INTERVENTIONAL CARDIOLOGY AND SURGERY

Off pump coronary artery bypass surgery for significant left ventricular dysfunction: safety, feasibility, and trends in methodology over time—an early experience

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Objective: To examine the safety and applicability of off pump coronary artery bypass surgery (OPCAB) in patients with significant left ventricular dysfunction and to discuss the clinical implications for the surgical methods.

Design: Retrospective study.

Setting: Tertiary care university affiliated referral centre.

Participants: 353 consecutive patients with preoperative left ventricular ejection fraction $\leq 35\%$ who underwent coronary artery bypass over a three year period.

Main outcome measures: Postoperative morbidity and mortality.

Methods: 144 patients operated by OPCAB were compared with 209 patients operated by conventional coronary artery bypass. Multivariate and univariate analyses were performed on the pre- and postoperative variables to predict risk factors associated with hospital morbidity and mortality.

Results: Patients in the OPCAB group were more likely to be women and to have congestive heart failure, chronic obstructive pulmonary disease, hypertension, and diabetes; patients in the on pump group were more likely to have had a recent myocardial infarction and to have more severe angina pectoris and an urgent/emergent status. The groups did not differ significantly in length of stay, major postoperative complication rates, or mortality. Comparison of the impact of the procedures on surgical methods over time showed an increase in the use of OPCAB (13% to 67%), without any impact on morbidity or mortality.

Conclusions: OPCAB is feasible and applicable for patients with depressed left ventricular function. This high risk group can potentially benefit from the off pump approach.

Despite modern advances in technology, myocardial protection, and postoperative care, left ventricular dysfunction remains an essential prognostic factor in coronary artery surgery.^{1,2}

Off pump coronary artery bypass surgery (OPCAB) has theoretical and practical advantages over conventional coronary artery bypass grafting (CABG). The patients best suited for this procedure have not yet been clearly defined, although some studies show that high risk patients would probably gain the most benefit from avoiding cardiopulmonary bypass.^{3–6} The objective of this retrospective study was to examine the safety and applicability of OPCAB in patients with significant left ventricular dysfunction and to discuss the clinical implications for the surgical methods.

PATIENTS AND METHODS

Clinical data collection

The computerised records of 353 patients with an ejection fraction of $\leq 35\%$ who underwent CABG at Crawford Long-Emory Hospital between 1 January 1999 and 31 December 2001 were reviewed. OPCAB was used for 144 patients and conventional CABG for 209.

The specific surgical procedure was selected non-randomly by the surgeons on the basis of their experience and preference.

Operative technique

General anaesthesia was induced according to the institutional protocol (see appendix). A Swan-Ganz catheter and

transoesophageal echocardiography were used for additional monitoring.

In the OPCAB procedures, normothermia was maintained with warm intravenous fluids, a heating mattress, and a warm operating theatre. A standby perfusionist was available in all cases. The operation was performed through a median sternotomy. After conduit harvesting, heparin was given in doses of 1.5–3 mg/kg, depending on the individual surgeon's protocol, to achieve an activated clotting time of ≥ 300 seconds. Values were checked every 30 minutes and heparin was added, if necessary. The pericardium was opened widely and the right pleura was opened to facilitate changes in the heart position without significant haemodynamic changes. Epi-aortic ultrasound was performed in every patient. Deep pericardial traction stitches were used according to the surgeon's preference. Stabilisation was achieved with a suction device (Octopus 3/4 and Starfish 1 or 2; Medtronic Inc, Minneapolis, Minnesota, USA). Coronary shunts were not used routinely. Heparin was reversed with 75 mg protamine to achieve an activated clotting time of ≥ 140 seconds.

In the conventional CABG procedures, anticoagulation was achieved with 3–4 mg/kg heparin to reach and maintain an activated clotting time of > 400 seconds. Cardiopulmonary bypass was instituted through a single right atrial cannula and an ascending aorta cannula. Standard cardiopulmonary bypass management included a membranous oxygenator, arterial line filters, non-pulsatile flow, and mean arterial pressure above 60 mm Hg. The myocardium was protected with antegrade and retrograde cold blood cardioplegia and

Table 1 Preoperative characteristics

Variable	Off pump (n = 144)	On pump (n = 209)	Odds ratio	p Value
Age (years)	63 (10.6)	61.9 (10.9)	NA	0.215
Women	40 (28%)	36 (17.5%)	1.8	0.024
Body mass index (kg/m ²)	29 (5.4)	29 (5.7)	NA	0.892
Congestive heart failure	69 (48%)	84 (40%)	1.36	0.156
CCS class III and IV	53 (37%)	103 (49%)	0.467	0.022
Ejection fraction (%)	28 (7)	27.8 (6.3)	NA	0.982
Preoperative atrial fibrillation	20 (14%)	38 (18%)	0.72	0.309
Hypertension	109 (75%)	143 (68%)	1.43	0.151
Diabetes	67 (46%)	80 (38%)	1.40	0.015
Insulin dependent	17 (12%)	22 (10%)	1.13	0.731
Family history	66 (46%)	115 (55%)	0.693	0.104
COPD	58 (40%)	48 (23%)	2.26	<0.001
Renal failure	19 (13%)	26 (12%)	1.07	0.871
Dialysis dependent	4 (3%)	2 (1%)	3.1	0.230
Current smoker	55 (38%)	73 (35%)	0.81	0.573
Prior cardiovascular accident	11 (7%)	18 (8%)	0.872	0.844
Prior cardiac enlargement	10 (7%)	8 (4%)	1.89	0.222
Prior myocardial infarction	106 (73%)	162 (77%)	0.808	0.447
< 24 hours	10 (7%)	28 (13%)	0.480	0.056
1–7 days	38 (26%)	69 (33%)	0.727	0.196
Diseased vessels				
One	13 (9%)	11 (5%)	1.8	0.198
Two	24 (16%)	43 (20%)	0.772	0.48
Three	107 (74%)	155 (74%)	1.00	1
Status				
Elective	136 (94%)	181 (87%)	2.63	0.019
Urgent	6 (4%)	12 (6%)	0.716	0.625
Emergent or emergent/salvage	2 (1%)	16 (7%)	0.170	0.011
All repeat	8 (5%)	27 (13%)	0.391	0.028
Length of stay (days)				
Admission to surgery	2.9 (2.9)	2.8 (2.6)	NA	0.753
Surgery to discharge	7.4 (7.3)	8.3 (8.6)	NA	0.272
Total length of stay	10.3 (7.9)	11.1 (9.2)	NA	0.374

Data are mean (SD) or number (%).

COPD, chronic obstructive pulmonary disease; CCS, Canadian Cardiovascular Society; NA, not applicable.

mild systemic hypothermia. Epiaortic ultrasound was performed in every patient. At the end of surgery, heparin was reversed with protamine.

Statistical analysis

Numerical variables are presented as mean (SD). Student's *t* test was used to compare categorical parameters and χ^2 test or Fisher's exact test was used to compare patient characteristics and postoperative complications. A probability value of $p < 0.05$ was considered significant.

RESULTS

Table 1 summarises the patients' demographic characteristics and preoperative clinical data. The patients in the OPCAB group were more likely to be women and to have chronic obstructive pulmonary disease, congestive heart failure, hypertension, and diabetes mellitus. Patients undergoing conventional CABG had more recent myocardial infarctions and tended to have more severe angina pectoris (Canadian Cardiovascular Society class III/IV).

Mean (SD) ejection fraction was 28 (7)% in the OPCAB group and 28 (6)% in the conventional (on pump) CABG group. This difference was not significant.

Figure 1 shows the number of distal anastomoses made and the trends in the surgical methods over time applied to patients with left ventricular dysfunction. The application of OPCAB to patients with low ejection fraction increased from 13% in 1999 to 67% in 2001.

The statistical difference in the number of distal anastomoses between the two groups was eliminated as experience with OPCAB and the level of confidence increased.

Table 2 summarises postoperative complications, extubation time, and the length of stay. The groups did not differ statistically in early or late mortality or major complications.

Mean (SD) duration of follow up for the OPCAB group was 160 (229) days with median of 67.5 days and for the conventional CABG group was 328 (498) days with a median of 101 days.

The OPCAB patients were more likely to undergo extubation earlier and had a lower tendency to develop new renal failure and gastrointestinal bleeding, resulting in less time spent in the intensive care unit. However, these findings did not reach significance.

DISCUSSION

Improvements in myocardial preservation, monitoring, and postoperative care have made CABG much safer than before.⁷ Although success rates have risen for patients with left ventricular dysfunction, this population also has a wide variety of co-morbid illnesses, as noted also in the present series, which may complicate surgery and have a detrimental effect on outcome. Furthermore, cardiopulmonary bypass has several well recognised practical disadvantages, especially the risk of myocardial injury and systemic inflammatory response, which can lead to multiorgan failure and a need for blood transfusions.^{8–11}

In contrast to the global ischaemia caused by CABG with cross clamping and cardioplegic arrest, OPCAB causes only regional ischaemia. This may explain its apparent myocardial protective effect as indicated by the low incidence of myocardial infarction and enzyme leakage associated with this procedure.^{3–6, 12} This advantage translates into greater haemodynamic stability, less postoperative low cardiac output syndrome, and shorter intensive care unit stay. Further support is provided by the present finding of a similar clinical outcome in the two groups, even though the OPCAB group had more co-morbid illnesses.

An early, potential drawback of the OPCAB is the fewer distal anastomoses performed for each patient, which can mean incomplete revascularisation,^{4 13} with a possible negative impact on surgical outcome.¹⁴ We, too, noted a significant difference in this factor between the on pump CABG and OPCAB groups. However, further analysis over time indicated that the difference was related to the learning curve and was almost completely eliminated as surgeons gained experience with the technique. Indeed, the most recent studies report no statistical difference in the number of distal anastomoses between patients undergoing CABG and those undergoing OPCAB.^{15 16}

The low incidence of neurological events among patients after both on pump and off pump bypass in our series may be attributable to our consistent use of epiaortic ultrasound to evaluate the ascending aorta. In the presence of a finding of high grade disease in the ascending aorta, the operative technique was changed accordingly.

For OPCAB to be considered feasible for high risk patients, its durability, effectiveness, and safety need to be at least equal to those of conventional CABG. Our data, together with recent reports, show that OPCAB meets these criteria and potentially benefits patients with left ventricular dysfunction.^{4 5 15 17-19} Furthermore, as opposed to previous reports in which the OPCAB mortality was lower than in the conventional CABG group, suggesting inherited bias, we noted a

similar low mortality between the two groups.¹⁷⁻¹⁹ This may reflect the balanced, strict, and comprehensive institutional approach to this group of patients.

Others have reported that OPCAB has an important cost saving potential as well.²⁰

Our study is limited by its retrospective, non-randomised design. However, no results of prospective randomised studies on OPCAB versus conventional CABG for high risk patients have been published. We have found our data valuable, and our initial good results with this procedure have led to a growing trend in its use at our centre, especially for high risk patients.

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APPENDIX

ANAESTHESIA PROTOCOL

1) Induction of anaesthesia

- Fentanyl 8 µg/kg
- Propofol 0.5–2.0 mg/kg
- Pancuronium 0.1 mg/kg
- Isoflurane to achieve bispectral index of < 40
- Blood pressure support with phenylephrine or other appropriate vasoactive drug as necessary
- Intubation when bispectral index is < 40 and adequate neuromuscular relaxation achieved.

2) Maintenance of anaesthesia

- Fentanyl infusion at 1.2 µg/kg/h
- Isoflurane to maintain bispectral index between 40 and 60
- No additional muscle relaxant
- No additional midazolam.

Table 2 Postoperative events

Variable	Off pump (n = 144)	On pump (n = 209)	p Value
Ventilation time (hours)	12.9 (27)	25 (78)	0.035
Reintubated	5 (3%)	13 (6%)	0.042
ICU length of stay (days)	2.9 (5.9)	3.6 (7.4)	0.312
Reoperative bleeding	4 (3%)	2 (1%)	0.230
Cardiovascular accident	2 (1.4%)	2 (1%)	1
Postoperative MI	0	2 (1%)	0.515
Gastrointestinal bleeding	1 (<1%)	9 (4%)	0.052
New atrial fibrillation	4 (3%)	2 (1%)	0.230
Deep surgical wound infection	1 (<1%)	2 (1%)	1
New renal failure	3 (2%)	11 (5%)	0.169
New dialysis	1 (<1%)	0	0.407
Status at discharge (death)	5 (3%)	4 (2%)	0.494
Follow up (death)	12 (8.3%)	16 (7.7%)	0.0524

ICU, intensive care unit; MI, myocardial infarction.

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IMAGES IN CARDIOLOGY

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Unusual case of coronary–subclavian steal syndrome

A 46 year old man presented with an acute coronary syndrome in October 2003. Coronary angiography revealed severe triple vessel disease and urgent bypass grafting was performed, joining the left internal mammary artery (LIMA) to the left anterior descending artery (LAD). During two attempts to close the thorax, episodes of severe hypotension occurred. These were considered by the surgeons to be associated with the LIMA (vasospasm). Therefore they decided to perform additional venous bypass grafting to the LAD, distal to the LIMA graft. The patient was admitted to the intensive care unit with an open thorax until he stabilised haemodynamically. Closure of the thorax was carried out four days later.

In November 2004 the patient presented with complaints of effort related left shoulder pain, left arm paraesthesia, and mild angina pectoris. Angiography of the left coronary artery showed an occluded native LAD. The LIMA had competitive flow in the graft. In addition there was a systolic pressure gradient of 45 mm Hg between the left subclavian artery and the aorta. Accordingly arch angiography demonstrated severely reduced flow in the left subclavian artery, caused by a proximal high grade subclavian artery stenosis (panel A). Injection of contrast dye into the venous bypass graft to the LAD revealed a large vessel responsible for the circulation of the left upper limb by reversed flow in the LIMA graft (panel

B). On the basis of these findings, an unusual case of coronary–subclavian steal syndrome could be confirmed with predominant ischaemia of the upper limb instead of the myocardium. Consequently, stenting of the proximal left subclavian artery was performed.

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Arch aortogram. In contrast to the aorta (Ao), innominate artery (IA), and left common carotid artery (LCCA), there is a severely reduced blood flow in the left subclavian artery (LSCA).

Coronary angiography. Injection of contrast dye into the aortic–coronary venous bypass (ACVB) demonstrates that in addition to perfusion of the left anterior descending artery (LAD), the main function of this graft is perfusion of the left subclavian artery (LSCA), and therefore the left upper limb, by reversed flow in the LAD and the left internal mammary artery (LIMA).