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Research Paper

Off-pump versus on-pump coronary artery bypass surgery for the treatment of left main with triple coronary artery disease☆

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Abstract

Objective:To obtain early results of off-pump coronary artery bypass grafting(OPCAB) in patients with significant left main coronary artery(LMCA) and triple vessels stenosis by comparing with those of a similar group undergoing conventional coronary artery bypass surgery(CCAB). Methods:Data for patients with significant LMCA and triple vessels stenosis who underwent CCAB or OPCAB were collected retrospectively between January 1999 and May 2006. Non-randomized, retrospective data analysis included demographic and preoperative risk factors, operative details, clinical outcome and early follow-up. Results: The number of distal anastomosis and grafts varied from 3 to 6. The average number per patient was similar in the two groups (OPCAB group:3.76 ± 0.98, CCAB group:3.81 ± 1.02). Thirty-day mortality occurred to one patient in the OPCAB group whereas two early deaths were observed in the CCAB group but did not reach statistical significance ($P > 0.05$). The frequency of atrial fibrillation (AF), IABP usage, mediastinitis, re-operation for bleeding (or tamponade) were similar in the two groups ($P > 0.05$). Postoperative inotropic requirements, peak CK-MB, ventilation time, blood loss, FFP, RBC transfusion need and the length of ICU-stay were all significantly lower in the OPCAB group compared with CCAB group($P < 0.05$).Conclusion: Significant LMCA and triple-vessel stenosis can safely and effectively undergo myocardial revascularization using OPCAB surgery. LMCA should no longer be seen as a contraindication to perform OPCAB grafting.

Key words: left main coronary artery; triple-vessel stenosis; off-pump coronary artery bypass grafting

INTRODUCTION

Significant(50%) stenosis of the left main coronary artery(LMCA) is an anatomic lesion of critical importance and confers a poor prognosis when untreated[1].The preferred treatment of this disorder has traditionally been conventional coronary artery bypass surgery(CCAB) with the aid of extracorporeal circulation(ECC). Compared with medically treated patients, CCAB surgery has been demonstrated in both observational and randomized trials to prolong life and lessen symptoms in patients with significant LMCA stenosis.

The presence of significant left main coronary stenosis(LMS) disease has been considered a relative contraindication to off-pump coronary artery bypass grafting(OPCAB) surgery[2-3]. However, the development in exposure and stabilization techniques, the introduction of intra-coronary shunts, and an increasing understanding of the hemodynamic changes which occur during off-pump surgery should enable patients with critical LMS disease to undergo OPCAB surgery[4-5].

In the last few years, the number of OPCAB case reported has been increasing. Improvements of the surgical technique and the perioperative anesthesiological management have lowered the surgeon's threshold to perform OPCAB surgery. As a consequence, the indication and the choice of patients have changed. But there has been a great inconsistency in whether the patients

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with LMCA and triple-vessel disease are suitable for OPCAB surgery, and the key point lies in whether the patients can get complete revascularization and the same effect as conventional CABG surgery[6-8].

In this study, we aimed to obtain the early results of OPCAB in patients with significant LMCA and triple-vessel stenosis by comparing with those of a similar group undergoing standard CCAB surgery.

MATERIALS AND METHODS

Patient characteristics

After obtaining institutional review board approval, a retrospective chart review was performed among 70 consecutive patients with left main and triple-vessel disease who had undergone OPCAB surgery. The findings were compared with a control group of 75 patients who had undergone CCAB surgery using CPB. Data was collected by manually searching the cases chart and the cardiac surgery database from January 1999 to May 2006.

All the surgeries were completed by the same surgeon (CHENX). Patients came to OPCAB or CCAB based on the order of coming, but not the coronary artery anatomic structure or the size of the heart or the left ventricular ejection fraction(LVEF) of each patient. However the patients associated with many combined diseases were preferred to OPCAB.

Surgical technique

All procedures were performed under general anesthesia via a median sternotomy. The left internal mammary artery was regularly harvested, and the great saphenous vein was prepared at the same time for the surgery.

After a total-dose heparinization(3 mg/kg) in CCAB group, CPB was established as usual. After the aorta was cross-clamped, the cold crystal cardiopledia was given through the root of the aorta. 7-0 Prolene was used to do the distal anastomosis. After taking off the cross-clamp, side-biting was applied to the aorta, and 5-0 Prolene was used to finish the proximal anastomosis (single aortic cross clamp was used without side-biting in 6 cases for the calcified aorta).

In OPCAB group, single deep pericardial stay suture between left inferior pulmonary vein and inferior vena cava was used with a sling snared down. By adjusting the two ends of the sling along with adjusting the operating table all the target coronary vessels were exposed. After systematic haperinization, ACT was maintained more than 300 seconds, and mechanical heart stabilizer (Octopus Ⅱ ~ Ⅲ) was used to facilitate the distal anastomoses. Endovascular shunts were placed into the vessels when necessary. Generally LIMA to LAD was done first, then grafts to RCA, PDA, DIAG, OM were orderly done[9]. While exposing OM and PDA, trendelenburg position was adopted to promote better access and reduce hemodynamic compromise brought by manipulation of heart. Proximal anastomosis was completed with the help of side-bitting clamp in the ascending aorta. In 7 patients, the proximal anostomosis of the grafts to the OMs and RCAs was done by "T" or "Y" grafts to LMA for heavily calcified aorta. The graft flow in all patients was measured by real-time Medi-Stim Butterfly Flowmeter during operation[10].

Postoperative management and data collection

At the end of surgery, patients were transferred to the intensive care unit(ICU). The lungs were ventilated with 60% oxygen using volume-controlled ventilation and a tidal volume of 10 ml/kg with 5 cmH_2O of positive end-expiratory pressure(PEEP). Adjustments in FiO_2 and respiratory rate were made according to routine blood gas analysis. Patients were extubated as soon as they met the following criteria, haemodynamic stability, no excessive bleeding, normothermia and consciousness with adequate pain control.

The number of distal anastomoses, peak Creatine Kinase myocardial band(CK-MB) values, the need for inotropic support for more than 12 h, intra-aortic balloon pump(IABP) usage, neurological complications [defined as global or focal neurological deficit, lasting less (transient ischemic attack) or more(stroke) than 24h], new atrial fibrillation(requiring treatment), mediastinitis (defined as mediastinal collection with positive microbiological culture), mechanical ventilation time, postoperative length of stay, and 30-day mortality(defined as death occurred within 30 days after operation, regardless of causes, in or out of the hospital and any death occurred later than 30 days as a direct result of a perioperative complication of the operation) was compared between the two groups. All patients were followed up at least 2 months after discharged from the hospital.

Statistical analysis

Data were expressed as $\bar{x} \pm s$. Comparison between the two groups were established with unpaired *t* - test (two-tailed) for continuous variables and the x^2 and Fisher exact test for categorical variables. A *P* value of less than 0.05 was considered significant.

RESULTS

Baseline and intraoperative characteristics are summarized in Tab 1. There were no differences between the OPCAB and CCAB groups in terms of age, gender, Parsonnet score and EuroScore, prevalence of unstable symptoms, urgency for CABG intervention and incidence of co-morbid diseases. The only significant difference between the two groups was found in the inci-

dence of Diabetes mellitus which was nearly two-fold higher in the OPCAB patients compared with the CCAB patients(15.8% vs. 30.6%, $P < 0.05$)(Tab 1).

Tab 1 Preoperative characteristics

	OPCAB(n=70)	CCAB(n=75)	P value
Age(years)	65.2 ± 10.05	64.6 ± 7.81	> 0.05
Female gender[n(%)]	9(12.9%)	8(10.7%)	> 0.05
Parsonnet core	7.1 ± 6.53	7.41 ± 6.32	> 0.05
EuroScore	3.80 ± 3.41	3.61 ± 3.38	> 0.05
Unstable angina(in-hospital)	59(84.3%)	65(86.7%)	> 0.05
CCS angina status[n(%)]			> 0.05
Class 1	23(32.9%)	34(45.3%)	
Class 2	13(18.6%)	10(13.3%)	
Class 3	21(30.0%)	23(30.7%)	
Class 4	13(18.6%)	8(10.7%)	
Ejection fraction ≤ 40[n(%)]	5(7.1%)	4(5.3%)	> 0.05
Plasma creatinine(mmol/L)	114.1 ± 38.92	114.5 ± 36.47	> 0.05
Diabetes mellitus[n(%)]	11(15.8%)	23(30.6%)	< 0.05
Cerebrovascular disease[n(%)]	4(5.7%)	3(4.0%)	> 0.05
Chronic airways disease [n(%)]	3(4.3%)	3(4.0%)	> 0.05

CCS, Canadian Cardiovascular Score.

There was no significant difference in the number of grafts used between the two groups(OPCAB group: 3.71 ± 0.75, CCAB group:3.80 ± 0.98)(Tab 2). One patient in group OPCAB was converted to ECC for hemodynamic instability without any mortality. In both groups the internal mammary artery usage was similar in the rate at which additional arterial conduits were used.

Thirty-day mortality occurred to one patient in the OPCAB group whereas two early deaths were observed in the CCAB group, but did not reach statistical significance($P > 0.05$). The frequency of atrial fibrillation(AF), IABP usage, mediastinitis, re-operation for bleeding, or tamponade were similar in both groups($P > 0.05$). There were no neurological events in the OPCAB group whereas five major neurological complications(three transient ischemic attacks, two strokes) occurred in the CCAB group($P > 0.05$). Postoperative inotropic requirements, peak CK-MB, ventilation time, blood loss, FFP, RBC transfusion need and the length of ICU stay were significantly lower in the OPCAB group than CCAB group($P < 0.05$)(Tab 3). There was no additional procedure or readmission in the early follow-up of both groups.

Tab 2 Operative details

	OPCAB(n=70)	CCAB(n=75)	P value
Distal anastomosis	3.76 ± 0.98	3.81 ± 1.02	> 0.05
Number of grafts	3.71 ± 0.75	3.80 ± 0.98	
ITA to LAD grafts[n(%)]	68(97.1%)	73(97.2%)	> 0.05
Graft to diagonal[n(%)]	52(74.3%)	58(77.3%)	
Graft to RCA/PDA[n(%)]	64(91.4%)	68(90.7%)	
Grafts to Cx/OM[n(%)]	60(85.6%)	66(88.0%)	

Values in parentheses are percentages. ITA, internal thoracic artery; LAD, left anterior descending; RCA, right coronary artery; PDA, posterior descending coronary artery; Cx, circumflex; OM, obtuse marginal. *NS:No significant difference*

DISCUSSION

Observational and randomized studies have shown that coronary artery bypass grafting (CABG) prolongs life in patients with significant LMCA and triple-vessel stenosis as compared with medical therapy alone. However, left main stem stenosis is considered as an adverse prognostic factor in the early and late outcome of the surgical treatment of coronary artery disease[11-13].

Myocardial revascularization without ECC through median sternotomy is a developing surgical strategy

Tab 3 Postoperative characteristics

groups	OPCAB	CCAB	P value
Peak CK-MB	40.2 ± 27.3	95.2 ± 13.4	< 0.05
Inotropic requirement			< 0.05
3~5 μg/(kg•min)	7	21	
> 5 μg/(kg•min)	2	10	
IABP usage(n)	1	2	> 0.05
Atrial fibrillation(n)	12	16	> 0.05
Bleeding(ml)	423 ± 156	615 ± 327	< 0.05
Reoperation for bleeding or tamponade(n)	1	3	> 0.05
Mean RBC(U)	0.26 ± 0.08	0.72 ± 0.21	< 0.05
Mean FFP(U)	1.48 ± 1.24	3.57 ± 2.02	< 0.05
Ventilation time(min)	304 ± 178	532 ± 326	< 0.05
Mediastinitis(n)	0	3	> 0.05
Neurological complications(n)	0	2(1 TIA, 1 stroke)	> 0.05
Length of stay(days)	2.23 ± 0.53	3.46 ± 1.18	< 0.05
Mortality(n)	1(cardiac)	2(1 cardiac, neurological)	> 0.05

ECC, extracorporeal circulation; XCL, cross-clamp; CK-MB, creatine kinasemyocardial band; IAB, intra-aortic balloon; RBC, red blood cells; FFP, fresh frozen plasma; TIA, transient ischemic attack

today. Eliminating the need for ECC and cardioplegic arrest is suggested to improve clinical outcomes, particularly in high risk patients[14-15]. The application of OPCAB was limited to patients without LMCA stenosis, due to some concern about the inability of these patients to tolerate cardiac manipulations during beating heart revascularization. Kim *et al*[16] suggested preoperative insertion of IABP in patients with critical LMCA (=75%) to facilitate posterior vessel off-pump CABG. Although 25% of the patients had LMCA stenosis more than 80% in our study, they did not require IABP support due to hemodynamic instability, in contrast to the recommendation of some investigators. Recently, however, there have been encouraging reports about the safety and efficacy of OPCAB for patients with LMCA stenosis[17-18].

The results of the present study suggest that myocardial revascularization in the presence of critical LMS with triple-vessel stenosis can be safely and effectively achieved by OPCAB techniques. We observed lower rates of morbidity in the OPCAB patients compared to CCAB patients. In particular, OPCAB patients required less postoperative inotropic support, less temporary pacing, lower postoperative transfusion requirements and had a reduced incidence of postoperative chest infections compared to the CCAB group[19]. The reduced requirement for blood transfusions in the OPCAB patients, despite of similar total postoperative blood loss, may be due to greater haemodilution and/or increased intraoperative blood loss which would be expected in the CCAB patients. The relative small sample size in the present study remains a limiting factor preventing a detailed analysis of the various subgroups, and it is possible that with further experience these differences will become more apparent. We also could not find a significant difference between in-hospital and 24-month mortality.

The(consecutive) 145 patients entered into this study all had triple-vessel disease, which excluded significant differences in patient selection. Patients in two groups (100%) needed to be grafted at the lateral and posterior part of the heart. The data revealed that the key factor, which affected the outcome of OPCAB surgery, lied in the favorable exposure and fixation of the coronary arteries at the lateral and posterior part of the heart. We adopted a single deep pericardial stay suture with a sling snared down by adjusting the two ends of the sling. All the target vessels can be exposed satisfactorily without severely affecting the hemodynamics. With local heart stabilizer, accompanied by vessel shunt and CO_2 blower, we can avoid the myocardial ischemia while anastomosing, and can get a clear surgery field. In this way, we can guarantee the quality of anastomosis. The outcome in this study shows that there is no significant difference in the number of distal anastomosis(OPCAB:3.76 $\pm$ 0.98, CCAB:3.81 $\pm$ 1.02) and the number of grafts (OPCAB:3.71 $\pm$ 0.75; CCAB:3.80 $\pm$ 0.98) between groups, as indicates that only if the operative technique is appropriate, will OPCAB also get complete revascularization[20-21]. There is aobvious learning curve for OPCAB, favorable exposure to a large degree depending on the experience of the operator. The study is on the basis of a completion of more than 500 cases of CCAB surgery and 100 cases of OPCAB surgery, and no case in this OPCAB group needed to be converted to CCAB in this study. 3 cases in OPCAB group ventricular fibrillation appeared, the reasons being hyperkalemia, blood block of the large DIAG by stabilizer and pressures due to a high manipulation of the heart, respectively. With timely disposure, the OPCAB surgery after the hemodynamics was stable and succeeded at last.

Our current strategy is to perform coronary artery bypass grafts using OPCAB surgery unless electrical or haemodynamic instability. The degree of LMS stenosis, the presence of concomitant right coronary artery disease or the presence of impaired left ventricular function are not considered contraindications to OPCAB. The grafting strategy is the same as any OPCAB case where the LAD is grafted firstly and circumflex subsequently applied[22].

One further limitation to the present study is that it is a non-randomized, retrospective study comparing outcome in patients undergoing either OPCAB or CCAB procedures. However, all of the procedures were conducted within a single institute in similar numbers, by the same surgeons, during an identical time period, and the data were collected prospectively. Additionally, comparison of preoperative demographic risk factors, demonstrated that the two cohorts were well-matched.

In summary, OPCAB is feasible and safe to perform in patients with significant LMS and triple-vessel stenosis. There is no difference between the groups with respect to mortality. Both early results of OPCAB compare very favorably to those obtained by conventional coronary artery bypass techniques.

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