ORIGINAL REPORT

Clinical Outcome and Cost in Patients with Off-pump vs. On-Pump Coronary Artery Bypass Surgery

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Abstract- General concept and major emphasis on off-pump coronary artery bypass surgery (OPCAB) is maintaining quality of care and patient safety while reducing cost and resource utilization. OPCAB probably avoids the potential complications of cardiopulmonary bypass. However its acceptance depends on clinical and economic outcome. The aim of this study is to compare clinical and economic outcome of off-pump and on pump coronary artery bypass surgery. This is a report of an analytic cross-sectional study on 304 patients underwent coronary artery bypass surgery that were randomized into conventional on pump and off-pump groups. Variables and costs were obtained for each group and these data were analyzed using parametric methods. There was no difference between the two groups with respect to perioperative and intraoperative patient's variables. OPCAB reduced the need for postoperative transfusion requirement (P<0.05) which was statistically significant and showed a trend towards reduction of morbidity although didn't reach statistical significance (P>0.05). There were no statistically significant differences in surgical re exploration and length of stay between the two groups. The mean cost for an on pump surgery was 8312000 ± 2859 Rials per patient that was significantly higher than an off-pump surgery. Based on the findings of this study, clinical outcome has no statistically significant difference between on pump and off-pump CABG but the costs are significantly higher in the on pump group.

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Keyword: On-pump CABG; Off-pump CABG; Outcome; Cost

Introduction

Coronary artery bypass grafting (CABG) is a widely used procedure in the management of symptomatic coronary artery disease around the world (1).

Previous reports have indicated long term survival and relief of angina after on pump surgery however, this procedure is associated with significant perioperative morbidity, increased resource utilization and hospital stay, which have been largely attributed to the use of cardiopulmonary bypass (CPB) (2-3).

Recent emphasis on cost in health care has focused attentions on the economics of medical procedures. Selection of the appropriate method of coronary artery bypass grafting is of increasing concern, particularly with regards to the lower initial cost of coronary angioplasty as an alternative procedure (4).

The relatively recent technique of operating on a beating heart as a cardiac surgical procedure for coronary artery bypass grafting is intended to decrease the adverse side effects typically associated with cardiopulmonary bypass. The advantages of using off-pump procedure may include fewer postoperative complications, shorter length of hospital stay and cost containment (5,6). The main target of this study is evaluation of clinical outcome and cost effectiveness of OPCAB.

Materials and Methods

This is an analytic cross sectional study, on 304 patients undergoing elective CABG between 2005 and 2006. The study was approved by the local ethics committee and informed consent was obtained from all patients. The patients were allocated into two groups: In group A (n=154) conventional myocardial revascularization (on-pump CAB) was performed with hypothermic cardiopulmonary bypass and cold blood cardioplegic

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arrest and in group B (n=150) the patients had OPCAB with multistage third generation octopus stabilizer and mister blower. Exclusion criteria included left ventricular dysfunction (ejection fraction of <30%), recent myocardial infarction (<1month), combined valve surgery, emergency or urgent operation, history of renal insufficiency (Cr >2 mg/dl), stroke or transient ischemic attack (TIA) within 1 month, redo CABG and patient without insurance support.

Data including age, gender, preoperative risk factors including diabetes, hypertension, hyperlipidemia, NYHA classification, ejection fraction, cardiac catheterization results, history of myocardial infarction (MI), stroke (CVA), smoking and family history of CAD lab test, need for reoperation due to bleeding, chest tube drainage, and incidence of complications including death, stroke, renal failure, and infection. Intensive care unit (ICU) stays and length of hospital stay (Table 1).

We calculated total cost variable and fixed costs for each patient according to the activity based costing methodology and included drug costs, clinical support services such as radiology and laboratory services, anesthetic costs, theater costs, and bed occupancy.

Continuous variables are expressed as mean ± standard deviation. For categorical variables, analysis included frequencies and percentages. All tests of significance were paired t-test, t-test, Fisher exact test, and Chi-square test for discrete variables and analysis of variance (ANOVA) for continuous variables. Statistical significance was measured with P values of ≤ 0.05.

Results

A total number of 304 patients were included in this study. There were no significant differences between the groups based on preoperative variables. As shown in Table 2 the two groups were balanced preoperatively with respect to age, gender, diabetes mellitus, hypertension, hyperlipidemia, left ventricular function, previous MI and CVA (Table 1).

Table 1. Perioperative variables in on pump and off pump groups

Perioperative variables			On pump n = 154	Off pump n = 150	*P* value
			Mean or Prevalence (n)		
Pre-operative	Age (yr)		59.1 ± 10	58 ± 9.7	NS
	Male Sex		72.7% (112)	74% (111)	NS
	Diabetes		41.6% (64)	32% (48)	NS
	Hypertension		40.3% (62)	42.7% (64)	NS
	Hyperlipidemia		40.3% (62)	44% (66)	NS
	History of Smoking		25.3% (39)	38.7% (58)	NS
	Family history of CAD		30.5% (47)	34.7% (52)	NS
	Prior MI		15.6% (24)	23.3% (35)	NS
	Prior CVA		0.6% (1)	2% (3)	NS
	Ejection fraction		43.7 ± 9.5	45.3 ± 9	NS
Post-operative	Deaths		2.6% (4)	0.7% (1)	NS
	ARF		0.6% (1)	0	NS
	SSI		1.9% (3)	0.7% (1)	NS
	CVA		1.3% (2)	0	NS
	Re-exploration		3.2% (5)	3.3% (5)	NS
	Bleeding		1.9% (3)	2.7% (4)	NS
	Transfusion requirements (units)	PRBC	1.7 ± 1.7	0.6 ± 1.0	~ 0
		FFP	0.7 ± 1.1	0.1 ± 0.5	~ 0
		PLT	0.2 ± 1.2	0.0 ± 0.3	0.03
	Hospital stay	ICU	2.5 ± 3.0	2.3 ± 1.1	NS
		Ward	6.7 ± 3.1	6.8 ± 3.0	NS

* CAD: coronary artery disease, SSI: surgical site infection, ARF: acute renal failure, PRBC: packed RBC, NS: not significant

Table 2. Costs of on pump and off-pump groups (RIALS)

Group / Cost Component	Off-pump N= 150		On-Pump N=154		*P*-Value
	Mean	SD	Mean	SD	
Anesthesia	1366000	1259	1536000	830	0.165
Pharmacy	50000	34	205000	225	≃ 0.000
Transfusion	7000	13	25000	25	≃ 0.000
Operating Room	2263000	275	2676000	320	≃ 0.000
Clinical Laboratory	1012000	378	1344000	855	≃ 0.000
Radiology	86000	97	107000	66	0.022
Ward Cost	1091000	1276	822000	316	0.012
ICU Cost	1342000	616	1597000	2387	0.206
Total	7217000	-	8312000	-	-

The conventional CABG group had a greater proportion of patients with three vessel CAD compared to the off-pump group (*P*=0.002). Operative characteristics were similar between the two groups. OPCAB patients underwent fewer grafts per patient than on pump CPB group (2.82 ± 0.81 vs. 3.21 ± 0.63). However, there were no significant associations between the number of grafts performed with either complications or hospital death.

The coagulation indices (including PT and PTT) were similar between the two groups preoperatively but the analysis of hematologic indices showed greater reduction in hemoglobin and hematocrit levels and platelet counts in the on pump group after the operation.

No significant difference was recorded in blood loss between the two groups (*P*~0.911).

On pump CABG patients received more red blood cells (median 1.71 unit vs. 0.55 unit), fresh frozen plasma (FFP) (0.73 unit vs. 0.08 unit) and platelets (0.24 unit vs. 0.02 unit, *P*~0.032) than OPCAB patients, which didn't reach statistically significant difference (Table 1). The transfusion requirements of the two groups were significantly different when measured by "required" and "did not required" criteria. FFP and platelet transfusion was less than 4% in OPCAB group and 36% and 4% respectively in on pump group.

The significant difference in transfusion requirements was also reflected in the related costs attributable to each group (mean transfusion cost per patient was 7000 ± 13 Rials and 25000 ± 25 Rials in the off-pump and on pump groups respectively) (Table 2).

There were no statistically significant differences in surgical exploration between the two groups (*P*~1.00).

The mean intensive care unit stay was 2.31 days (range, 1 to 9 days) for OPCAB and 2.51days (range, 1 to 36 days) for the on pump group and the median length of stay in the ward for OPCAB was 6.78 days (range, 2 to 21 days) and 6.74days for the on pump group (range, 3 to 36 days) there were no differences between the two groups considering the length of ICU and hospital stay (*P*>0.05) (Table 1).

There were no patients with stroke and renal failure in the off-pump group, but we had 3 strokes and a renal failure requiring dialysis in the on pump group.

With regard to postoperative outcomes, although OPCAB group exhibited reduced hospital mortality and postoperative morbidity (including renal failure, infections, CVA and other complications), but the difference was not statistically significant.

Theater costs per patient needed for a routine operation were significantly higher in the on pump than the off-pump group (2263000 ± 275 Rials vs 2676000 ± 320 Rials respectively), off-pump surgery reduced the pharmacy, radiology and clinical laboratory costs (*P*<0.05).

ICU cost were higher in the on pump group, but it was not (*P*=0.206) statistically significant.

Finally, the total cost for each patient was determined by adding the cost of operation materials, bed occupancy, transfusion, pharmacy, radiology and clinical laboratory, the mean cost for an on pump patient was 8312000 ± 2859 Rials, that is significantly higher than off-pump patient (7217000 ± 2044 Rials) (Table 2).

We did not match the two groups for the history of smoking (more common in off-pump patients) and New York Heart Association (NYHA) class щ (more common in on pump CAB).

Discussion

In this study we tried to answer whether eliminating CPB reduces morbidity and costs after CABG. We

prospectively evaluated 304 patients with multi vessel coronary artery disease who were candidates for either OPCAB or CABG with CPB.

The present strategy of health care places major emphasis on reducing costs and resources while maintaining quality of care and patient satisfaction. Clinicians are being challenged in achieving this goal within the framework of a patient subset that is increasing in severity of disease and risk adjusted mortality. On pump CABG is a common and expensive procedure there are now a number of alternative therapies claiming lower cost, such as coronary angioplasty and stenting (7), minimally invasive direct coronary artery bypass (MIDCAB) grafting(8), and off-pump surgery through a midline sternotomy. However, we should notice that first and foremost priority is the comprehensive management of the patient; cost should not be considered as a determinant of the procedure administered.

Off-pump surgery is reported to provide better myocardial protection, lower perioperative morbidity, conserve blood constituents, and avoids neurological deficits caused by under-perfusion during CPB and embolic events from the CPB and cross clamping of the aorta(9). Performing off-pump surgery through a median sternotomy allows complete revascularization in multi vessel disease, which is a limiting factor in MIDCAB surgery. Recently Buffolo *et al*. showed in a retrospective study that CABG without CPB is a safe and cost effective procedure, with a mortality rate of 2.5% and perioperative myocardial infarction rate of 4.8% (10). However, to date, there are few data from prospective randomized trials addressing the issue of whether cost can be reduced using an alternative surgical strategy such as off-pump coronary revascularization.

Kastanioti *et al.* (11) designed a prospective non randomized study to compare functional and economic outcome of off-pump and on pump surgery at 1 year follow up. They found no statistically significant differences in cardiac outcome, symptoms, or quality of life. Off-pump group experienced a reduction in costs without an increase in mortality. Similarly, Raimondo *et al*. also reported that off-pump surgery was significantly less costly than conventional on pump surgery. This is similar to other recent reports in the literature (12).

We found no difference in the incidence of post operative complications between the two groups. Based on the patient profiles in our study, one might predict a low incidence of complications for both the OPCAB and CABG with CPB groups. In our experience, patients with on pump CABG have low morbidity and mortality rates and shorter ICU stay.

OPCAB may lower morbidity for particular subgroups of patients after CABG (13). But in low risk patients morbidity is not different between OPCAB and on pump CABG.

Similar to our findings, Davies and colleagues (2) also reported their recent experience with off-pump multi vessel revascularization. They observed no difference in the incidence of postoperative complications and overall length of stay between off-pump and conventional on pump CABG patients.

Transfusion requirements were significantly lower in the off-pump group that is similar to previous reports in the literature (14). Nearly 10% of the 2.3 million annual recipients of red blood cell transfusions in the US are patients undergoing CABG. Therefore, routine implementation of this surgical technique would significantly reduce blood product transfusion complications. This includes the reduced risk of transfusion transmitted diseases such as acquired immunodeficiency syndrome, hepatitis B and C (15).

Our findings showed increased red blood cell transfusions in on pump versus off-pump patients, similar to our results, were recently reported by Ascione *et al.* (16). They demonstrated increased red blood cell loss and higher red blood cell, platelet, and FFP transfusion in on pump patients. CPB can lead to increased red blood cell transfusion requirements in multiple ways. Surface activation of platelets and coagulation proteins during CPB results in platelet dysfunction and coagulopathy, leading to postoperative bleeding (17). The crystalloid solutions needed to prime the pump, result in hemodilution, and the turbulence, cavitations, and osmotic stresses during CPB result in red blood cell membrane injury and hemolysis.

The reduction of cost related to less transfusion requirement observed in the off-pump group may clearly be compared with other reported strategies of cost containment, while avoiding the detrimental effects of CPB (15).

One of the first effects of excessive bleeding is the fall in hemoglobin and hematocrit levels. In the present study hemoglobin and hematocrit levels decreased more over time in the on pump group despite the fact that this group required a significantly higher amount of postoperative red blood cell transfusion. The fall in the blood hemoglobin level observed at the end of the operation in the off-pump group might be related to intra operative blood loss. However, the effects of hemodilution must be considered because the infusion of

colloid or crystalloid solutions is required during off-pump coronary operations to maintain the mean systemic pressure higher than 60 mm Hg, particularly during distal anastomoses.

In this study, similar to other study we observed a greater reduction of platelet counts throughout the study in the on pump group that suggests a depletion caused by contact activation by extracorporeal surfaces, bubble oxygenator, cardiotomy suction, and filters However, the decrease of platelet counts in the on pump group was rarely less than the amount normally required for hemostasis (50000-100000/μ L), suggesting a degree of impaired platelet function. Platelet dysfunction with a loss of aggregability is largely reported as a cause of bleeding after CPB (16). Holloway and colleagues found that the decrease in platelet count during CPB was in excess of that accounted for the hemodilution for priming the extra corporeal circuit (18).

In our study we found no statistically significant difference in postoperative blood loss between off-pump and on pump patients.

Based on the result of this study off-pump surgery significantly reduced the costs compared to conventional on pump surgery with respect to transfusion requirements, pharmacy, radiology, anesthesia and clinical laboratory costs. Operation costs are significantly lower in the off-pump and probably are due to multistage of stabilizer.

Several previously published randomized trials reported economic assessment of off-pump versus on pump surgery. Each trial found off-pump to be less costly versus on pump, with a reported range of hospital cost reductions, approximately 15-35% (19). These studies utilized various methodologies to capture different components of health service and patient costs.

Regression analysis in our study demonstrated a positive correlation between the number of vessels grafted per patient and the total costs after OPCAB or CABG with CPB. Patients undergoing two or one vessel grafts with OPCAB would therefore be expected to have comparatively decreased costs.

Raimondo *et al*. performed a prospective, randomized trial of off-pump versus conventional CABG and compared the operative and post operative costs (12). Off-pump CAB was significantly less costly than on pump surgery with respect to operation material, (probably due to multistage of stabilizer and blower) bed occupancy, transfusion requirements and complication management.

Recently there has been a suggestion that by performing coronary revascularization on the beating heart, there may be a reduction of blood loss (20). Raimondo *et al*. designed a prospective randomized study to investigate the effects of coronary bypass with or without cardiopulmonary bypass on postoperative blood loss and transfusion requirements (12). They found that CABG on beating heart is associated with a significant reduction in postoperative blood loss, transfusion requirement, and transfusion- related costs when compared with conventional revascularization by cardio pulmonary bypass and cardioplegic arrest. Although the blood loss seems slightly high in the on pump group in their study, these losses are in accordance with other recently published data (21).

OPCAB represents an alternative method for safe and effective revascularization, allowing the surgeon to consider whether CABG might be accomplished more safely in a particular patient without the use of CPB. Indeed, the greatest application of OPCAB may lie in extending CABG to patients who would not otherwise be candidates for CABG because of an increased operative risk with exposure to CPB.

In conclusion we suggest a multicenter clinical trial to evaluate the efficiency of OPCAB on clinical outcome and costs.

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