. The cause of hospital death was bleeding upon dissection of the adhesion in three patients. The remaining one patient was 78 years old with respiratory dysfunction which was pointed out preoperatively. He had a history of right-side thoracoplasty for pulmonary tuberculosis, and the RMS approach was selected to avoid increasing the operative risk by LT. He developed pneumonia and died 42 days after the surgery. In the LT group, two patients had respiratory dysfunction similar to this patient, but they survived without postoperative respiratory failure.

As it is expected that the number of emergency reoperative CABG cases will increase, the LT approach is considered to be useful for reducing the operative risk and for rapid isolation of the target coronary artery. Furthermore, it is suggested that the LT approach may be

useful even for primary surgery in the patients who are at high risk by median sternotomy.

Conclusion

Redo CABG via LT was performed in nine patients and provided acceptable and satisfactory surgical results compared with that through re-median sternotomy. In the patients who underwent the RMS approach, it is necessary to perform dissection of the adhesion between the left ventricle and pericardium in order to isolate the LCX branches even in off-pump CABG. Furthermore, if free grafts are used in the patients who undergo the RMS approach, exposure of the ascending aorta is generally unavoidable for proximal anastomosis. As it is expected that the number of emergency reoperative surgical cases will increase, the LT approach is considered to be useful for reducing the operative risk and for rapid isolation of the target coronary artery.

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