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Cross-sectional Study

Retrospective observational analysis of a coronary artery bypass grafting surgery patient cohort: Off-pump versus on-pump

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A R T I C L E I N F O

Keywords:
Coronary artery bypass grafting
Off-pump
On-pump

A B S T R A C T

Objectives: To determine whether surgical technique has an effect on prognosis in coronary artery bypass grafting (CABG).
Design: Retrospective observational.
Setting: Single center.
Participants: All the off-pump (OPCABG) and on-pump (ONCABG) patients at Turku University Central Hospital in 2018.
Interventions: None.
Measurements and main results: After propensity score matching, perioperative, 1-year and 3-year mortality did not differ between the groups. The ONCABG patients received more allogenic red blood cells (1.3 vs. 0.6 units, $p = 0.020$), autologous red blood cells (564 vs. 285 ml, $p < 0.001$) and crystalloids (3388 vs. 2808 ml, $p < 0.001$), and had higher postoperative values of troponin T (581 vs. 222, $p = 0.001$) and lactate (1.69 vs. 1.23, $p < 0.001$) than the OPCABG patients.
Conclusions: The both techniques seem equally safe. However, there may be some benefits to avoiding using a heart-lung machine, such as lower infused fluid volumes. Myocardial damage may also be milder and postoperative hemodynamics more balanced in OPCABG patients, based on lower levels of troponin T and lactate.

1. Introduction

Despite the increase in the number of percutaneous procedures, coronary artery bypass grafting (CABG) is still the most common cardiac surgery procedure [1]. The debate over the on-pump (ONCABG) and off-pump (OPCABG) CABG methods has continued for a long time [2,3]. Both techniques have their pros and cons, and cardiac surgery units around the world have different approaches and opinions on the subject [4]. The both ONCABG and OPCABG techniques have their own challenges; OPCABG complicates the technical performance of the surgeon, but ONCABG requires the use of a heart-lung machine. It has recently been discussed that the experience of the surgeon is a one of the major factors behind a successful outcome of OPCABG [5,6].

Our cardiac surgery unit has a long tradition of performing OPCABG, and we have experienced surgeons who are specialized in this technique. According to different national registries, 15–30% of all the CABG cases are OPCABGs [7]. In our own cardiac unit approximately 40% of all the CABGs are OPCABG patients. In most cases, the patients have not been specifically selected for ONCABG or OPCABG due to their characteristics, but were selected for either group according to the method used by the surgeon, although in some cases OPCABG was performed because aortic clamping was not possible. For this reason, our data is quite applicable to compare treatment outcomes in these patient groups, and to determine whether surgical technique has an effect on prognosis.

Therefore, in this study, we have reviewed all patients who underwent CABG in our cardiac unit in 2018, and examined the effect of surgical technique on short- and long-term mortality, the need for reoperations, and postoperative outcomes such as length of hospital stay

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and need for blood transfusions.

2. Methods

2.1. Ethics

Ethical approval for this study (Ethical Committee N° T35/2019) was provided by the Ethical Committee of the Turku University Hospital, Turku, Finland (Chairperson Sirkku Jyrkkiö) on January 31, 2019. The work has been reported in line with the STROCSS criteria [8]. The study is registered to Research Registry: identifying number researchregistry8316 [9].

2.2. Data collection and statistics

All isolated CABG surgeries performed during 2018 in Turku University Hospital were extracted from the operating theatre management system (Centricity Opera, GE Healthcare). The data from the hospital software were combined and all patient data including name, identification number and day of surgery were deidentified prior to statistical analyses. Cases with concomitant valve surgery and reoperative CABG were excluded. Individual patient data was manually extracted from the electronic health records (Uranus, 2M-IT and Centricity Critical Care, GE Healthcare). Statistical analyses were performed with R 4.0.2 [10]. Comparisons in numerical variables between ONCABG and OPCABG groups were performed using the Mann-Whitney *U* test. A p-value < 0, 05 was considered statistically significant.

To account for bias in patient selection for OPCABG, we performed one-to-one propensity score matching. A propensity score was calculated using a logistic regression model with age, sex, number of bypasses and preoperative ejection fraction (EF) performed as covariates. Optimal pair matching was performed using the MatchIt package [11] in R, which calls functions from the optmatch package [12]. Quality of matching was assessed by visual assessment and by analyzing the standardized mean differences and variance ratios.

Outcome variables selected for analysis were length of stay in intensive care unit (ICU), need for resternotomy, perioperative mortality and 1-year mortality. Additionally, we collected data on fluids and blood products used during surgery: crystalloids, allogenic and autologous red blood cells (RBC), fresh frozen plasma (FFP) and prothrombin complex concentrate (PCC). We also measured the highest troponin T (TnT, normal value < 14 ng/L) and lactate levels (normal value < 2.2 mmol/L), and the volume of blood lost from mediastinal drainage during the ICU stay. Missing laboratory values were imputed with mean substitution (four patients in the ONCABG group). At 3-year follow-up of percutaneous coronary interventions (PCIs) and reoperations, data for only 64 ONCABG and 44 OPCABG patients were available due to transfer to another hospital district.

3. Results

After excluding concomitant valve surgery and reoperations, 217 CABG patients were operated, 86 of which were OPCABG. No OPCABG was converted to ONCABG in 2018. The mean (SD) age of all patients was 68,3 (9,2) years and 15,7% were women.

Preoperative characteristics of the patients are reported in Table 1. Preoperative parameters did not differ between the ONCABG and the OPCABG groups. Technical surgical data are presented in Table 2.

Perioperative and 1 year mortality did not differ between the groups (Fig. 1). In the unadjusted comparison, however, the ONCABG patients received more allogenic RBCs (1.2 vs. 0.6 units, p = 0.020), autologous RBCs (583 vs. 284 ml, p < 0.001), PCC (49.6 vs. 5.8 IU, p = 0.025) and crystalloids (3501 vs. 2800 ml, p < 0.001) than the OPCABG patients (Fig. 2). The ONCABG patients also had markedly higher postoperative values of TnT (mean 1150 vs. 312 ng/L, p = 0.009) and lactate (1.69 vs. 1.23 mmol/L, p < 0.001) than OPCABG patients (Table 3).

Table 1
Characteristics of the CABG patients in 2018.

	ONCABG	OPCABG	p
N (%)	131	86	
Age, mean (SD)	67.8 (8.9)	69.1 (9.6)	0.309
Women, n (%)	16 (12.2)	18 (20.9)	0.124
Urgency			0.256
Elective, n (%)	60 (45.8)	47 (54.7)	
Urgent, n (%)	61 (46.6)	36 (41.8)	
Emergent, n (%)	10 (7.6)	3 (3.5)	
Preop Hb, mean (SD)	135.6 (17.4)	136.4 (15.8)	0.730
Preop Krea, mean (SD)	105.3 (82.0)	103.8 (51.2)	0.878
Preop INR, mean (SD)	1.0 (0.6)	1.0 (0.2)	0.707
Euroscore, mean (SD)	2.8 (2.8)	2.8 (2.9)	0.935
EF, mean (SD)	54.7 (11.2)	51.3 (13.7)	0.050

Urgency of the surgery was divided into 3 sections: elective, urgent (need of operation in 1–4 days) and emergent (need to proceed to surgery in <24 h). CABG, Coronary Artery Bypass Grafting; ONCABG, on-pump coronary artery bypass grafting; OPCABG, off-pump coronary artery bypass grafting; SD, standard deviation; EF, ejection fraction; Hb, haemoglobin; Krea, creatinine; INR, international ratio.

Table 2
Unadjusted comparison of peri- and postoperative parameters between the groups of ONCABG and OPCABG patients.

	ONCABG	OPCABG	p
RBC units, mean (SD)	1.2 (2.2)	0.6 (1.5)	**0.020**
Autologous blood ml, mean (SD)	583 (237)	284 (223)	**<0.001**
FFP units, mean (SD)	0.7 (1.9)	0.3 (0.9)	0.091
PCC IU, mean (SD)	49.6 (173.8)	5.8 (53.9)	**0.025**
Platelets units, mean (SD)	0.47 (1.09)	0.26 (0.65)	0.110
Drainage ml, median (IQR)	690 (567–896)	720 (576–949)	0.277
Crystalloids, ml, mean (SD)	3501 (1256)	2800 (807)	**<0.001**
Highest TnT, ng/l, median (IQR)	577 (391–907)	222 (143–330)	**0.009**
Highest Lact, mmol/l, mean (SD)	1.69 (0.81)	1.23 (0.48)	**<0.001**
Early resternotomy, n (%)	7 (5.4)	1 (1.2)	0.215
Prolonged ventilator therapy >24h, n (%)	5 (4.0)	3 (3.6)	1.000
Stroke during hospital stay, n (%)	4 (3.2)	1 (1.2)	0.632
New dialysis during hospital stay, n (%)	1 (0.8)	0 (0.0)	1.000
ICU stay, days, mean (SD)	1.63 (3.06)	1.22 (1.14)	0.233
3-year PCI/redo, n (%)*	2 (3.1)	3 (6.8)	0.666
Perioperative mortality, n (%)	5 (3.8)	1 (1.2)	0.457
1-year mortality, n (%)	5 (3.8)	2 (2.3)	0.829
3-year mortality, n (%)	10 (7.6)	2 (2.3)	0.171

ONCABG, on-pump coronary artery bypass grafting; OPCABG, off-pump coronary artery bypass grafting; RBC, red blood cells; SD, standard deviation; IQR, interquartile range; FFP, fresh frozen plasma; PCC, prothrombin complex concentrate; TnT, Troponin T; Lact, Lactate; ICU, intensive care unit; PCI, percutaneous coronary intervention. * Number of patients: n(ONCABG) = 64 and n(OPCABG) = 44.

After propensity score matching, 86 OPCABG patients were compared to 86 matched ONCABG patients. Significant differences between groups in allogenic and autologous RBCs, crystalloids and laboratory markers remained after propensity score matching. Also, the short- and long-term mortality rates nor need for reoperation or PCI did not differ (Table 4).

The low number of female patients (n = 34) made it impossible to compare the differences between women and men.

4. Discussion

Our results on OPCABG and ONCABG demonstrate that surgical outcomes are equally good at 1-year and 3-years follow-up. The risk profiles of the both groups were low and preoperative characteristics were similar. However, ONCABG patients received more often red blood

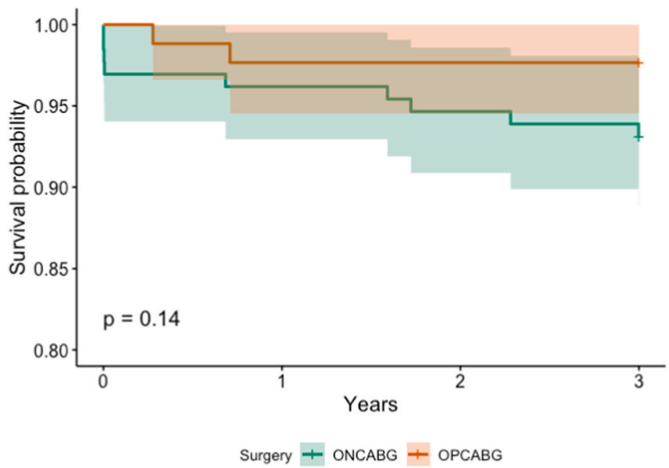

Fig. 1. 3-year Kaplan Meyer survival curve with 95% confidence intervals (light shading) for ONCABG and OPCABG patients. OPCABG, off-pump coronary artery bypass grafting; ONCABG, on-pump coronary artery bypass grafting.

cells and higher amounts of crystalloids, and had higher postoperative TnT and lactate values.

The differences between OPCABG and ONCABG surgery have sparked years of debate for and against [13]. The current main view, however, seems to be that the surgeon's experience contributes to a successful outcome at OPCABG [5,6], and a similar survival profile in both types of surgery can be seen in a follow-up of up to 20 years [14]. In our study, the OPCABG surgeons had several years of experience and they used principally OPCABG technique for all their CABG patients. Approximately 40% of patients are OPCABG in our center, which is a large proportion compared to other cardiac centers [7]. For these reasons, it was to be expected that there would be no difference in the outcome of the surgery per se.

OPCABG has been proposed to be more beneficial in the high-risk elderly patients [15]. Because the main factor deciding if the patient was going to be treated by OPCABG in our study was surgeon preference, the patients treated by OPCABG also included a usual case mix of low-risk CABG patients. Only 15,7% of the patients were female. Female sex is associated with smaller target vessels, more comorbidities and higher age at the time of CABG. These factors put women in higher risk for mortality and peri- and postoperative complications. The proportion of female patients has typically been low in RCTs, but observational analyses [16,17] suggest a survival benefit for OPCABG in female patients.

Although the surgical outcome may be equal in both types of CABG surgery, avoiding cardiopulmonary bypass (CPB) may still be beneficial for some patients. CPB causes disturbances in the coagulation system, dilution of the blood and also the development of a systemic inflammatory response (SIR) [18]. We found that ONCABG patients received more red blood cells and markedly more crystalloids. Both postoperative fluid accumulation [19] and administration of blood products [20] have been associated with increased morbidity to patients. It is possible that the administration of red blood cells causes a detrimental immunological reaction [21]. SIR caused by CPB potentiates immunological disorder of the body further [22].

Perioperative elevated lactate level has been shown to be associated with increased mortality [23]. Although there are several possible mechanisms causing elevated lactate levels during and after cardiac surgery [24], the difference detected in our study could be explained by insufficient oxygen delivery during CPB or the increased need for allogenic RBC transfusion [23].

Troponin T can be used to quantify the myocardial injury during CABG [25]. Troponin levels during 24 h after CABG are an independent predictor of long-term mortality [26]. However, clinical trials have not shown a mortality benefit despite the lower troponin levels after OPCABG as compared to ONCABG. It is possible that the troponin level

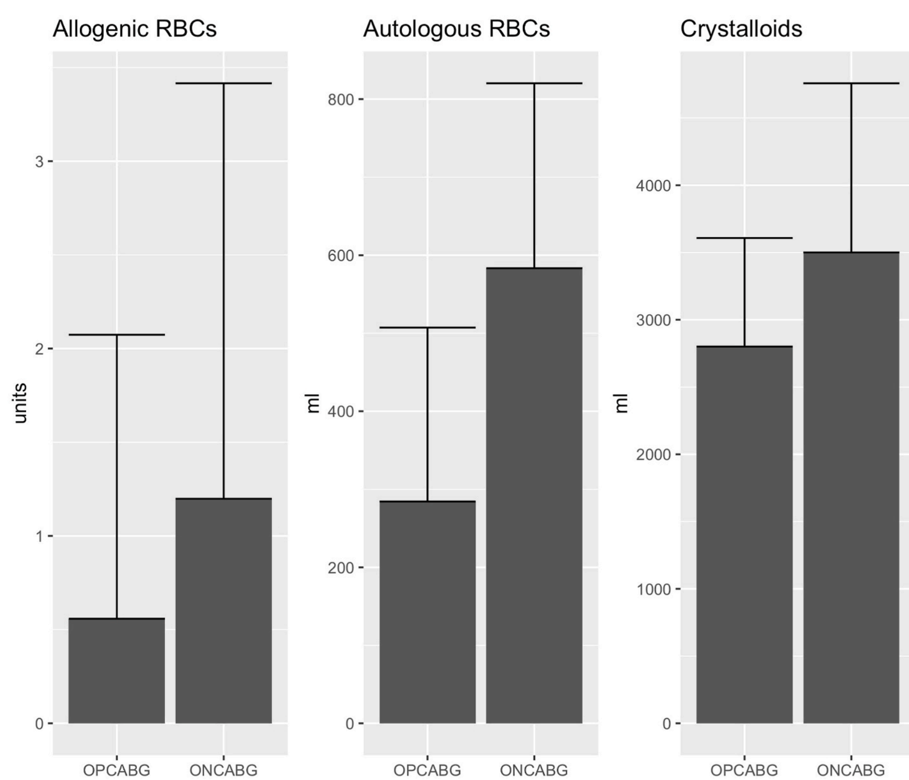

Fig. 2. Average (with standard deviation line) RBC and crystalloid intake in OPCABG and ONCABG patients.
RBC, red blood cell; OPCABG, off-pump coronary artery bypass grafting; ONCABG, on-pump coronary artery bypass grafting.

Table 3
Propensity score matched comparison of peri- and postoperative parameters between the groups of ONCABG and OPCABG patients.

	ONCABG	OPCABG	p
RBC units, mean (SD)	1.3 (2.1)	0.6 (1.5)	**0.016**
Autologous blood ml, mean (SD)	564 (221)	285 (224)	**<0.001**
FFP units, mean (SD)	0.6 (1.9)	0.3 (0.9)	0.184
PCC IU, mean (SD)	29.4 (118.3)	5.88 (54.2)	0.097
Platelets units, mean (SD)	0.26 (0.74)	0.26 (0.66)	1.000
Drainage ml, median (IQR)	725 (595–1000)	720 (574–950)	0.211
Crystalloids, ml, mean (SD)	3388 (1196)	2808 (809)	**<0.001**
Highest TnT ng/l, median (IQR)	581 (407–1002)	222 (143–330)	**0.001**
Highest Lact mmol/l, mean (SD)	1.69 (0.76)	1.23 (0.48)	**<0.001**
Early resternotomy, n (%)	4 (4.7)	1 (1.2)	0.364
ICU stay, days, mean (SD)	1.72 (2.78)	1.22 (1.15)	0.130
3-year PCI/redo, n (%)*	1 (2.4)	3 (6.8)	0.642
Perioperative mortality, n (%)	4 (4.7)	1 (1.2)	0.364
1 year mortality, n (%)	4 (4.7)	2 (2.4)	0.678
3-year mortality, n (%)	8 (9.4)	2 (2.4)	0.103

ONCABG; on-pump coronary artery bypass grafting; OPCABG, off-pump coronary artery bypass grafting; RBC, red blood cell; SD, standard deviation; IQR, interquartile range; FFP, fresh frozen plasma; PCC, prothrombin complex concentrate; TnT, Troponin T; Lact, Lactate; ICU, intensive care unit. PCI, percutaneous coronary intervention. * Number of patients: n(ONCABG) = 42 and n(OPCABG) = 44.

Table 4
Technical operative data.

	ONCABG	OPCABG	p
Perfusion time, min, mean (SD)	115.0 (37.4)		NA
Aortic cross-clamp time, min, mean (SD)	87.2 (23.6)		NA
Number of bypasses, mean (SD)	3.4 (0.8)	3.6 (1.1)	0.297
LITA, n (%)	123 (99.2)	80 (95.2)	0.172
LITA skeletonized, n (%)	97 (78.2)	79 (94.0)	**0.004**
RITA, n (%)	2 (1.6)	3 (3.6)	0.657
Radial artery graft, n (%)	9 (7.3)	10 (11.9)	0.370
Endovena, n (%)	16 (12.9)	9 (10.7)	0.796

ONCABG, on-pump coronary artery bypass grafting; OPCABG, off-pump coronary artery bypass grafting; SD, standard deviation; LITA, left internal thoracic artery; RITA, right internal thoracic artery.

is associated with underlying disease severity and the different mechanisms of myocardial injury during ONCABG and OPCABG require different cut-off limits to be used for prognostication [27].

The main limitation of our study is its retrospective and observational setting and the preoperative condition of the patients was not comprehensively compared. We were also unable to 3-year follow-up all patients regarding the need for reoperations, as they were transferred to another hospital district. Furthermore, in the long-term follow-up, we were only able to examine mortality, not late complications or graft patency. Yet, a strength of the study is that patients were not specifically selected for either group according to their characteristics, but were selected according to the surgeon's preferences. This makes the retrospective analysis more valid, although there is a possibility that some patients with a highly calcified aorta ended up in the OPCABG group to avoid aortic clamping. Also, as we are a low volume center, the number of patients was limited.

In conclusion, we found no difference in immediate postoperative or 1-year or 3-year survival, or reoperations or postoperative PCI rates in OPCABG and ONCABG patients in retrospective analysis. Despite this, there might be some benefits in avoiding CPB, including lower amounts of blood products and crystalloids received. Myocardial damage may also be milder and postoperative hemodynamics more balanced in OPCABG patients, based on lower levels of TnT and lactate, which may make OPCABG technique particularly suitable for frail patients.

Ethical approval

Ethical approval for this study (Ethical Committee N° T35/2019) was provided by the Ethical Committee of the Turku University Hospital, Turku, Finland (Chairperson Sirkku Jyrkkiö) on January 31, 2019.

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Author contributions

JA: Study conception and design. MR: Data analysis and interpretation. JA, MR, RY: Drafting of manuscript. MK, MP, VH, OS, TS, VA: Data collection. MR, RY, MK, VH, MP, OS, TS, VA, JA: Critical revision and final approval of the manuscript to be published. All the co-authors contributed to this paper and are responsible for all aspects of the work and approved the final manuscript.

Registration of Research Studies

Retrospective, patient hospital record -based study.

Guarantor

Jenni Aittokallio.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Consent

The study is retrospective. The patient's consent was not used, but ethical approval was given by the Ethical Committee of Turku University Hospital. No personal data was used after data collection.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.104812.

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