Propensity score analysis of early and late outcome after redo off-pump and on-pump coronary artery bypass grafting

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Abstract

Background: The purpose of this study was to compare early and late results of redo-CABG with (redo-ONCAB) and without (redo-OPCAB) cardiopulmonary bypass. Methods: From April 2001 to September 2006 redo-CABG was performed in 110 patients (redo-ONCAB = 50 and redo-OPCAB = 60). Applying the propensity score, 43 OPCAB patients were matched with 43 ONCAB patients. The mean EuroScore was 5.6 ± 2.8 in redo-ONCAB and 6.1 ± 1.8 in redo-OPCAB, respectively (p < 0.01). Results: Twelve patients underwent OPCAB through anterior thoracotomy while the rest of the patients (n = 74) underwent median sternotomy. Mean number of grafts performed was 3 ± 0.8 in redo-ONCAB and 2 ± 0.6 in redo-OPCAB (p < 0.05). The need for postoperative insertion of intra-aortic balloon pump (IABP) was higher (p = 0.02) in redo-ONCAB (n = 9, 21%) than redo-OPCAB (n = 1, 2%). The duration of postoperative ventilation was 55 ± 98.7 h for redo-ONCAB and 10 ± 12.8 h for redo-OPCAB (p = 0.008). No differences were found in the incidence of other postoperative complications. The 30-day mortality rate was 6.9% for redo-ONCAB (n = 3) and 2.3% redo-OPCAB (n = 1; p = NS). Mean follow-up for redo-ONCAB was 30 ± 21.3 months (range 0.1–63 months) and that of redo-OPCAB was 37 ± 21.3 months (range 0.1–62.5 months). Actuarial survival at 5 years was 87 ± 5.5% for redo-ONCAB and 95 ± 3.2% for redo-OPCAB (p = 0.17). Event-free survival was 71 ± 8.0% for redo-ONCAB and 78 ± 7.2% for redo-OPCAB (p = 0.32). Conclusion: OPCAB is an acceptable strategy in selected patients requiring redo-CABG. Employing a strategy of OPCAB for those patients with 2 or fewer lesions and ONCAB for those with more diffuse disease, redo-OPCAB and redo-ONCAB have similar early and late outcomes.

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1. Introduction

Morbidity and mortality associated with redo-CABG are higher than those for first-time CABG [1,2]. Although there has been a considerable reduction in mortality associated with redo-CABG, morbidity remains significant [3–5]. Factors implicated in higher risk include increasing age, left ventricular (LV) dysfunction and associated comorbidities. Redo-CABG poses increased risk of haemorrhage, graft injury and embolisation into native coronaries due to graft manipulation. Particular issues include availability of conduits, complete revascularisation, myocardial protection and use of blood products [6]. Strategies to avoid the above problems include different approaches of re-entry, careful graft dissection to minimise graft atheroembolism and modification in myocardial protection techniques on the basis of coronary anatomy and graft patency. Off-pump coronary revascularisation is an alternative method that avoids the inherent risks of cardiopulmonary bypass (CPB) [7,8].

To avoid the particular hazards of re-sternotomy, redo off-pump coronary artery bypass grafting (OPCAB) through a thoracotomy has been advocated, especially for patients requiring revascularisation of the circumflex and/or left anterior descending (LAD) coronary arteries [9]. Careful patient selection and modification of the operative technique are of paramount importance in such cases.

The purpose of our study was to compare early and late results of redo-CABG with (redo-ONCAB) and without (redo-OPCAB) CPB performed at our centre.

2. Patients and methods

From April 2001 to September 2006 isolated elective redo-CABG was performed in 110 patients (redo-ONCAB = 50 and redo-OPCAB = 60) at our tertiary referral centre. Applying
the propensity score, 43 OPCAB patients were matched with 43 ONCAB patients. Institutional Board approval for the study was obtained. All five surgeons who operated on these patients were accustomed to both OPCAB and ONCAB surgery. Information for the study was obtained from the cardiac surgical Patients Analysis and Tracking System (PATs) database and hospital records. Cardiac catheterisation and coronary angiography were performed in all patients. The preoperative left ventricular ejection fraction (LVEF) was measured from biplane ventricular angiography by the area—length method. Patients who required emergency surgery (n = 8) and those in cardiogenic shock (n = 1) were excluded from the study. All the patients had previously undergone ONCAB.

The mean age of redo-OPCAB was 65 ± 7.9 years and was similar to that of redo-ONCAB (p = NS). The mean EuroScore was 5 ± 4.7 and 5 ± 3.4 for redo-ONCAB and redo-OPCAB, respectively (p = 0.5). The number of diseased coronary arteries was 3 ± 0.5 and 2 ± 0.8 in redo-ONCAB and redo-OPCAB, respectively (p < 0.01). There were no differences in other preoperative risk factors between the two groups (Table 1).

The threshold for extubation was similar in both the groups and followed a standard protocol. Postoperative myocardial infarction (MI) was defined as persistent electrocardiographic (ECG) changes such as new Q waves, loss of R wave progression, new intraventricular conduction defects or new echocardiographic evidence of wall motion abnormality. ECGs were performed in all patients on the day of surgery and day 4 postoperatively (more frequently if required).

3. Surgical procedure

Anaesthesia was induced using propofol 1–2 mg/kg, pancuronium 0.1 mg/kg, and fentanyl 8–15 μg/kg and maintained by air, oxygen and propofol 2–3 mg/kg h. After the chest was opened, the left internal mammary artery (IMA) was harvested as a wide pedicle including artery, vein, muscle, fascia, and adipose tissue. The pedicle was sprayed with diluted papaverine solution (50 mg/20 ml normal saline). If the radial artery was used, it was flushed with a solution of 50 mg phenoxymethylbenzamine, 20 ml of blood and 2000 units of heparin.

3.1. Off-pump technique

3.1.1. Sternotomy

Normothermia was maintained with warm intravenous fluids, a heating mattress, a humidified airway and a warm operating theatre. Standard intraoperative monitoring techniques were used. A CPB circuit was on stand-by for all cases. A cell-saving device for blood recovery was used. To minimise haemodynamic compromise, the right pleural space was opened to create a space for the rotated and vertically positioned heart. Suction-type (Octopus® 3; Medtronic, Inc, USA) and the compression type (Ultima™ OPCAB system, CTS-Guidant, USA) mechanical stabilisers were used to stabilise the target coronary artery. One deep pericardial retraction suture was placed at the posterior fibrous pericardium very close and medial to the most proximal part of the inferior vena cava. This acted as a lever to help the surgeon manipulate and rotate the heart to vertical and lateral positions along with the stabiliser. Anticoagulation was achieved with 150 U/kg of heparin. If required, heparin was supplemented to maintain the activated clotting time above 250 s and was reversed by protamine at the end of the procedure. Blood pressure was continually optimised during the procedure, and the mean arterial pressure was maintained above 50 mmHg by repositioning the heart and by intravenous fluids, selective use of vasoconstrictors or both. The distal anastomosis was constructed using 8-0 polypropylene for LAD and 7-0 polypropylene for other vessels. Aspirin 300 mg was administered 6 h postoperatively if bleeding had settled.

3.1.2. Thoracotomy

A double-lumen endotracheal tube was inserted. External defibrillation pads were placed before skin prepping.

Table 1

<table>
<thead>
<tr>
<th>Preoperative patient characteristics</th>
<th>OPCAB</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>65.7 ± 6.9 years</td>
<td>0.3</td>
</tr>
<tr>
<td>Male</td>
<td>41 (95.3%)</td>
<td>1</td>
</tr>
<tr>
<td>CCS class III/IV</td>
<td>27 (62.8%)</td>
<td>1</td>
</tr>
<tr>
<td>NYHA III/IV</td>
<td>12 (27.9%)</td>
<td>0.2</td>
</tr>
<tr>
<td>Previous MI</td>
<td>21 (48.8%)</td>
<td>1</td>
</tr>
<tr>
<td>Diabetes</td>
<td>10 (23.2%)</td>
<td>1</td>
</tr>
<tr>
<td>Hypertension</td>
<td>27 (62.8%)</td>
<td>0.2</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>39 (90.7%)</td>
<td>1</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>1 (2.3%)</td>
<td>1</td>
</tr>
<tr>
<td>COPD</td>
<td>4 (9.3%)</td>
<td>1</td>
</tr>
<tr>
<td>Poor LV (ejection fraction &lt; 30%)</td>
<td>19 (44.1%)</td>
<td>0.2</td>
</tr>
<tr>
<td>LMS disease</td>
<td>10 (23.2%)</td>
<td>1</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>4 (9.3%)</td>
<td>1</td>
</tr>
<tr>
<td>Urgent</td>
<td>11 (25.6%)</td>
<td>1</td>
</tr>
<tr>
<td>No. of coronary arteries with stenosis &gt;50%</td>
<td>3 ± 0.9</td>
<td>0.01</td>
</tr>
<tr>
<td>IV nitrates</td>
<td>5 ± 3.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>

CCS: Canadian Cardiovascular Society; NYHA: New York Heart Association; MI: myocardial infarction; COPD: chronic obstructive pulmonary disease; LMS: left main stem; LV: left ventricle; IV: Intravenous; IABP: intra-aortic balloon pump.
Patients requiring bypass to the circumflex system had a posterolateral thoracotomy. The patient was positioned in a right lateral decubitus position with the pelvis externally rotated (45°) to allow access to the femoral vessels, if required. The left femoral vessels were not exposed routinely. After the left lung was deflated, an incision was made in the fourth or fifth intercostal space. When the subclavian artery was used for inflow, the fourth intercostal space was chosen. As necessary, the thoracotomy was extended a few centimetres anteriorly or posteriorly to gain exposure of the target coronary vessel and the descending aorta or left subclavian artery. The lung was dissected free and the inferior pulmonary ligament incised. With a patent LIMA graft, the anteromedial aspect of the lung was dissected from the pericardium only enough to locate the circumflex target, thus avoiding the LIMA graft. Palpation of the pericardium was performed to locate previous vein grafts if present. The pericardium was opened posterior to the phrenic nerve. Careful and limited dissection was performed to locate the target vessel and trace old grafts. After the target coronary was identified, the proximal anastomosis was then performed. This allowed accurate assessment of the length and lie of the conduit and flushing of the debris from the graft before performing the distal anastomosis. The descending aorta was generally chosen as the source of inflow. The patient was heparinised as for redo-OPCAB. A side-biting clamp was used to help in completion of the proximal anastomosis on the descending aorta. In cases where the descending aorta was severely atherosclerotic, the left subclavian artery was used for inflow. Proximally, the vessel was dissected circumferentially and occluded with a side-biting clamp or with vessel loops. Anastomosis was fashioned proximal to the origin of LIMA. With a patent LIMA to LAD graft, if a test occlusion of the subclavian artery did not result in ECG changes or clinical ischaemia, only then the arteriotomy was performed and proximal anastomosis completed. The distal anastomosis were completed using bulldog occluders proximally and a stabiliser (Ultima™ OPCAB system, CTS-Guidant, USA). Endovascular shunts were not used. Distal anastomoses were completed with running 7-0 or 8-0 polypropylene. Grafts originating from the left subclavian artery as well as the descending aorta were routed anterior to the hilum. Before chest closure, grafts were examined with the lung inflated to ensure that they were neither kinked nor under tension. Chest tubes were placed, intercostal bloc with bupivicaine 0.25% was performed and full expansion of the lung ensured before routine chest closure.

3.2. On-pump technique

The heart was exposed using a standard midline sternotomy incision. CPB was instituted with a single right atrial two-stage cannula and an ascending aorta perfusion cannula. Standard CPB management included membrane oxygenators, arterial line filters, systemic hypothermia down to 32 °C, and non-pulsatile flow of 2.4 l/min m², with a mean arterial pressure greater than 50 mmHg. The myocardium was protected by using intermittent antegrade cold blood cardioplegia (4:1 blood to crystalloid ratio). Combined antegrade and retrograde cardioplegia was employed selectively, particularly in patients with left main stem disease and tight right coronary artery. Anticoagulation was achieved using 300 U/kg of heparin. If required, heparin was supplemented to maintain the activated clotting time above 480 s and was reversed at the end of the procedure. Anastomoses were constructed with the same suture material used for redo-OPCAB. Aspirin 300 mg was administered 6 h postoperatively if bleeding had settled.

4. Statistics

In this paper, we have compared the two techniques by the propensity score analysis [10]. Propensity score matching of 50 redo-ONCAB and 60 redo-OPCAB patients was carried out using the pmatch2 command in STATA 9.2 (StataCorp, TX). A probit model was used with patients matched according to the variables listed in Table 1. The model was then used to calculate a propensity score for each patient. This score was subsequently used to match patients in the on- and off-pump groups, using nearest-neighbour propensity score matching. Comparable patient groups were identified by matching 43 redo-ONCAB patients with 43 redo-OPCAB patients. Pre- and postoperative data are expressed as mean ± SD. Continuous variables were compared between groups using Student’s t-test, and categorical data was compared between the two groups using the chi-square test. Mann-Whitney test and Fisher’s exact test, where appropriate, were used. The Kaplan—Meier method was used to analyse actuarial survival and freedom from events (death, myocardial infarction and repeat intervention). The log rank test was used to compare the survival and freedom from events between redo-ONCAB and redo-OPCAB. A value of p < 0.05 was considered significant in all statistical analyses. Statistical analysis was performed using SPSS software (release 12.0.1 for Windows).

5. Results

Twelve patients underwent redo-OPCAB through anterior thoracotomy (1 double and 11 single grafts): 8 left anterior descending artery grafts (1 pedicled left internal mammary artery, 5 radial arteries [RA] and 2 saphenous veins [SV]), 3 circumflex grafts (3 SV) and 2 diagonal grafts (2 SV). The five RAs were anastomosed proximally to the subclavian artery and SVs to the descending aorta. The remaining patients underwent median sternotomy. In one patient OPCAB was converted to ONCAB because of haemodynamic instability. The mean number of grafts performed was 3 ± 0.8 in redo-ONCAB and 2 ± 0.6 in redo-OPCAB (p < 0.05). The need for postoperative insertion of an intra-aortic balloon pump (IABP) was higher (p = 0.02) in redo-ONCAB (n = 9, 21%) than redo-OPCAB (n = 1, 2%). The IABP was inserted for haemodynamic instability in all patients. However, there was no significant difference in inotrope use in the two groups (0.02 ± 0.05 mcg/kg min in redo-ONCAB vs 0.01 ± 0.002 mcg/kg min in redo-OPCAB; p = NS). The duration of postoperative ventilation was 55 ± 98.7 h for redo-ONCAB and 10 ± 12.8 h for redo-OPCAB (p = 0.008). One patient in the redo-ONCAB group sustained a clinically significant
periparoperative myocardial infarct (as determined by new Q waves and a rise in Troponin I). No other differences were found in the incidence of postoperative atrial fibrillation, reoperation for bleeding, acute renal failure, readmission to the ICU, wound infection and the length of hospital stay \((p = \mathrm{NS})\) between the two groups (Table 2). The 30-day mortality rate was 6.9% for redo-ONCAB \((n = 3)\) and 2.3% redo-OPCAB \((n = 1); p = \mathrm{NS}\) with an overall mortality of 4.6%. The mean follow-up for redo-ONCAB was 30 ± 21.3 months (range 0.1—63 months) and that of redo-OPCAB was 37 ± 19.2 months (0.1—62.5 months). Actuarial survival at 5 years was 87 ± 5.5% for redo-ONCAB and 95 ± 3.2% for redo-OPCAB \((p = 0.17)\). Event-free survival (death, myocardial infarction and repeat intervention) was 71 ± 8.0% for redo-ONCAB and 78 ± 7.2% for redo-OPCAB \((p = 0.32)\) (Figs. 1 and 2).

6. Comment

The hypothesis that redo-OPCAB improves clinical outcome as compared to redo-ONCAB is supported by the finding that prolonged CPB increases the risk of mortality in repeat surgical revascularisation [2]. Patients requiring repeat surgical revascularisation commonly have advanced atherosclerosis and redo-OPCAB with minimal aortic manipulation may reduce the incidence of stroke. Furthermore, studies have demonstrated clinical advantages of performing redo-OPCAB for single-vessel disease [11,12].

Our study is the first in the literature comparing redo-ONCAB and redo-OPCAB by the propensity score analysis [10,13]. This statistical technique eliminates investigational bias especially in relation to preoperative patient characteristics, which is one of the key criticisms of retrospective studies. In this study, we did not show any difference in the postoperative hospital stay, re-exploration for bleeding and incidence of postoperative MI between the two approaches. In contrast, Trehan et al. [14] showed results in favour of redo-OPCAB in their observational study in relation to the above postoperative characteristics. In another retrospective study by Stamou et al. [11], it was shown that redo-OPCAB improves morbidity and mortality in comparison with redo-ONCAB for single-vessel disease. As in our study, they have also showed that redo-ONCAB patients require a longer period of mechanical ventilation than the redo-OPCAB group. The reason for this remains to be explored but may be explained partly by atelectasis, ventilation—perfusion \((V—Q)\) mismatch and lung reperfusion injury post-CPB. The latter leads to impairment of vascular endothelial integrity leading to vasoconstriction (pulmonary hypertension) and increased vascular permeability (pulmonary oedema). This is especially so with redo-ONCAB where CPB times are longer than first-time ONCAB. It was also shown that conventional redo-ONCAB was associated with a two-fold higher incidence of postoperative new-onset AF [15] which is similar to our results, but not statistically significant in our experience. The predisposition to AF may be explained by the effects of hypothermia, right atrial manipulation, aortic cross-clamping and greater surgical trauma in patients undergoing CABG with CPB [16]. The surgical trauma is reflected by the higher levels of cardiac troponin T [17] and reduced heat shock protein 70 expression [18] after on-pump CABG. In the preoperative elective setting, IABP has been shown to enhance cardiac performance and improve the outcome of redo-ONCAB [19]. Also, in first-time OPCAB patients, this
strategy is very effective in preventing haemodynamic instability [20] and reducing morbidity [21] in high-risk patients. Here we have shown for the first time that, in the postoperative setting, the need for insertion of IABP was higher in redo-ONCAB than redo-OPCAB. In the context of redo surgery, the reason for this is unclear and remains to be explored. However, the greater use of postoperative IABP with redo-ONCAB may reflect reduced cardiac contractility as a result of myocardial oedema secondary to global ischaemia and greater reperfusion injury leading to stunning. OPCAB has also been shown to lead to better recovery of myocardial oxidative metabolism, myocardial function and a lower requirement for inotropic agents.

In agreement with some other publications of first-time OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups as the number of grafts corresponded to the number of significantly diseased coronary arteries in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups. We do not consider small targets and intramyocardial vessel to be contra-indications to redo-OPCAB, either via sternotomy or thoracotomy. Although OPCAB surgery is criticised for the contra-indications to redo-OPCAB, there were more anastomoses performed with CPB than otherwise in our study. However, the index for completeness of revascularisation was similar in both groups.

Our study is limited by the small number of patients in each group along with the absence of angiographic follow-up that would enable a comparison of the early and late graft patency between the two groups. Technical improvements in redo-CABG will continue to evolve as cardiac surgeons are expected to deal with a rising number of patients requiring repeat revascularisation. Redo-OPCAB is one more technique that allows surgery to be tailored to the needs of the individual patient. Although safe and feasible, this operation is technically challenging and requires cumulated experience. In highly selected patients redo-OPCAB can be performed safely and effectively with satisfactory early and late results.

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References


