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Off-pump coronary bypass grafting is safe and efficient in patients with left main disease and higher EuroScore☆

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Abstract

Background: Summary Left main disease (LMD) and associated cardiac risk factors are often perceived as a limiting factor for the outcome of off-pump coronary artery bypass (OPCAB) grafting. In this study, we assess whether the outcome of OPCAB surgery is affected in such patients. **Methods:** We retrospectively compared perioperative parameters in 66 OPCAB patients (group A) with LMD and 216 OPCAB patients without (group B) LMD. The patients were operated in the time frame between 2002 and 2007. LMD was defined as a stenosis >50%. **Results:** Patients in group A had a higher EuroSCORE (logistic: 3.7 ± 0.1 vs 6.3 ± 0.3, $p = 0.027$), increased coronary artery disease (CAD) family history ($p = 0.015$) and cerebrovascular accidents ($p = 0.027$), increased history of congestive heart failure ($p = 0.013$), more urgent surgery ($p = 0.008$), previous percutaneous transluminal coronary angioplasties (PTCAs) ($p = 0.05$) and previous stent implantation ($p = 0.023$). An intra-aortic balloon pump (IABP) was inserted more frequently in the LMD group preoperatively ($p = 0.004$). There were two conversions to on-pump during OPCAB surgery. There were no differences in the postoperative outcomes in the LMD group A versus group B, such as cardiac-related events, neurological deficits, cardiac enzyme course, arrhythmias, blood loss, infections and renal failure. **Conclusions:** The presence of LMD and higher EuroSCORE does not yield adverse outcomes in OPCAB patients.

Keywords: Off-pump; Coronary artery bypass grafting (CABG)

1. Introduction

Left main coronary artery disease is an entity known for almost a century and is recognised as a risk factor for cardiac-related adverse events [1,2]. It is associated with higher calcific load of the aorta and other peripheral arteries and constitutes an indication for operation rather than medical or interventional therapy [3–5]. This is in accordance to the commonly accepted guidelines of the American Heart Association, with a level of evidence: A [6]. Left main disease (LMD) is frequently associated with a higher EuroSCORE and therefore higher operative risk [7,8]. With the evolution of less-invasive surgery for coronary re-vascularisation, off-pump techniques have been established and proven similar to conventional on-pump coronary artery surgery [9]. These techniques have been established decades ago, were initially abandoned with the wide use of cardiopulmonary bypass (CPB) and were used again to avoid the CPB-associated adverse events, such as organ damage, inflammatory reactions and myocardial injury [10,11]. The off-pump coronary artery bypass (OPCAB) surgery, as it is practiced today, involves rigorous displacement of the heart, mechanic fixation and prolonged phases of hypotension and myocardial ischaemia and low cardiac output, particularly when the circumflex territory is addressed. Many surgeons have been cautious so far to expose patients with significant

Abbreviations: LMD, left main disease; LM, left main coronary artery; CX, circumflex coronary artery; RCA, right coronary artery; LITA, left internal thoracic artery; RPDA, right posterior descending coronary artery; OPCAB, off-pump coronary bypass grafting; vs, versus; CAD, coronary artery disease; PTCA, percutaneous transluminal coronary angioplasty; IABP, intra-aortic balloon pump; CPB, cardiopulmonary bypass; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; AV, atrio-ventricular; MI, myocardial infarction; ICU, Intensive Care Unit; NYHA, New York Heart Association; NCP, no coronary perfusion; PCP, passive coronary perfusion; ACP, active coronary perfusion; SSI, surgical side infections; CCS Class, Canadian cardiovascular society class; CK, creatine kinase; CKMB, creatine kinase-myocardial band; EuroSCORE, European system for cardiac operative risk evaluation.

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LMD to such distorting manoeuvres, because of concerns of jeopardising myocardial perfusion and eventually causing decompensation. When such incidents occur, usually severe ischaemia or even infarction may occur and is often associated with conversion to on-pump surgery under myocardial massage and risk of damage to other organs [12,13]. The underlying mechanism may be an acute kinking of the left main stem and therefore total occlusion, the mobilisation of plaques and debris, which may embolise distally, acute septal dyskinesia and de-synchronisation, acute mitral valve regurgitation and left ventricular decompensation. Yeatman et al., on the other hand, reported that OPCAB surgery is a safe and efficient option for advanced coronary disease including left main stenosis [14]. This group compared OPCAB and conventional CABG techniques in their efficacy on operative outcome. They found that patients in the OPCAB group required less inotropes, epicardial pacing and blood product transfusion, at the cost of a slightly less complete re-vascularisation. Similarly, Merharwal et al. have found a similar outcome of OPCAB and on-pump surgery in patients with multi-vessel disease and overall higher risk [15]. Finally, Virani et al. reported on the safety of OPCAB inpatients with LMD and reduced ejection fraction (EF) [16]. OPCAB practice is now widely accepted and expands further. Some surgeons perform OPCAB surgery exclusively [17]. We found worthwhile investigating whether the presence of LMD and a higher overall cardiovascular risk affects the outcome of OPCAB surgery and conducted the present retrospective study.

2. Patients and methods

This is a retrospective study conducted in a cohort of 282 patients who had been operated between 2002 and 2007 in our institution using the OPCAB technique. LMD was defined as stenosis of the main stem of the left coronary artery of more than 50%. Of the 282 patients, 66 had LMD and constituted group A. Group B comprised the rest without LMD (216 patients, group B). The patients had been operated by a heterogeneous group of six surgeons (CNL, TK, CT, MC, ES and UK) in our department with variable experience and an OPCAB/on-pump ratio of 30–50% in their practice.

2.1. Operative technique

We performed on-pump coronary re-vascularisation using the state-of-the-art techniques, meticulously described elsewhere. We used cold-blood-based cardioplegia supplemented by a solution of potassium, magnesium and procaine at a 1:4 volume ratio. Off-pump surgery was carried out according to internationally established techniques [18]. Briefly, following sternotomy and pericardiotomy, 150 IU of heparin were administered to achieve an activated clotting time of 250–300 s. The left internal thoracic artery was harvested before pericardiotomy. Next, a deep pericardial stitch was placed using 0/0 silk sutures, through which a gauze was passed for traction and exposure [14]. Cannulation purse-string sutures were placed in aorta and right atrium as a standby measure in case of conversion to on-pump technique. Epicardial pacemaker wires were inserted on the surface of the right ventricle for heart rate manipulations, the heart was adequately filled with volume and the table broken for variably 'head down' Trendelenburg position manipulations. In case of an enlarged heart, a deep vertical pericardiotomy as well as right pleurotomy were carried out to allow for rigorous exposure of the heart without haemodynamic compromise. For distal anastomosis, the target vessel was occluded proximally to the anastomotical site using silicone-supported tourniquets. The anastomotical area was stabilised using the Medtronic Octopus stabiliser (Medtronic, Minneapolis, MN, USA), and if found necessary by the surgeon, a Starfish heart suction-stabiliser (Medtronic, Minneapolis, MN, USA) was used. Ischaemic pre-conditioning before anastomosis and intra-coronary shunts were used variably by the surgeons, according to preference, experience and intra-operative judgement. A blower–mister device was used in all cases. The sequence of distal grafting varied also from surgeon to surgeon. For instance, the most experienced and quickest of the team chose to vascularise the collateralised right coronary artery (RCA) or right posterior descending coronary artery (RPDA) first in many cases of LMD featuring a stenosis of 50–75%. The saphenous vein grafts were then de-aired, and proximal anastomosis using side-biting clamps was performed, commonly using 6/0 Prolene suture. In compliance with international experience, ischaemia or hypotension were addressed by volume, heart rate, inotrope or beta-blocker-based manipulations and short release of very vigorous exposure and torsion. The heparin effect was antagonised variably.

The set of variables evaluated included preoperative patient characteristics, intra-operative variables and postoperative outcome data. The following preoperative patient characteristics were recorded: gender, age, race (Chinese, Malay, Indian, Caucasian), smoking history, diabetes, family history of coronary artery disease (CAD), hypercholesterolaemia, hypertension, past cerebrovascular accident, cerebrovascular disease, morbid obesity, chronic obstructive pulmonary disease (COPD), renal failure and dialysis.

Cardiac-related preoperative conditions were: preceding myocardial infarction (MI), myocardial infarction within 90 days prior to surgery, preceding cardiogenic shock, cardiomegaly, congestive heart failure, angina pectoris, past resuscitation, arrhythmias, ejection fraction, number of diseased coronary vessels, previous CABG, elective, urgent/or emergent presentation and indication for surgery, previous coronary intervention, previous percutaneous transluminal coronary angioplasty (PTCA), previous stent implantation, previous thrombolysis and finally, logistic EuroSCORE. We recorded the following intra-operative variables: conversion to conventional on-pump surgery, defibrillation and a number of distal anastomoses. Postoperative variables were operative mortality, mortality of other causes, need for intra-aortic balloon pump (IABP) implantation, requirements for pacing, inotropes, anti-arrhythmics, postoperative ventilation time, re-intubation, cardiac arrest, advanced stage heart arterioventral (AV) block, atrial fibrillation, postoperative MI, postoperative creatine kinase (CK), creatine kinase-myocardial band (CK–MB) at 12 h postoperatively, total blood product requirements (including intra-operative requirements), pulmonary complications, pneumonia, dialysis required, surgical-site infections (deep vs superficial) and septicaemia.

2.2. Data processing and statistical analysis

We performed descriptive statistical analysis in both groups. Continuous data were presented as mean ± standard deviation. Categorical or dichotomous data were presented in frequencies and percentages. The two groups (these were normally distributed datasets) were compared to assess any negative impact of LMD on postoperative outcome: numerical variables were compared between groups using the Student's *t*-test for independent variables. Dichotomous variables were compared using the chi-square test with the Fisher's exact adjustment. Statistical significance was assumed when $p < 0.05$.

Table 1
Patient demographics and preoperative characteristics.

	Group A (OPCAB LM disease)	Group B (OPCAB)	*p* value
Gender (male)	83.5%	79.6%	0.50
Age	61.43 ± 9.4	59.2 ± 10.2	0.059
Race			
Chinese	71.6%	70.2%	0.83
Malay	17.9%	14.1%	0.45
Indian	8.96%	11.3%	0.58
Caucasian	1.52%	4.2%	0.29
History of smoking	52.2%	60.4%	0.27
Diabetes	41.7%	49.5%	0.31
History of CAD	19.4%	8.8%	**0.015**
Hypercholesterolemia	65.6%	76.8%	0.09
Hypertension	74.6%	72.2%	0.57
Past cerebrovascular accident	14.9%	6.5%	**0.027**
Cerebrovascular disease	11.9%	6.9%	0.17
Morbid obesity	0%	3.2%	0.13
COPD	13.4%	8.8%	0.25
Renal failure	7.4%	6.9%	0.86
Dialysis	4.4%	1.4%	0.12
Preceding MI	0%	4.1%	0.09
MI within 90 days prior to surgery	42.3%	50.0%	0.24
Preceding cardiogenic shock	4.4%	1.8%	0.21
Cardiomegaly	7.4%	6.9%	0.86
Congestive heart failure	8.9%	2.3%	**0.013**
Angina pectoris (CCS)	2.69 ± 0.93	2.4 ± 0.8	0.07
Past resuscitation	1.4%	0.9%	0.68
Arrhythmias	4.4%	3.7%	0.75
EF (%)	47.4 ± 14.4	48.1 ± 14.3	0.36
Number of diseased coronary vessels	2.72 ± 0.5	2.64 ± 0.7	0.15
Previous CABG	0%	2.2%	0.58
Presentation			
Elective	59.7%	79.8%	**0.001**
Urgent	10.4%	9.3%	0.79
Emergency	28.3%	10.8%	**0.0004**
Previous intervention			
PTCA	14.9%	8.3%	0.053
Stent	7.4%	0%	**0.023**
Thrombolysis	5.9%	5.0%	0.75
EUROscore	6.3 ± 0.3	3.7 ± 0.1	**0.027**

CAD: coronary artery disease, CCS class: Canadian cardiovascular society class, COPD: chronic obstructive pulmonary disease, EF: ejection fraction, EuroSCORE (shown in logistic): European system for cardiac operative risk evaluation, IABP: intra-aortic balloon pump, LM: left main coronary artery, MI: myocardial infarction, OPCAB: off-pump coronary bypass grafting, PTCA: percutaneous transluminal coronary angioplasty.

3. Results

Ethnic and demographic characteristics are displayed in Table 1. Briefly, groups A and B were comparable in age, gender and ethnicity distribution. Co-morbidities and adverse cardiac conditions or cardiovascular risk factors were more frequent in group A. Congestive heart failure occurred more frequently in group A (9% vs 2.3%, $p = 0.013$). Preceding cardiological interventions were more frequent in group A (7.4% vs 0%, $p = 0.023$ for stent implantation). There was a trend for more frequent PTCA in the same group as well (14.9% in group A vs 8.3% in group B, $p = 0.053$). Moreover, group A patients presented as an emergency, whereby operation was performed within 24 h from admission (28.36% vs 10.8%. $p = 0.0004$). Consequently, elective cases were more frequently represented in group B ($p = 0.001$). The EF was similar in the two groups (47.4 ± 14.4 vs 48.1 ± 14.3). Although the extent of coronary artery disease was comparable between the two groups (2.7 ± 0.5 in group A vs 2.6 ± 0.7 in group B, $p = 0.15$) the cumulative logistic EuroSCORE was higher in group A: 6.0 ± 0.3 vs 3.7 ± 0.1 ($p = 0.027$).

As shown in Table 2, there were no significant differences in the intra-operative course between the two groups. There was one conversion to on-pump surgery due to haemodynamic instability in each group. Intra-operative defibrillation became necessary equally frequently in both groups. The number of distal anastomoses per patient was similar between the two groups (2.6 ± 1.1 group A vs 2.7 ± 1.1 group B, $p = 0.14$).

Postoperative comparisons between the groups: postoperative 30-day mortality was 2.7% (six cases) in group B and 0% (none) in group A ($p = 0.17$). Cardiac-related events (MI, resuscitation, cardiac arrest, heart block, atrial fibrillation) occurred in similar percentage of patients in the two groups. All other parameters were to be found in similar frequencies in both groups. These results are indicated on Table 3.

4. Discussion

The prominent finding of our retrospective study is that the presence of LMD, higher cardiovascular burden and higher EuroSCORE is not associated with worse operative

Table 2
Intraoperative data.

	Group A (OPCAB LM disease)	Group B (OPCAB)	*p* value
Conversion to on-pump	1.5%	0.4%	0.37
Defibrillation	0.4%	1.5%	0.37
Number of distal anastomoses	2.55 ± 1.07	2.72 ± 1.06	0.14

LM: left main coronary artery, OPCAB: off-pump coronary bypass grafting.

Table 3
Postoperative data.

	Group A (OPCAB LM disease)	Group B (OPCAB)	*p* value
Operative mortality	0%	2.3%	0.21
Mortality of other causes	0%	2.7%	0.17
Perioperative IABP	18.1%	6.4%	**0.004**
Requirements			
Pacing	24.2%	26.3%	0.72
Inotropes	66.6%	69.4%	0.6
Antiarrhythmics	1.5%	4.6%	0.25
Postoperative ventilation (h)	16.47 ± 16.8	32.5 ± 126.2	0.33
Reintubation	0%	3.2%	0.17
Cardiac arrest	0%	5.8%	0.26
Advanced stage heart AV block	0%	2.9%	0.43
Atrial fibrillation	50%	45.5%	0.43
Postoperative MI	7.1%	0%	0.07
CK (U/l)	657.58 ± 731.24	571.8 ± 750.1	0.68
CK-MB (U/l)	29.96 ± 56.57	14.8 ± 17.7	0.20
Total blood (including intraoperative requirements)	12.1%	13.4%	0.54
Pulmonary complications	3.0%	4.6%	0.57
Pneumonia	14.2%	5.8%	0.56
Dialysis required	7.1%	4.4%	0.93
Infections			
SSI deep	0%	1.4%	0.58
SSI superficial	0%	0%	ns.
Septicemia	0%	2.9%	0.43

AV: atrio-ventricular, CK: creatine kinase, CKMB: creatine kinase-myocardial band, IABP: intra-aortic balloon pump, LM: left main coronary artery, MI: myocardial infarction, OPCAB: off-pump coronary bypass grafting, SSI: surgical side infections.

course or postoperative outcomes in patients undergoing OPCAB. This is in compliance with Yeatman et al., who reported similar mortality in an OPCAB to on-pump comparison in patients with LMD. They also displayed lower requirements for inotropes and postoperative pacing, less transfusion requirements as well as slightly shorter in-hospital stay, at the price of less complete re-vascularisation [14]. These can be explained by the avoidance of the deleterious impact of CPB and reperfusion following removal of the aortic cross clamp in on-pump patients, and have been described to a great extent [19,20].

As noted in our cohort, patients who present with LMD are generally more morbid. It is well known that left main coronary disease, carotid artery disease and peripheral arterial disease may co-exist and reflect advanced stages of atherosclerosis. Doonan et al. have elucidated the frequency of their co-existence in the same patient [3]. They showed that patients with significant LMD more frequently had associated carotid stenosis $\geq$60% compared with patients without LMD (31.2% vs 15.2%). Furthermore, they found that patients with LMD had lower mean ankle–brachial indexes compared with patients without LMD (0.78 vs 0.87). The same demographics are replicable in our preoperative dataset. This explains the almost double EuroSCORE in our patient sample, rendering our patients with LMD at higher operative risk. This should not deter an experienced OPCAB surgeon from considering OPCAB surgery, even in the urgent setting.

Moreover, our patients with LMD presented significantly more frequently as urgent or emergent cases compared to patients without LMD. This has also not obscured the postoperative outcome. Rastan et al. compared the outcome of beating heart versus conventional CABG strategies in acute coronary syndromes for emergency indications [21]. OPCAB surgery led to a significantly less drainage loss, less transfusion requirement, less inotropic support, shorter ventilation time, lower stroke rate and shorter intensive care unit stay. In cardiogenic shock, beating heart surgery was associated with lower incidence of stroke, inotropic support, acute renal failure, new atrial fibrillation and sternal wound-healing complications. In-hospital mortality rate was reduced when using beating heart strategies. Overall survival, major adverse cerebral and cardiovascular event rate and repeated re-vascularisation were comparable during a 5-year follow-up. They concluded that beating heart strategies are associated with an improved hospital outcome and comparable long-term results for high-risk patients presenting acute coronary syndrome with or without CS. Merharwal et al. have shown that OPCAB can be performed safely in high-risk patients with multi-vessel CAD [15]. Their findings were that OPCAB may result in comparable post-operative mortality but less morbidity in this patient group. The potential underlying mechanisms have been investigated by Steed et al. who, more than a decade ago, have shown marked subendocardial underperfusion during bypass [22]. Akins et al. as well have provided a physiological–mechanistic contributor to better outcomes by demonstrating preservation of interventricular septal function in patients having coronary artery re-vascularisation without CPB [23]. Considering the above, the improved myocardial preservation, reduced reperfusion injury and lack of the hypothermic insult may explain the compensation of the adverse prediction for worse outcomes in OPCAB patients with LMD, based on the EuroSCORE prediction model. The efficacy of OPCAB surgery in patients with higher-risk scores and LMD could only be established due to constantly improving operative techniques and well-designed intra-operative strategies. One of them may be to graft the LAD first, mostly using the LITA to preserve myocardial supply during heart torsion and proximal occlusion manoeuvres. The use of shunts is recommendable whenever possible. Some surgeons employ active distal perfusion until completion of the proximal anastomoses. Vassiliades et al. demonstrated the efficacy of latter methodology in a comparative study [24]. Patients were prospectively randomised to receive one of three OPCAB coronary perfusion treatments: (1) no coronary perfusion (NCP), (2) passive coronary perfusion (PCP) or (3) active coronary perfusion (ACP). Cardiac performance postoperatively was superior in the ACP group compared to the PCP and ACP groups. Troponin I levels were lower in the coronary perfusion groups (PCP and ACP). Even though we have not employed active perfusion techniques, our results were comparable in the two groups.

Another finding of our study is that previous cardiological intervention (PTCA or stenting) does not have a negative impact on intra- or postoperative performance in our patients. To our knowledge, there are no specific reports on stent occlusion or reversal of PTCA results in patients undergoing OPCAB. One may argue that this may occur due to incomplete heparinisation and torsion of the heart. In contrast, OPCAB may be the preferable option for patients with shortly preceding interventional re-vascularisations, due to the risk of acute re-occlusion at the time of protamine administration. It may be reasonable not to reverse the heparin action completely in this subgroup of patients when OPCAB is used.

There are some limitations to our study. First, it is only a retrospective clinical study with data arising from our general clinical database and patient charts. There is no consistency in the intra-operative myocardial preservation strategy (use of coronary shunt, preconditioning, extent of traction, etc.), due to the various surgeons involved. One may argue why we did not compare the OPCAB to the on-pump technique for patients with LMD. We decided to analyse our experience from another angle of view: whether the presence of LMD with concomitant high cardiovascular burden and higher EuroSCORE should deter surgeons from deciding for an OPCAB grafting. Another limitation of our study is the fact that there were six different surgeons with variable OPCAB/on-pump rates. We have assessed each surgeons' complication rates within this group but could not detect any significant differences (data not shown).

In summary, significant LMD accompanied by higher EuroSCORE and higher cardiovascular burden should not deter a surgeon from performing OPCAB grafting.

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