

Off-Pump versus On-Pump Coronary Artery Bypass Procedures: Postoperative Renal Complications in an Asian Population

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Abstract

Introduction: Diabetes and habitual smoking cause advanced coronary artery disease (CAD) in Asian patients at a younger age. No definite data exist as to whether off-pump (OPCAB) is better than conventional on-pump coronary artery bypass grafting (CCAB) in terms of postoperative renal complications. Thus, we aimed to compare the renal outcomes of on-pump and off-pump coronary artery bypass grafting (CABG) on our patients, which constituted a predominantly Asian population. **Materials and Methods:** A cohort of 395 patients following CCAB were compared with 293 patients who underwent OPCAB. Baseline demographics, comorbidities, intraoperative data, intensive care unit stay, number of grafts, New York Heart Association (NYHA) score, American Society of Anesthesiologists (ASA) score, EuroSCORE risk assessment model, and postoperative complications particularly renal, were collected and analysed. **Results:** The off-pump group consisted of significantly older patients with higher Canadian Cardiovascular Society (CCS) and ASA scores. Additionally, the off-pump group involved a significantly greater number of smokers and chronic obstructive pulmonary disease (COPD) patients. Other demographic parameters were not different between the groups. Postoperative investigations showed a significantly elevated serum creatinine (100.3 ± 42.5 vs 127.6 ± 114.2 $\mu\text{mol/L}$; off-pump vs on-pump; $P = 0.039$) and urea levels (5.9 ± 3.1 vs 10.6 ± 15.6 mg/dL ; off-pump vs on-pump; $P = 0.006$) in the on-pump group. Moreover, there was a high tendency towards a higher rate of renal dysfunction associated death in this group. **Conclusions:** OPCAB is a safe and equally efficient operative method compared to CCAB, and has a significant lower risk for postoperative renal complications as a treatment modality for surgical coronary revascularisation.

Ann Acad Med Singapore 2010;39:112-7

Key words: Cardiopulmonary bypass, Renal dysfunction

Introduction

To date, the major part of routine cardiac surgery is performed using extracorporeal circulation with cardioplegic arrest. Regardless the technique of cardioplegia, temporary renal dysfunction can be observed frequently. Renal dysfunction requiring dialysis occurs in less than 5% of the patient undergoing cardiac surgery with cardiopulmonary bypass. Even so, this small number of patients should not be underestimated because renal failure requiring dialysis is associated with an extremely high mortality rate.¹

The reasons for renal dysfunction and failure are multifactorial and include many factors like renal hypoperfusion, non-pulsatile flow, hypothermia, microembolic events in the renal vasculature and stimulation of the inflammatory

response during cardiopulmonary bypass (CPB).^{2,3} However, the explicit contribution of these factors still remains unclear and needs to be fully elucidated.

Off-pump coronary artery bypass grafting (OPCAB) is known to eliminate several CPB-linked non-physiological conditions. Due to the fact that OPCAB eliminates the use of CPB and cardioplegia, the CPB- and cardioplegia-associated morbidity and mortality risks are significantly reduced compared to patients undergoing coronary artery bypass grafting (CCAB).⁴ Therefore, it has been suggested that OPCAB could have beneficial effects in patients with multiple preoperative risk factors for renal dysfunction undergoing coronary artery bypass surgery.^{5,6} Nevertheless, the data on this topic remain contradictory. Several studies

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have reported that OPCAB in comparison to CCAB may minimise renal injury.⁷⁻⁹ Other studies failed to show any significant beneficial effects on renal function.^{10,11} One possible explanation of these contradictory findings may be that these studies were performed in different institutions and thereby the study populations also show major differences.

It is now well accepted that there exist inherent differences between Asian and European patients with regard to differences in the size of target coronary vessels, genetic make-up of the histological structure of vessel, as well as the acquired external environment – in terms of food, lifestyle, cultural practices, the incidence and severity of diabetes.¹² Thus, this study aims to assess the efficacy of the OPCAB procedure as a treatment modality for coronary revascularisation in our institution where the vast majority of patients are Asians, in the area of postoperative renal complications. Some observe a lesser incidence of acute renal failure requiring renal replacement therapy with OPCAB whereas others do not. The objective was to compare the occurrence of renal-related adverse outcome between CCAB and OPCAB.

Materials and Methods

Study Population

This is a retrospective, single centre, multiple surgeon study. Between December 2002 and November 2007, 395 patients who underwent CCAB were compared to 293 who underwent OPCAB in our institution. Multiple variables such as demographics, co-morbidities of patients, intensive care unit (ICU) stay, number of grafts done, New York Heart Association (NYHA) score, American Society of Anesthesiologists (ASA) score, and EuroSCORE risk assessment model, as well as postoperative complications particularly renal, were compared between the 2 groups. Patients who underwent combined procedures were excluded. Exclusion criteria were patients with mechanical complications of myocardial infarction such as ventricular septum defect (VSD), papillary muscle rupture, mitral valve regurgitation, and patients with cardiogenic shock persisting for a length of 24 hours.

Data Collection

In our study, data was collected from patients' case notes in the Medical Records Office of our institution, National University Hospital of Singapore (NUH), and a database was established. Institutional Review Board (IRB) approval was obtained from our institution's cardiovascular section of the DSRB Board (DSRB Domain C/08/368). The outcomes of the patients who had been through the OPCAB procedure were looked into and where possible, comparisons were made with respect to outcomes from the conventional coronary artery bypass grafting (CABG) patient group.

Factors looked at were considered to be good predictors of postoperative renal complications such as postoperative urea, creatinine, creatine kinase (CK) and CKMB. Data on the duration of postoperative ICU stay, as well as total duration of ventilation, were also analysed.

The preoperative, risk classification and postoperative data of the patients in this study were taken from the Perfusion Department's database. Patients were followed for a period of 30 days after the procedure. Mortality was taken into account if it occurred within 30 days following the procedure.

Surgical Technique and Procedure: Conventional CABG (On Pump)

The conventional CABG operations were performed by 7 cardiothoracic surgeons in our institution. We performed on-pump coronary revascularisation using state-of-the-art techniques, extensively described elsewhere. Briefly: We used cold blood-based cardioplegia supplemented by a solution of potassium, magnesium and procaine at a ¼ volume-ratio. The grafts utilised for the vascularisation will be mentioned below. All the operations were performed through a median sternotomy. Standard techniques of CPB were used. The aorta was cross-clamped, distal anastomoses were first performed, followed by the proximal anastomoses. Heparin was reversed following weaning from the CPB.

Surgical Technique and Procedure: OPCAB (Off Pump)

Three different surgeons adopted the OPCAB technique. Off-pump surgery was carried out according to internationally established techniques. All the operations were performed through a median sternotomy and pericardiotomy. To achieve an activated partial thromboplastin time of 250 to 300 seconds, 150 IU of heparin was administered. Cannulation purse string sutures were placed in the aorta and the right atrium as a standby measure in case of conversion to CCAB. Epicardial pacemaker wires were inserted on the surface of the right ventricle for the heart rate manipulations, then the heart was filled with volume adequately and the table 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 hemodynamic 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 Octopus® tissue stabiliser (Medtronic, Minneapolis, MN, USA), and if found necessary by the surgeon, Starfish heart suction-stabiliser of the same manufacturer was used for additional traction and stabilisation, prominently for the exposure of the circumflex region. Ischaemic preconditioning before anastomosis and intracoronary shunts were used variably

by the surgeons, according to preference, experience and intraoperative judgement. A blower-mister device was used in all cases. The saphenous vein grafts were then de-aired, and proximal anastomosis using tangential clamps was performed, mostly using 6.0 Prolene suture. Coronary shunts were used to maintain target vessel haemostasis. In compliance with international experience, ischaemia or hypotension were addressed by volume, heart rate, inotrope or beta-blocker based manipulations and short release of too vigorous exposure and torsion. Half of the heparin effect was antagonised using protamine.

Statistical Analysis

Data collection and subsequent statistical analysis was performed with MS Excel for Windows and SPSS for Windows. Statistical tests of significance were performed and a *P* value less than 0.05 was assumed to be statistically significant. Continuous variables are shown as mean and standard deviation of the mean and were analysed using 2-tailed Student's *t*-test for independent samples. Categorical or dichotomous data are presented in percentages (%) and were compared using chi-square test.

Results

Patient demographics and disease characteristics are listed in Table 1. There were no major differences between patients with regard to gender, BMI, diabetes, hypertension, hypercholesterolaemia, ejection fraction, NYHA and EuroSCORE. However, the incidence for COPD was significantly higher in the OPCAB group (57.0% vs 44.7%; *P* = 0.001). Most likely this is associated with the significantly higher number of smokers in this group (11.0% vs 2.0%; *P* < 0.001). Besides that, the OPCAB group of patients were older than the CCAB group of patients (59.7 ± 10.3 vs 57.3 ± 15.8 years; *P* = 0.0025). Both Canadian Cardiovascular Society (CCS) and ASA scores were significantly higher in the OPCAB group. Similarly, the number of diseased vessels was slightly higher in the CCAB group (Table 1).

The intraoperative data is illustrated in Table 2. There were no differences between the groups with respect to core temperature during the operation. A significant fewer number of distal anastomoses were performed in patients who underwent OPCAB surgery (2.7 ± 1.0 vs 3.3 ± 1.0; *P* < 0.001). The cross-clamp time in the CCAB group was 59.0 ± 26.3 minutes and the perfusion time was 108.2 ± 43.9 minutes.

Postoperative data are displayed in Table 3. Total ICU time was significantly higher in the CCAB group (63.1 ± 115.0 vs 82.5 ± 93.5 h; *P* = 0.020). In the OPCAB group, less patients required blood products (12.6% vs 47.6%; *P* < 0.001) and pacing (26.3% vs 50.1%; *P* < 0.001). Also, the development of deep sternal infection was less frequent

Table 1. Population Characteristics

Parameter	OPCAB n = 293	CCAB n = 395	<i>P</i>	Statistical analysis
Age (y)	59.7 ± 10.3	57.3 ± 15.8	0.0025	<i>t</i> -test
Male (%)	79.9	83.0	0.2900	chi-square test
BMI (kg/m ²)	24.5 ± 3.2	25.1 ± 4.9	0.367	<i>t</i> -test
History of smoking (%)	57.0	44.7	0.001	chi-square test
Diabetes (%)	46.7	47.4	0.851	chi-square test
Hypertension (%)	71.8	75.6	0.261	chi-square test
Hyper- cholesterolaemia (%)	73.2	73.4	0.948	chi-square test
COPD (%)	11.0	2.0	<0.001	chi-square test
Number of diseased vessels	2.7 ± 0.6	2.8 ± 0.4	<0.001	<i>t</i> -test
Pre-op Troponin T (ng/mL)	0.47 ± 1.50	0.16 ± 0.51	0.095	<i>t</i> -test
NYHA score	2.1 ± 0.8	2.2 ± 0.8	0.162	<i>t</i> -test
CCS score	2.3 ± 1.1	2.0 ± 1.2	0.018	<i>t</i> -test
ASA score	3.0 ± 0.6	2.9 ± 0.6	0.043	<i>t</i> -test
EuroScore	4.2 ± 5.3	4.7 ± 6.7	0.302	<i>t</i> -test
EF (%)	48.2 ± 14.3	47.2 ± 15.1	0.374	<i>t</i> -test

ASA: American Society of Anesthesiologists; BMI: body mass index; CABG: coronary artery bypass grafting; CCS: Canadian Cardiovascular Society; COPD: chronic obstructive pulmonary disease; EF: ejection fraction; EuroSCORE: European system for cardiac operative risk evaluation; NYHA: New York Heart Association; OPCAB: off-pump coronary artery bypass grafting

Nominal parameters are given as % of the study group.

Ordinal parameters are given as mean ± standard deviation.

Table 2. Intraoperative Data

Parameter	OPCAB n = 293	CCAB n = 395	<i>P</i>	Statistical analysis
No. of distal anastomosis	2.7 ± 1.0	3.3 ± 1.0	<0.001	<i>t</i> -test
Cross-clamp time (min)	-	59.0 ± 26.3	-	<i>t</i> -test
Perfusion (min)	-	108.2 ± 43.9	-	<i>t</i> -test
Core temp (°C)	32.3 ± 1.6	32.5 ± 2.3	0.618	<i>t</i> -test

CABG: coronary artery bypass grafting; OPCAB: off-pump coronary artery bypass grafting

Values are given as mean ± standard deviation.

in the OPCAB group (1.2 vs 6.3%; *P* = 0.074).

Preoperative renal function markers did not show any major differences between the groups (Table 4). However, postoperative measurement of creatinine (100.3 ± 42.5 vs 127.6 ± 114.2 µmol/L; *P* < 0.039) and urea (5.9 ± 3.1 vs

Table 3. Postoperative Outcomes

Parameter	OPCAB n = 293	CCAB n = 395	P	Statistical analysis
Total ICU time (h)	63.1 ± 115.0	82.5 ± 93.5	0.020	t-test
Total ventilation time (h)	21.3 ± 48.3	25.9 ± 21.7	0.136	t-test
Blood products required (%)	12.6	47.6	<0.001	chi-square test
Deep sternal infection (%)	1.2	6.3	0.074	chi-square test
Complicated infection (%)	3.8	7.6	0.037	chi-square test
Pacing (%)	26.3	50.1	<0.001	chi-square test
Cardiac arrest (%)	4.8	7.8	0.382	chi-square test
Operative cardiac death (%)	1.7	3.3	0.199	chi-square test

CABG: coronary artery bypass grafting; OPCAB: off-pump coronary artery bypass grafting

Nominal parameters are given as % of the study group.

Ordinal parameters are given as mean ± standard deviation.

Table 4. Data Related to Postoperative Renal Complications

Parameter	OPCAB n = 293	CCAB n = 395	P	Statistical analysis
Pre-existing renal disease (%)	16.9	22.7	0.349	chi-square test
History of renal failure (%)	7.2	6.6	0.764	chi-square test
Pre-op CK (IU/L)	197.3 ± 383.4	182.2 ± 436.5	0.814	t-test
Pre-op CKMB (IU/L)	10.7 ± 36.0	13.3 ± 44.7	0.675	t-test
Pre-op creatinine (μmol/L)	109.0 ± 86.9	107.6 ± 89.4	0.921	t-test
Pre-op urea (mg/dL)	6.1 ± 3.4	5.9 ± 3.2	0.719	t-test
Post-op CK (IU/L)	51.0 ± 156.5	30.5 ± 109.3	0.341	t-test
Post-op CKMB (IU/L)	0.65 ± 1.91	0.38 ± 1.94	0.366	t-test
Post-op creatinine (μmol/L)	100.3 ± 42.5	127.6 ± 114.2	0.039	t-test
Post-op urea (mg/dL)	5.9 ± 3.1	10.6 ± 15.6	0.006	t-test
Renal failure				
Associated death (%)	0.3	1.5	0.126	chi-square test
Renal complications (%)	2.7	4.6	0.213	chi-square test
Dialysis required (%)	4.8	7.9	0.386	chi-square test

CABG: coronary artery bypass grafting; CK: creatine kinase; CKMB: creatine kinase-myocardial band; OPCAB: off-pump coronary artery bypass grafting

Nominal parameters are given as % of the study group.

Ordinal parameters are given as mean ± standard deviation.

10.6 ± 15.6 mg/dL; $P = 0.006$) showed significantly lower counts of these parameters compared to the CCAB group. Our data also indicate less renal complications (Table 4). Other renal function-related parameters did not show any significant differences after the operation.

Discussion

The prominent finding in our study is that OPCAB surgery preserves renal function. Also, OPCAB seems to reduce postoperative morbidity and mortality.

Though many improvements in cardio-pulmonary bypass techniques have been made, renal dysfunction remains one major problem in cardiac surgery. The incidence of transient renal dysfunction is reported in up to one third of the patients undergoing open heart surgery. Transient renal dysfunction itself is associated with a high mortality rate.¹³ Cardiopulmonary bypass thereby contributes significantly to postoperative morbidity and mortality.

One reason which has been identified to be the cause of acute renal failure is, in the large majority of cases, acute tubular necrosis.¹⁴ Despite a lot of scientific efforts which have been made to understand the mechanisms and exact reasons for cardiopulmonary bypass associated renal dysfunction, many controversies regarding the exact triggers of renal impairment remain unsolved. However, it has been hypothesised that inadequate or non-pulsatile renal perfusion, macro- and microembolic loads to the renal vasculature, and the inflammatory response to CPB are potential aetiological factors for the development of postoperative renal dysfunction.¹¹

Since the mid-1990s, CCAB has been challenged by OPCAB surgery.¹⁵ OPCAB surgery by avoiding cardiopulmonary bypass eliminates most of the factors that have been identified to be the cause of complications in cardiac surgery. Many studies have exposed the advantages of OPCAB surgery. Probably the most important findings are less mortality, less morbidity, less blood transfusions, faster recovery¹⁵⁻¹⁹ and a slight reduction in hospitalisation.^{6,20,21} However it has also been suggested by authors, reporting no significant benefit, that it may not be the OPCAB procedure but the selection of young and relatively healthy patients that generated better outcomes.^{22,23} The tendency to select young patients with fewer co-morbidities can be understood easily when the technical difficulties are taken into account.

The difference of our study lies in the blend of Asian ethnicities and thereby in the different genetic make-up as well as on the habituations-associated risk factor profile of the Asian population. In our cardiac centre, we have experienced benefits of OPCAB surgery – especially in older patients having co-morbidities. However, so far

this has not been proven by numbers and the surgeons of our centre decided, according to their experience, which method of surgical intervention a patient should undergo.

As Table 1 shows, particularly old patients with a significantly higher rate of COPD, of whom many are smokers, CCS and ASA scores have been selected for OPCAB surgery. Furthermore, Table 1 also indicates that the OPCAB group of patients had significantly lower numbers of diseased vessels. This may be explained by the decisions of our surgeons facing the well known technical difficulties during OPCAB on the posterior side of the heart.

Postoperative findings showed a significantly reduced ICU time, infection rate, requirement of pacing and blood products. These findings can all be explained by the absence of cardiopulmonary bypass associated inflammation²⁴ and cardioplegic arrest of the heart. ICU time and total ventilation time in the OPCAB as well as in the CCAB group may seem exorbitantly high compared to other centres. The former is due to anaesthesia residents having to cover 2 ICU-wards at the same time and are less aggressive with extubations at night. The latter is due to the fact that ICU time equals ICU and high dependency time in our clinic. The transfer to the general ward may be delayed because there are mixed wards in our institution and a lack of specialised nursing staff.

We also expected a significant reduction of cardiac death. Our present study could not give any evidence to support this thesis. However, our results disagree with the findings of Ascione's research group.⁵ In their study, they have clearly proven a benefit on cardiac outcome after OPCAB surgery. Probably the difference in these results could be explained by the higher CCS scores of the patients in our OPCAB group.

Table 4 shows that preoperatively both of our study groups, OPCAB and CCAB groups, did not show major differences in any of the renal function associated parameters such as CK, CKMB, urea and creatinine blood levels. Both groups also had a similar incidence of pre-existing renal disease and history of renal failure. Previous studies have suggested serum creatinine levels to be a compelling parameter for renal dysfunction after cardiac surgery.²⁵ Postoperatively, especially serum creatinine and urea levels revealed a significant increase in the CCAB group compared to the OPCAB group. Moreover, data show a high tendency (0.3% vs 1.5%; $P = 0.126$) towards a lower rate of renal-failure associated death in the OPCAB group. CK and CKMB levels proved no different between both groups.

Conclusion

There are certain limiting factors to this study. One important limitation is that not all of the surgeons employ the OPCAB technique in the same frequency. Therefore, it is not possible to segregate surgeons by experiences with regard to differences in postoperative outcome. Furthermore this study is retrospective, observational and limited to a single institution. All data were entered into the database as part of patient management.

In summary, we believe that the results of this study contribute to the evaluation of the efficacy of OPCAB surgery in the Asian population. From these results, the (i) reduced creatinine and (ii) urea levels and (iii) the lower incidence of renal-failure associated death, we conclude that OPCAB surgery can have beneficial effects in Asian patients – especially in old patients with certain comorbidities. To our knowledge this is the first study comparing renal impairment in OPCAB and CCAB surgery in a selected group of patients of Asian origin.

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