Original Article

COMPARATIVE STUDY OF ON-PUMP AND OFF-PUMP CORONARY BYPASS SURGERY IN PATIENTS WITH TRIPLE VESSEL CORONARY ARTERY DISEASE

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ABSTRACT

Objective: *To analyze comparatively the clinical results of on-pump and off-pump coronary bypass surgery in patients with triple vessel coronary artery disease.*

Material and Methods: *Consecutive 300 isolated multiple coronary artery bypass patients entered into off-pump coronary artery bypass (group OPCAB, n=150) or coronary artery bypass with cardiopulmonary bypass (CPB) (group CCABG, n=150). There was no significant difference with regards to the degree of angina, history of myocardial infarction, diabetes and left main stem disease between two groups. The ejection fraction in group OPCAB before surgery was lower than in group CCABG (P<0.01). Group OPCAB had more patients with history of stroke, and abnormal renal function than group CCABG pre-operatively (P<0.01). All patients had coronary bypass surgery through full sternotomy. Group of CCABG underwent the support of CPB but Group OPCAB did not. Single deep pericardial stay suture with a sling snared down was used to help expose the target coronary vessels in group OPCAB, along with the stabilizers and coronary shunts. Medi-Stim Butterfly Flow meter was used to measure the flow of grafts in both groups.*

Results: *No one in group OPCAB needed to be converted into CCABG. The mean number of the distal anastomosis and the ICR (index of completeness of revascularization) were similar in both groups. The respiratory support time, the chest tube drainage and blood transfusion were less in group OPCAB than in group CCABG post-operatively (both P<0.01); Pulmonary dysfunction and abnormal renal function were less common in group OPCAB than in group CCABG post-operatively (both P<0.05). There was no significant difference in the mortality and other morbidities (peri-operative MI, stroke, atrial fibrillation).*

Conclusion: *OPCAB can be applied to patients with triple coronary vessels coronary artery disease and achieve similar completeness of revascularization, similar early surgical results with shorter respiratory support, reduced transfusion requirement, less pulmonary dysfunction and less abnormal renal function, as compared to patients undergoing CCABG.*

Key words: *off-pump, coronary artery bypass, multiple vessels disease, complete revascularization.*

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INTRODUCTION

Since 20th century, minimal invasive surgery has become a trend .With regard to coronary artery bypass surgery, avoiding cardiopulmonary bypass (CPB) has a vital significance of the minimal invasive surgery, for it can avoid the ischemia-reperfusion injury and a series of pathophysiological disorders of the organs brought by the CPB. Since Benetti and Buffolo[1-2] first reported their experiences of off-pump CABG (OPCAB), quite a few investigators have compared the effect between OPCAB and conventional on-pump CABG (CCABG).

For the difference of patient selection, in many conditions, the OPCAB group were low risk patients with single and, or double vessel disease[3-5]. But there has been a great debate in whether the patients with triple vessel disease are suitable for the OPCAB surgery, and the key point lies in whether the patients can get the complete revascularization and the same effect of the conventional CABG surgery. To get the satisfactory conclusion, we undertook a comparative study in patients of the same class in a random way. The objective of this study was to compare the surgical outcome of patients with triple vessel disease between the OPCAB and CCABG surgery treated groups.

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METHODS

1.Patient enrollment and characteristics:

From June 2001 to April 2003, 300 consecutive patients with triple vessel disease who underwent isolated CABG surgery were divided into OPCAB and CCABG group (each group, n=150). The patients who had only single and double vessel disease or accompanied with cardiac valve surgery, cardiac aneurysm, TMR, and those who underwent re-do CABG surgery were excluded. All the surgeries were completed by the same surgeon (CHEN X). Patients came to OPCAG or CCABG based on the order of coming of each and not on the coronary artery anatomic structure, how big the heart is or the left ventricular ejection fraction (LVEF) of each patient. But the patients associated with many co-morbid diseases were preferred for OPCAB. Data and Information are seen in table 1.There is no significant difference with regards to the degree of angina, whether combined with chronic obstructive pulmonary disease (COPD), history of myocardial infraction, diabetes mellitus (DM), emergency surgery, left main trunk lesion and ejection fraction (EF), but the ratio of patients combined with history of stroke and abnormal renal function before surgery in OPCAB group is much higher than that in CCABG group ($p<0.05$).

Table 1. Patient characteristics in two groups

Characteristics	OPCAB (n=150)	CCABG n=150	Statistics	The value of P
Age	66.5 ± 8.8/	64.3 ± 6.2	U=2.503	p<0.05
Sex male/female	111 / 39	120 / 30	χ^2=1.526	p=0.217
Angina CCS III-IV	128	117	χ^2=2.693	p=0.101
Combined with COPD	30	23	χ^2=1.123	p=0.289
History of Myocardial infraction	46	40	χ^2=0.587	p=0.444
History of stroke	39	20	χ^2=7.617	p=0.006
Combined with DM	48	42	χ^2=0.571	p=0.45
Abnormal renal function	45	19	χ^2=13.427	p=0.001
LMA lesion	33	38	χ^2=0.461	p=0.497
LVEF(%)	50 + 6.7	54 + 7.5	U=4.871	p<0.01
Emergency surgery	22	16	χ^2=1.085	p=0.298

Table 2. Surgical results of two groups.

Surgical results	OPCAB group(n=150)	CCABG group (n=150)	Statistic	P value
IABP assisted	3 all pre-operatively	4 1 case before surgery	EP**	P=1.00
The number of anastomoses per patient	3.84 + 1.06	3.75 + 0.94	U=0.778	p>0.05
ICR*	1.00 ± 0.16	1.02 ± 0.09	U=1.334	p>0.05
Surgical time(hrs)	3.7 ± 1.3	3.9 ± 1.5	U=1.234	p>0.05
Respiratory support after surgery hrs	4.9 ± 2.6	8.3 ± 4.3	U=8.287	p<0.01
Chest tube drainage (ml)	285±130	590± 246	U=13.43	p<0.01
Blood transfusion ml	255 ± 110	480± 214	U=11.45	p<0.01
ICU stay time hrs	18.3	20.4	U=1.925	p>0.05

number of grafts performed/number of grafts intended.
**EP-Exact probability

2. Surgical technique: Every patient had a full 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 (3mg/kg) in CCABG group, CPB was established as usual. After the aorta was cross-clamped, the cold crystal cardioplegia 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-bitting was applied to the aorta and 5-0 Prolene was used to finish the proximal anastomosis (single aortic cross clamp was used without side-bitting in 12 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 can be exposed. After systematic heparinization, ACT was maintained at greater 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. While exposing OM and PDA, Trendelenburg position was adopted to help better exposure and also to 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 intra-operatively by Medi-Stim Butterfly Flowmeter.

3.Statistical analysis: SPSS 10.0 was adopted for statistical analysis. P value <0.05 was taken as the level of significance.

Table 3. The anatomic position of multi-target vessels in both groups

Grafted CA	OPCAB n=150	CCABG(n=150)	Statistic	P value
LAD with LIMA	150 / 148	150 (146)	EP*	0.684
DIAG	81	70	χ^2=1.613	0.204
OM x1/x2/x3	118/30/2	127/20/3	EP*	0.272
RCA	23	47	χ^2=10.733	0.001
PDA	138	120	χ^2=8.970	0.003

RESULTS

All 300 patients got through the surgery smoothly and no one in OPCAB group needed to be converted to CCABG. IABP was used pre-operatively in 3 cases in group OPCAB for low LVEF, and was removed 6-25 hrs after surgery. IABP had been assisting for 29-47 hrs in 4 cases in CCABG group (1 before and 3 after surgery). The number of distal anastomoses varied from 3 to 6; the average number per patient was similar in both groups (OPCAB group: 3.84±1.06, CCABG group: 3.75±0.94); the assisted respiratory time of OPCAB group was much shorter than that of CCABG group; the chest tube drainage and blood transfusion were less in group OPCAB than in group CCABG post-operatively (table 2).

The main perioperative complications are given in

table 4. The perioperative myocardial infarction in OPCAB and CCABG group was seen in 1 and 5 cases respectively. Re-exploring because of bleeding was 2 and 6 cases, respiratory dysfunction 1 and 8. Newly appeared or primary abnormal renal function aggravation 1 and 8 cases in groups OPCAB and CCABG respectively. The incidence of stroke and atrial fibrillation (AF) in OPCAB group is slightly lower than that in CCABG group, but it did not reach the standard level of significance. There were a total of three deaths in 300 patients, one in OPCAB group (died of a large area cerebral infarction that happened 10 days after surgery and just before discharge), the other two in CCABG group (one died of low cardiac output syndrome and MODS 7 days after surgery, the other got stroke 2 days after surgery and died 15 days later).

Table 4. The main post-operative complications in two groups.

Post-operative complications	OPCAB(n=150)	CCABG (n=150)	Statistic	P value
Perioperative MI	1(0.67%)	5(3.33%)	EP	0.214
Re-exploring due to bleeding	2(1.33%)	6(4.00%)	EP	0.282
Respiratory dysfunction*	1**(0.67%)	8(5.33%)	EP	0.036
Abnormal renal function***	1(0.67%)	8(5.33%)	EP	0.036
Stroke	1(0.67 %)	2(1.33%)	EP	0.622
AF	21(14.00%)	28(18.67%)	$\chi^2=1.195$	0.274
Perioperative death	1(0.67%)	2(1.33%)	EP	1.000

*respiratory support time > 48hrs,**extubation 6hrs after surgery, reintubated 19 hrs after surgery due to CO_2 retention, ***Primary renal function abnormally aggravated or newly appeared

DISCUSSION

Due to its avoidance of a series of pathophysiological disorders brought by CPB, the respiratory support time after OPCAB is remarkably shorter than after CCABG. Also, the ratio of respiratory dysfunction after OPCAB is lower than after CCABG. The chest tube drainage and blood transfusion in OPCAB group is remarkably less than in CCABG group, which reveals the superiority of OPCAB and is similar to the report of the majority of the literatures[1-4]. In our study, though the ratio of patients combined with abnormal renal function and the history of stroke in OPCAB group is evidently higher than in CCABG group. The incidence of the main perioperative complications is lower than in CCABG group, which further illuminates the superiority of OPCAB[5]. The analysis of Stamou[6] et al reveals that CPB is an important independent risk factor of nervous system complication after surgery. Four cases out of 300 had stroke post-operatively in our study and the incidence in OPCAB group (0.67%) is slightly lower than in CCABG group (1.99%), but the difference is of no statistical significance, and this echoes the report of Sabik[7]. Among the 4 cases, only one case had stroke immediately after surgery the other three had 4-10 days after surgery (2 cases recovered), which might be relative to other factors except CPB and the manipulation of the aorta.

In most reported OPCAB literatures, most patients have only single or double vessel disease. In the report of Van Dijk[8], only 25% patients had triple vessel disease; and 78% patients had normal left ventricular function; the number of distal anastomosis per patient in OPCAB group was remarkably less than that in CCABG group, which was the same in patients with multi-vessel disease. The reason why patients in OPCAB group received less grafts than in CCABG group was that it was hard to get satisfactory exposure of the lateral and posterior part of the heart and then it was hard to achieve complete revascularization in OPCAB surgery[9-10]. And it is not hard to apprehend that why among nearly 500,000 patients who underwent CABG surgery in United States, the ratio of OPCABG surgery was only 18%[11]. In a study of 80 randomly matched cases, Czerny[12] found that the ratio of complete revascularization in OPCAB group was only 65%. About 12.5% patients failed to be grafted to target vessels, which might have been grafted, due to technical reason. 22.5% OPCAB patients had to be converted into CCABG because of the inaccessible target vessels or unstable hemodynamics. The number of distal anastomoses per patient in OPCAB group (2.6 ± 0.5) was remarkably less than in CCABG group (3.1 ± 0.8) ($P<0.05$)[12].Ascione et al[13] reported that the number of graft per patient in OPCAB group was 2.23 ± 0.83, while 2.31 ± 0.86 in CCABG group, which seemed indistinctive, but in his total 200 cases, no case needed to be grafted to the OM (lateral of the heart), and 80% cases had normal LVEF preoperatively[13]. Accordingly, the difference in patient selection may cause the statistical outcome to favor OPCAB group.

All the patients entered in this study had triple vessel disease, which excludes the distinct difference in patient selection. Although the ratio of history of stroke and abnormal renal function in OPCAB group was distinctly higher than in CCABG group, yet the comparability in the anatomic position of the target vessels in two groups was very strong. All patients in the two groups needed to be grafted at the lateral and posterior part of the heart. The data reveals that the key factor, which affects the outcome of OPCAB surgery, lies 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, ac-

companied 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 distinct difference in the number of distal anastomoses (OPCAB:3.84±1.06, CCABG 3.75±0.94) and the ICR (OPCAB:1.00±0.16,CCABG 1.02±0.09) between the groups, which indicates that if only the operative technique is appropriate, OPCAB can also get complete revascularization. There is an obvious learning curve for OPCAB; favorable exposure to a large degree rests with the experience of the operator. The study is on the basis of a completion of more than 400 cases of CCABG surgery and 50 cases of OPCAB surgery (3 cases were converted to CCABG), no case in this OPCAB group needed to be converted to CCABG in this study, 3 cases in OPCAB group had ventricular fibrillation, the reasons for that were hyperkalemia, blood block of the large DIAG by stabilizer and extreme manipulation of the heart. With timely disposure, the OPCAB surgery continued after the hemodynamics was stable, and succeeded at last.

We can conclude from the experience of the patients in this small group: (1) favorable exposure is the precondition to guarantee the quality of the anastomosis; (2)emergency surgery and left main trunk disease may be treated with OPCAB, as long as the hemodynamics are stable;(3)low LVEF is not an absolute contraindication of OPCAB. In this study the preoperative EF in OPCAB group was lower than in CCABG group. OPCAB was successfully done in 3 patients with very low EF (19-31%) with the help of IABP. High risk patients with low EF can benefit more from the OPCAB surgery[7]; (4) the patients combined with abnormal renal function and a history of stroke are preferred for OPCAB surgery, which can reduce corresponding complications[14].

There is a disaccord of reporting in the literature about whether OPCAB can reduce the post-operative incidence of AF. The outcome in the study shows that the incidence of AF in OPCAB is relatively lower (14%) compared with CCABG group, but the difference reaches no statistical significance, which indicates that besides CPB, other factors may contribute to post-operative atrial fibrillation.

Although we did not make a follow–up of the graft patency via coronary angiogram post-operatively in this study, before the closure of the chest, the flow meter was used to measure the graft flow of all patients. We made a comprehensive judgment from the waveform of the flow and pulsitile index. The flow of all the grafts was satisfactory except in one case where the flow was unsatisfactory, and got satisfactory after reanastomosis. This indicates indirectly that we can get the same anastomosis quality and graft flow in OPCAB surgery as we do in CCABG surgery.

CONCLUSION

OPCAB can be applied to triple vessels disease, and can reach the same revascularization and surgical results in experienced hands.

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