

## Cost Performance and Efficacy of Off-pump Coronary Artery Bypass Grafting

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### ABSTRACT

Off-pump coronary artery bypass grafting (Off-Pump CABG) may provide an alternative form of surgical revascularization by avoiding the unwanted complications of cardiopulmonary bypass, particularly in high-risk patients. To clarify the efficacy and cost performance of Off-Pump CABG, we studied the postoperative course of Off-Pump CABG and compared it to On-pump coronary artery bypass grafting (On-Pump CABG).

From Aug. 1998 to Feb. 2002, twenty-eight patients who had preoperative complications such as cerebral vascular disease (11), chronic renal failure (4), atheromatous aorta (4), one lung (1), severely impaired left ventricular function (6), re-do CABG (1), and cancer (1) underwent Off-Pump CABG. Another thirty-six patients who underwent On-Pump CABG served as a control.

The Off-Pump CABG patients were almost the same age as the On-Pump CABG patients ( $68 \pm 8$  vs  $64 \pm 8$  years, ns). The Number of grafts was similar in both groups ( $2.6 \pm 1.0$  vs  $2.9 \pm 1.0$ , ns). Peak CK, peak CKMB, peak LDH, and peak GOT release were significantly lower in the Off-Pump CABG group compared with the On-Pump CABG group. Graft patency rates were similar in both groups (98% in Off-Pump CABG vs 98 % in On-Pump CABG). The total cost for surgery and patient care was significantly lower ( $p < 0.0001$ ) in the Off-Pump CABG group ( $\$ 21000 \pm 7000$ ) compared with the On-Pump CABG group ( $\$ 33000 \pm 4200$ ).

Off-Pump CABG is less invasive to the myocardium, is less expensive, and has a similar efficacy in comparison with On-Pump CABG.

**Key words:** *Off-Pump CABG, Cost performance*

Interventional cardiologists have applied percutaneous myocardial revascularization to an increasing number of patients with coronary artery disease, leaving surgeons with an increasingly complex group of patients for surgical revascularization. Cardiopulmonary bypass may be less well tolerated in these elderly patients who present with significant comorbidities<sup>1,6,7,9</sup>. Therefore, the off-pump coronary artery bypass grafting procedure (Off-Pump CABG) has become a choice even for patients with multiple vessel graftings<sup>5,10</sup>. Avoiding the morbidity of cardiopulmonary bypass may provide safer surgical myocardial revascularization, particularly in the older age group or in patients with preexisting end organ dysfunction. The aim of this study was to evaluate the cost performance and efficacy of Off-Pump CABG in our population.

### MATERIALS AND METHODS

All the elective CABG candidates received head computed tomography (CT) or magnetic resonance image/angiography (MRI/A); carotid Doppler study to evaluate neck and cerebrovascular diseases; chest CT for ascending aorta evaluation, and epiaortic echography at the time of operation to detect thrombus or plaque at the clamping site. From Aug. 1998 to Feb. 2002, among sixty-four consecutive cases, twenty-eight patients were selected for undergoing Off-Pump CABG through median full sternotomy, because they had preoperative complications such as cerebral vascular disease in eleven cases, chronic renal failure in four (creatinine  $> 2.0$  g/dl), atheromatous aorta in four (by CT or epiaortic echography), one lung in one, severely impaired left ventricular (LV) function (ejection fraction  $< 30\%$ ) in six, re-do CABG in one, and cancer in one case. Off-Pump CABG was performed

utilizing a commercially available stabilizer and blower for visualization, and with or without using a shunt tube for distal perfusion. Another thirty-six patients who underwent conventional CABG (On-Pump CABG) under cardiac arrest induced by warm blood cardioplegia (antegradely only) or cold blood cardioplegia (antegradely and retrogradely) during the same period and by the same surgeon served as controls. All the emergency cases were included in On-Pump CABG group, rather than in the Off-pump CABG in this study.

Laboratory tests such as CK, CKMB, LDH, GOT were measured at 3, 12, and 48 hours after aortic unclamping and peak values were subjected to comparison. Graft patency was confirmed by coronary angiography at 14 days after bypass surgery. The criterion for graft patency was a graft without stenosis or with stenosis of less than 50%. The incidence of strokes with or without permanent deficit was evaluated. Bleeding during operation and ICU stay was measured and routine financial figures were collected from the total cost of the operation and patient care from admission to discharge lodged the insurance company. Operation time was measured. Hospital death rates were also compared.

Values were expressed as mean  $\pm$  SD. Statistical analysis was performed using a non-parametric test (Wilcoxon test) for comparing the two groups. A  $\chi^2$  test was used for comparing sex, the number of grafts, the rate of death, and the rate of stroke.  $p < 0.05$  was considered to be significant.

## RESULTS

In the Off-Pump CABG group, sixteen had a single graft, five had double grafting, three had triple grafting, and one had quadruple grafting. Demographics of the patients in both groups are shown in Table 1. Patients in the Off-Pump CABG group were the same age as those in the On-Pump CABG group ( $68 \pm 8$  vs  $64 \pm 8$  year). The number of grafts was similar in both groups ( $2.6 \pm 1.0$  vs  $2.9 \pm 1.0$ ). Procedure time was shorter in the Off-Pump CABG group ( $240 \pm 70$  vs  $362 \pm 70$  min) compared

**Table 1.** Characteristics of patients

	Off-Pump (n=28)	On-Pump (n=36)	p
Age	$68 \pm 8$	$64 \pm 8$	ns
Male/Female	16/12	22/14	ns
No. of grafts	$2.6 \pm 1.0$	$2.9 \pm 1.0$	ns
Arterial grafts	49/55	167/173	ns
Ejection fraction	$46 \pm 7$	$51 \pm 12$	ns
Death	1	1	ns
Stroke	0	3	ns

(Values were expressed as mean  $\pm$  SD, Off-Pump: off pump coronary artery bypass graft, On-Pump: conventional coronary artery bypass graft)

**Table 2.** Efficacy of Off-Pump CABG

	Off-Pump (n=28)	On-Pump (n=36)	p
CK (U/L)	$320 \pm 420$	$510 \pm 210$	<0.001
CKMB (U/L)	$22 \pm 7$	$120 \pm 35$	<0.001
GOT (U/L)	$45 \pm 18$	$80 \pm 20$	<0.001
LDH (U/L)	$500 \pm 80$	$950 \pm 143$	<0.001
Bleeding (ml)	$200 \pm 80$	$480 \pm 95$	<0.001
Patency rate (%)	98	98	ns
Total cost (\$)	$21000 \pm 7000$	$33000 \pm 4200$	<0.001

(Values were expressed as mean  $\pm$  SD, Off-Pump: off pump coronary artery bypass graft, On-Pump: conventional coronary artery bypass graft)

with the On-Pump CABG group. There was one conversion from Off-Pump to On-Pump CABG during this period due to sustained ventricular fibrillation. In the Off-Pump CABG group, a total of fifty-five grafts were placed on the left descending coronary artery (28), first diagonal artery (9), right coronary artery (12), and left circumflex coronary artery (6). There was one death in each group (the death in the Off-Pump CABG group was due to ventricular tachycardia, the other in On-Pump CABG was due to pulmonary embolism after bypass surgery. There were three strokes (two with permanent deficit and one without permanent deficit) in the On-Pump CABG group, however, there was none in the Off-Pump CABG group. Peak CK and peak CKMB release (Table 2) were significantly lower in the Off-Pump group compared with the On-Pump CABG group (CK:  $320 \pm 420$  U/L, CKMB:  $22 \pm 7$  U/L in Off-Pump CABG vs CK:  $550 \pm 210$  U/L, CKMB:  $120 \pm 35$  U/L in On-Pump CABG). Peak LDH and peak GOT (Table 2) were also significantly lower in the Off-Pump CABG group compared with the On-Pump CABG group (LDH:  $500 \pm 80$  U/L, GOT:  $45 \pm 18$  U/L vs LDH:  $950 \pm 143$  U/L, GOT:  $80 \pm 20$  U/L). Bleeding (Table 2) during the perioperative period in the Off-Pump CABG group was lower compared with the On-Pump CABG group ( $200 \pm 80$  ml vs  $480 \pm 95$  ml). The patency rate (Table 2) was 54/55 (98 %, occlusion including more than 50% stenosis) in the Off-Pump CABG group. By comparison, 170 out of 173 grafts (98 % occlusion including more than 50% stenosis) were patent in the On-Pump CABG group. The total cost from admission to discharge (Table 2) for the operation and patient care was significantly lower in the Off-Pump CABG group ( $\$ 21000 \pm 7000$ ) compared with the On-Pump CABG group ( $\$ 33000 \pm 4200$ ).

## DISCUSSION

The number of papers demonstrating the safety, broadening applicability, and efficacy of beating heart surgery is growing<sup>2,3,5</sup>. These beating heart methods allow us access essentially to all cardiac surfaces with surprisingly little hemodynamic disturbance. Comparing the elective On-Pump CABG

patients with the Off-Pump CABG patients, the operation time was considerably shorter, the amount of bleeding was remarkably smaller, and enzyme leakage from the heart was considerably lower in Off-Pump CABG patients than in On-Pump CABG patients. Furthermore, the number of grafts in Off-Pump CABG patients was similar to that in On-Pump CABG patients, which suggested the severity of the diseased vessels was comparable in both groups.

On the other hand, the fact that there no stroke occurred among the Off-Pump CABG patients, while three strokes occurred among the On-Pump CABG patients, might suggest the safety of the Off-Pump CABG method especially for cerebrovascular events, even though there was no statistical difference and the Off-Pump CABG patients were in a high risk group in terms of cerebrovascular disease. The strokes were presumably due to an embolic event caused by the aortic clamp. Two cases were emergency cases without cerebrovascular or ascending aortic evaluation who necessitated an aortic clamp and the other combined surgery for aortic arch aneurysm with a severely atheromatous aorta and also needed an aortic clamp. If the preoperative cerebrovascular or neck vessel evaluation revealed stenotic or occlusive signs, CT showed atheromatous aorta, or epiaortic echography showed plaque or calcification, Off-Pump CABG was chosen except for emergency cases, and re-do cases (approached through full sternotomy).

Finally, the total cost required for surgery and patient care was remarkably lower in Off-Pump CABG patients mainly because the cost of a cardiopulmonary bypass (including artificial lung, circuit, cannula, running fee, etc.) was eliminated and the anesthetic fees were low. The ICU stay and hospital stay were not significantly different between the groups. Furthermore, coronary angiography of the Off-Pump CABG group before discharge showed similar patency rates to On-Pump CABG<sup>4,8)</sup>, which led us to conclude that myocardial revascularization with "off pump" was feasible while maintaining the efficacy of conventional CABG.

Reasons for avoiding Off-Pump CABG and conversion to On-Pump CABG include the comfort level of the surgeons performing the procedure, hemodynamic instability including ventricular arrhythmia, the difficulty of bleeding control, and the difficulties associated with exploring the target coronary artery due to LV hypertrophy and other anatomical conditions which might influence long term graft patency.

There are several limitations in this study. First, this is not a randomized study. Second, the patients chosen for Off-Pump CABG were considered to be high-risk in terms of cerebrovascular disease. However, this study showed the excellent graft patency rate of the internal thoracic artery

(ITA) even though ITA is smaller in diameter in the Japanese population compared with Western population, and the cost effectiveness of Off-Pump CABG was also clearly shown through the Japanese insurance system. Above all, the most important finding from this study was the cost effectiveness of Off-Pump CABG without sacrificing the efficacy of On-Pump coronary bypass surgery.

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