Original Article

Off-pump Coronary Artery Bypass is a Safe Option in Patients Presenting as Emergency

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Abstract

Introduction: The applicability of off-pump coronary-artery bypass (OPCAB) in patients who present as emergency remains controversial. Herein, we explore the efficacy and safety of OPCAB in patients who were indicated for emergency surgery. Materials and Methods: Between 2002 and 2007, a total of 282 patients underwent OPCAB, of which 68 were presented as emergency. This cohort (group A) was compared to 68 patients who had traditional on-pump coronary artery bypass grafting (CABG, group B) under emergency indications during the same period of time. Baseline demographics, intraoperative data and postoperative outcomes were analysed. Results: Preoperative demographics were comparable in both groups. Mortality during the first 30 days was comparable in both groups and no stroke occurred in the whole series. Patients in group A had significantly less pulmonary complications (4.4% vs 14.7%, *P* = 0.04), less ventilation time (30.3 ± 33.6 hours vs 41.5 ± 55.4 hours, *P* = 0.18) and were less likely to have prolonged ventilation, (19.1% vs 35.3%, *P* = 0.03). Similarly, OPCAB patients had less postoperative renal-failure/dysfunction (5.9% vs 8.8%, *P* = 0.51) and required less inotropic support (66.2% vs 88.2%, *P* = 0.002), bloodtransfusions (23% vs 86.8%, *P* <0.0001), and atrial- (17.6% vs 35.3%, *P* = 0.02) or ventricular-pacing (17.6% vs 41.2%, *P* = 0.002). Although the number of diseased vessels was comparable in both groups, patients in group A received less distal anastomoses. (2.78 ± 1.19 vs 3.41 ± 0.89, *P* = 0.002). Similarly, complete revascularisation was achieved less frequently in group A (76.5% vs 94.1%, *P* = 0.004). Conclusion: OPCAB strategy is a safe and efficient in emergency patients with reasonable good short-term postoperative outcomes.

Ann Acad Med Singapore 2010;39:607-12

Keywords: Cardiac surgery, Coronary artery disease, Off-pump coronary-artery bypass

Introduction

Percutaneous coronary intervention (PCI) is the preferred therapy strategy for revascularisation in the case of an acute coronary syndrome (ACS) or acute myocardial infarction (AMI).[1]

In contrast, surgical emergency revascularisation remains controversial as it is associated with an increased operative mortality ranging from 1% to 32% depending on the preoperative haemodynamics.[2-4] However, if indicated, this procedure requires an appropriate timing and the preoperative optimisation of haemodynamic conditions whenever possible.[5] In such a critical situation, haemodynamic stability is crucial, and may be supported by rapid implantation of a cardiac-assisted device such as an intra-aortic balloon pump (IABP).[6] Emergency surgery may be indicated within the first hours especially if the patients are also presented with refractory symptoms or ST-segment elevation myocardial infarction (STEMI).[7]

Minimally-invasive techniques have led to the development of off-pump coronary artery bypass grafting (OPCAB). This approach permits complete myocardial revascularisation while avoiding cardiopulmonary bypass

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(CPB) which is well known for its associated deleterious effects such as an increase in myocardial injury,[8,9] stroke,[10] renal failure,[11] and inflammatory reactions.[12-14]

However, the current OPCAB application remains highly debated in emergency patients with a critical preoperative state. Besides intermittent stabilisation, off-pump procedures also involve repetitive dislocation of the heart, especially when the circumflex-territory is addressed. Additionally, the extended phases of hypotension and decreased cardiac-output may occur which may, in turn, lead to compromised haemodynamics and cardiac decompensation.[15,16] For this reason, surgeons have been cautious to expose emergency patients to this technique, which may put patients at risk for emergent conversion to CPB, and subsequently leading to the damage of multiple organs. In contrast, the current data demonstrate that OPCAB is generally associated with less major complications, and risk-adjusted reduced mortality.[17-22] Furthermore, Rastan and colleagues[7] had published a 5-year experience on patients with ACS and were indicated for emergency coronary artery bypass grafting (CABG). In that study, the heart beating strategies were associated with better outcomes such as reduced postoperative inotropic support, less blood loss, decreased incidence of stroke and lower renal failure rate. Rastan's study also found comparable long-term results for both CABG and OPCAB in ACS patients.

Our study aims at evaluating the efficacy of OPCAB vs CABG surgery in patients who were presented with indications for emergency surgery.

Materials and Methods

This is a retrospective single centre and multiple surgeons study. Our institution's electronic client/patient sample survey (CPSS) database identified patients who had been operated on between September 2002 and July 2007 using the OPCAB and CABG techniques. From a total of 282 patients who underwent OPCAB, 68 presented as emergency. This cohort of 68 patients (group A) was compared to 68 randomly selected patients who had traditional CABG (group B) under emergency indications in keeping with the current AHA/ESC guidelines.[1] Indication for emergency surgery was considered as non-elective surgery (within the next 24 hours) in patients with ongoing ischaemia, Non-ST-segment elevation myocardial infarction (NSTEMI), acute coronary syndrome (unstable angina), critical left main disease or left ventricle (LV) decompensation**.** Exclusion criteria were patients with mechanical complications of myocardial ischaemia, such as ventricular septal defect (VSD), papillary muscle rupture, mitral valve regurgitation, and patients with persistent cardiogenic shock (≤24 hours) or patients in cardiopulmonary resuscitation (CPR) conditions. Off-pump surgery in our institution is carried out according to internationally established techniques. Baseline demographics, procedural data and postoperative outcomes were extracted from the database. Institutional review board (IRB) approval was obtained to perform this study.

Operative Technique: On-pump CABG

The conventional CABG operations were carried out by 7 cardiothoracic surgeons in our institution. On-pump coronary bypass surgery was performed using state of the art techniques extensively described elsewhere. Briefly, cold, blood-based cardioplegia was supplemented by a solution of potassium, magnesium and procaine at a ¼ volume-ratio was used. All procedures were performed through a median sternotomy. Standard techniques of CPB were used. Heparin was reversed followed by weaning from the CPB.

Operative Technique: OPCAB

Off-pump surgery was carried out according to internationally established techniques. Briefly, after sternotomy and pericardiotomy, 150 IU of Heparin was administered to achieve an activated clotting time of 250 to 300 seconds. The left internal thoracic artery was harvested before pericardiotomy. Next, a deep pericardial stitch was placed using 0-silk sutures, through which the gauze was passed for the purpose of traction and exposure. Cannulation purse string sutures were placed in the aorta and right atrium as a standby measure in the case of conversion to On-Pump. Epicardial pacemaker wires were placed on the surface of the right ventricle for heart rate manipulations, the heart was filled adequately and the table was broken for variably "head down" trendelenburg position manipulations. In cases of enlarged hearts, a deep vertical pericardiotomy as well as right pleurotomy were carried out to allow for rigorous exposure of the heart without haemodynamic compromise. For the distal anastomosis, the target vessel was occluded proximally to the anastomotic site using silicon-supported tourniquets. The anastomotic area was stabilised using the Medtronic Octopus stabilizer, and if necessary, Starfish heart suction-stabilizer of the same company (Medtronic, Minneapolis, Minnesota, USA). Intra-coronary shunts were used whenever possible. A blower-mister device was used in all cases.

Intra-operative Management & Strategy for Revascularisation

In all patients, haemodynamic optimisation was attempted by fluid resuscitation, trendelenburg positioning, atrial pacing and catecholamine administration. When this conservative approach failed, re-stabilisation attempts were carried out using an IABP placed intra-operatively. Trans-esophageal echocardiography (TEE) and Pulmonary artery catheter (Swan-Ganz Catheter) measurements were

used to assess haemodynamic compromise. Surgical revascularisation was commenced by lateral anterior descending (LAD) coronary artery to left internal mammary artery (LIMA) grafting. After which the right coronary system was approached, and lastly, the circumflex territory was done. In patients with left main coronary artery disease, LAD and circumflex arteries were always grafted, regardless of the degree of stenosis. All other vessels with significant lesions (>70%) when identified preoperatively were selected as targets for revascularisation.

Analysed Parameters

The set of evaluated variables include preoperative patient characteristics, intraoperative variables and postoperative outcome data. Preoperative patient characteristics include gender, age, cardiovascular risk factors and comorbidities such as past cerebrovascular accidents, cerebrovascular disease, morbid obesity, chronic obstructive pulmonary disease (COPD), renal failure and dialysis. Cardiac related preoperative conditions were myocardial infarction (MI) within 1 to 7 days prior to surgery, preceding cardiogenic shock, cardiomegaly, congestive heart failure (CHF), ejection fraction (EF), preoperative creatine kinase (CK), creatine kinase, muscle and brain (CK-MB) and logistic EuroScore for preoperative risk stratification. Intra-operative variables included CPB data, the number of diseased coronary vessels and the total number of distal anastomoses. Completeness of revascularisation was assessed by the help of a 'Revascularisation Index' (RI) which was calculated for each patient. The RI was defined as the total number of distal grafts divided by the number of affected coronary vessels reported on the preoperative coronary angiogram. Postoperative variables include operative and early postoperative mortality (within first 30 days), requirements for pacing, inotropes, antiarrhythmics, postoperative ventilation time, postoperative CK, CK-MB at 12 hours postoperatively, need for blood transfusions, pulmonary complications, renal complications and surgical site infections.

Data Analysis and Statistical Method

Continuous variables that were shown as mean and standard deviation were analysed using Student's t-test for independent samples. Categorical or dichotomous data that were presented in frequencies and percentage (%) were compared using chi-square test with Fisher's – exact adjustment. Statistical significance was inferred with *P*-values <0.05. All the statistical analyses were performed using GraphPad PrismÒ software version 5.01 for Windows (GraphPad Software, San Diego, CA, USA). A powerful analysis to document a statistically significant 1-percent decrement in mortality was done using the software found in http://statpages.org/proppowr.html.

Results

Patient Characteristics and Preoperative Data (Table 1)

Patients in group A and B were comparable in terms of age, gender, cardiovascular risk-factors and co-morbidities, such as COPD. The mean Euroscore was 7 ± 4 in group A vs 8 ± 4 in group B ($P = 0.23$). Mean ejection fraction (EF) was similar in both groups (43 ± 14 vs 42 ± 15, $P = 0.58$), whereas recent myocardial infarction (within 1 to 7 days prior to surgery) (63.2% vs 44.1%, $P = 0.03$) as well as preceding cardiogenic shock (11.8% vs 7.4%, $P = 0.38$) were more frequent among patients in group A. Similarly, these patients required the preoperative implantation of an IABP more frequently (45.6% vs 39.7%, $P = 0.45$), had a higher incidence of left main disease (LMD) (42.6% vs 33.8%, $P = 0.29$) and CHF (7% vs 3%, $P = 0.14$). Furthermore, it became apparent that patients in group A were more frequently suffering from cerebrovascular disease (7.4% vs 1.5%, $P = 0.09$).

Table 1. Preoperative Patient Characteristics

Characteristics	OPCAB n = 68	CABG n = 68	OR	*P* Value
Age (y) *	60 ± 14	58 ± 18	-	0.518
Male (%)	85.3	88.2	0.77	0.613
Smoking (%)	64.7	50.0	1.59	0.129
Diabetes (%)	47.1	78.5	0.94	0.864
Hypertension (%)	75.0	63.2	1.74	0.138
Hyperlipidemia (%)	77.9	72.1	1.37	0.428
History of renal failure (%)	14.7	8.8	1.78	0.287
History of COPD (%)	11.8	8.8	1.38	0.779
History of CVA (%)	7.4	1.5	1.78	0.095
History of MI (%)	63.2	44.1	2.18	0.025
IABP (%)	45.6	39.7	0.75	0.452
Left main disease (%)	42.6	33.8	0.91	0.290
NYHA Class IV (%)	11.8	17.7	0.62	0.468
No of diseased vessels *	2.8 ± 0.6	2.8 ± 0.5	-	0.877
Ejection fraction *	43 ± 14	42 ± 15	-	0.581
Ejection fraction <30% (%)	22.0	22.0	1.00	1.000
CK (U/I)*	401 ± 529	379 ± 658	-	0.891
CKMB fraction (U/I\)*	20.7 ± 38	28.3 ± 53.8	-	0.570
EuroSCORE *	7 ± 4	8 ± 4	-	0.225

* Data given as mean ± SD; OPCAB: Off-pump coronary artery bypass grafting; CABG: Coronary artery bypass grafting; COPD: Chronic obstructive pulmonary disease; CVA: Cerebrovascular accident; MI: Myocardial infarction; IABP: Intra-aortic balloon pump; NYHA: New York Heart Association; CK: Creatine kinase; CKMB: creatine kinase-myocardial band; EuroSCORE: European system for cardiac operative risk evaluation

Intraoperative Data (Table 2)

There was no conversion to CPB among patients who underwent the off-pump approach. In group B, the mean CPB and aortic cross-clamp time were 125 ± 46 minutes and 63 ± 24 minutes, respectively. Due to haemodynamic instability, 2 patients of the on-pump cohort required intraoperative implantation of IABP. Although the number of diseased vessels was comparable in both groups (2.76 ± 0.58 vs 2.78 ± 0.46, $P = 0.87$), patients in group A received significantly less distal anastomoses than patients in group B (2.78 ± 1.19 vs 3.41 ± 0.89, $P = 0.002$). Similarly, the completeness of revascularisation was achieved less frequently in group A (76.5% vs 94.1%, $P = 0.004$) and the 'Revascularisation Index' was significantly lower among these patients (1.07 ± 0.42 vs 1.25 ± 0.36, $P = 0.02$).

Table 2. Intraoperative Data

	OPCAB n = 68	CABG n = 68	*P* Value
Intraoperative IABP (%)	1.5	4.4	0.3101
CPB time CABG (min)*		125 ± 46	-
Cross-clamp time CABG (min)*	-	63 ± 24	-
No of distal anastomosis/patient*	2.78 ± 1.2	3.41 ± 0.9	0.002
Completeness of Revascularisation (%)	76.5	94.1	0.004
Revascularisation Index (RI)	1.07 ± 0.42	1.25 ± 0.36	0.02

* Data given as mean ± SD; OPCAB: Off-pump coronary artery bypass grafting; CABG: Coronary artery bypass grafting; IABP: Intra-aortic balloon pump

Postoperative Data and Outcomes (Table 3)

Mortality during the first 30 days (4.4% vs 2.9%, $P = 0.64$) was comparable in both groups and no stroke occurred in the whole series. With 68 patients on the OPCAB group and 68 patients on CABG in our study, there will be a 7.5% (power = 7.5%) chance of detecting a significant difference in treatment effect on mortality [4.4% (group A) vs 2.9% (group B)] at a two-sided 0.05 significance level. The sample size of our study is limited. A further power analysis indicated that to have the chance to detect a 1% significant difference in treatment effect on mortality with an adequate power (80%) and at a two-sided 0.05 significance level, it would be required to recruit 6080 patients/group (total = 12,160). Due to the number of patients in our institution, such a sample collection would be unrealistic. Even though definitive conclusions cannot be derived from our study, it offers useful information regarding the safety of OPCAB in emergency patients.

Patients in group A had significantly less pulmonary complications (4.4% vs 14.7%, $P = 0.04$), less ventilation time (30.3 ± 33.6 hours vs 41.5 ± 55.4 hours, $P = 0.18$) and were less likely to have prolonged ventilation (>24 hours) (19.1% vs 35.3%, $P = 0.03$). Similarly, they had less postoperative renal failure / dysfunction (5.9% vs 8.8%, $P = 0.51$) and required less intermittent dialysis (4.4% vs 7.4%, $P = 0.47$). For a more straightforward clinical course, patients in group A required significantly less inotropes (66.2% vs 88.2%, $P = 0.002$), fewer blood transfusions (23% vs 86.8%, $P < 0.0001$) as well as lesser atrial (17.6% vs 35.3%, $P = 0.02$) or ventricular pacing (17.6% vs 41.2%, $P = 0.002$). Furthermore, a trend towards less time spent in the intensive care unit (ICU) was observed in the off-pump group (79.5 ± 56 hours vs 95.5 ± 56 hours, $P = 0.11$). In contrast to this, the occurrence of deep sternal wound infections was similarly frequent in both cohorts.

Table 3. Postoperative Outcome

	OPCAB	CABG	*P* Value
Mortality rate (%)	4.4	2.9	0.6365
Pulmonary complications (%)	4.4	14.7	0.04
Average ventilation time (hr)*	30.3 ± 33.6	41.5 ± 55.4	0.1875
Prolonged ventilation time (>24hr) (%)	19.1	35.3	0.03
Post-operative CK (U/I)*	614 ± 711	1001 ± 1067	0.2077
Post-operative CK-MB fraction (U/I)*	25.3 ± 61	28.3 ± 58.9	0.8803
Blood transfusion (%)	23.0	86.8	<0.0001
Atrial Pacing (%)	17.6	35.3	0.02
Ventricular Pacing (%)	17.6	41.2	0.002
Atrial fibrillation (%)	14.7	22.1	0.2683
Cardiac arrest (%)	5.9	4.4	0.698
Inotropic Support (%)	66.2	88.2	0.002
Acute renal dysfunction / failure (%)	5.9	8.8	0.505
Intermittent Dialysis (%)	4.4	7.4	0.470
Deep sternal infection (%)	1.5	1.5	1.00
Average stay in ICU (hr)*	79.5 ± 56	95.6 ± 56	0.116

* Data given as mean ± SD; OPCAB: Off-pump coronary artery bypass grafting; CABG: Coronary artery bypass grafting; CK: Creatine kinase; ICU: intensive care unit

Discussion

In our series, OPCAB appears to be safe and efficient for emergency patients. The mortality rate is comparable to the conventional technique, but with regards to postoperative complications and postoperative course, OPCAB seems to benefit emergency patients more. This is clearly reflected by the significantly less frequent pulmonary complications as well as fewer blood transfusions requirements.[23,24]

As regards to OPCAB safety and outcomes, various reports are available.[5-7,25,26] Stamou and colleagues[26] recently

evaluated 2273 patients who underwent the non-elective (urgent or emergent) off-pump surgery compared to a control group of 3487 patients who underwent the conventional on-pump approach. The authors found emergency off-pump surgery to have comparable mortality and stroke rates.[26] In another interesting study, Karthik et al[25] analysed 828 non elective patients of which 417 had off-pump surgery. The authors clearly demonstrated that off-pump surgery had lower mortality rates and was superior in terms of postoperative complications such as renal failure and the need for IABP implantation. In addition to their findings, our data also revealed a strong benefit for off-pump patients with regard to pulmonary complications and ventilation time. This is an important predictor for a better postoperative course and has also been highlighted in a recent paper from Rastan and associates.[7] The authors investigated 638 consecutive patients with acute coronary syndrome (ACS) receiving emergency CABG surgery. Of these patients, 398 patients underwent the classical on-pump approach whereas the other patients either had beating heart surgery without cardioplegic arrest (n = 116) or off-pump surgery (n = 124).[7] Furthermore, their findings support our results that off-pump patients have a straighter postoperative course in terms of a decreased need for inotropic support and temporary atrial or ventricular pacing.

We, together with the rest, believe that the improved postoperative course after OPCAB may be explained by the avoidance of CPB which is well established to have deleterious effects.[11-14,27] These negative effects may include inflammatory reactions,[12,14,28] an increased degree of myocardial injury,[8,9] a higher risk of stroke,[10] and a negative impact on renal function.[11]

One of the major concerns regarding the off-pump technique is that complete revascularisation seems not possible. This has been suggested to be an important predictor for long-term results.[22,29,30] Various studies highlighted this problem and indicated that complete revascularisation is still limited in off-pump surgery.[29,30] Although achieving the international average, our data confirm that off-pump patients had significantly less complete revascularisation and consecutively led to a significantly lower revascularisation index.

One major reason for this problem might be the general caution and limited confidence of the surgeon to perform dangerous manoeuvres such as temporary stabilisation or repetitive dislocation of the heart during off-pump surgery, especially when it is related to the circumflex territory. These manoeuvres may lead to severe arrhythmia, low cardiac-output and extended phases of hypotension which may not be tolerated haemodynamically. In this situation, the surgeon is forced to convert the patient to CPB emergently which is an additional risk, particularly for high-risk patients. Another aspect for incomplete revascularisation might be reflected by variable experience and by an overall lower performance rate of OPCAB procedures. At our institution, the OPCAB approach accounts for 30% to 50% of all coronary bypass procedures, whereas in countries such as the United States approximately only 20% of all coronary bypass procedures are performed using the off-pump method.[30] An efficient off-pump approach in high-risk patients can only be achieved by continuously improving surgical techniques as well as the development of a standardised strategy for revascularisation. These strategies may include the LAD grafting first to preserve myocardial supply before starting the other heart manoeuvres. Parallel to this, the standardised application of intracoronary shunts to maintain distal perfusion during anastomosis might be a useful tool during the off-pump approach. The feasibility of complete revascularisation in off-pump surgery has been recently demonstrated by Puskas and colleagues.[22] However, when compared to our series, their patients were not selected with an indication for elective surgery and were not presenting as an emergency.

All limitations of a retrospective study are applicable in our study. Many of the positive trends that we observed did not reach statistical significance due to the small number of patients in our cohort. The power analysis indicated that a sample size of 12,160 would be necessary to detect a 1% significant difference in the treatment effect on mortality with an adequate power (80%) and at a two-sided 0.05 significance level. Due to the number of patients in our institution, such a sample collection would be unrealistic. Though definitive conclusions cannot be derived from our study, it offers useful information regarding the safety of OPCAB in emergency patients. Furthermore, long-term follow-up data are required to evaluate the potential benefits of either technique. Thus, a large prospective randomised trial would be useful in quantifying these highlighted benefits of OPCAB in this group of patients.

In summary, our results show that the off-pump approach is safe and is as good as the standard CABG, if not, a better method for revascularisation of emergency patients with reasonably good short-term postoperative outcomes. With the evolution of stabilisation techniques and hybrid procedures, more myocardium may be salvaged without the compromise in completeness of revascularisation.

Acknowledgements

We thank Ms Sonja Muecke and Dr Felix Woitek for their help in data collection.

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