· Advances in Medical Sciences · Vol. 58(1) · 2013 · pp 58-66 · DOI: 10.2478/v10039-012-0046-2

Effect of on-pump versus off-pump coronary bypass surgery on cardiac function assessed by intraoperative transesophageal echocardiography

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Received 08.06.2012
Accepted 01.08.2012
Advances in Medical Sciences
Vol. 58(1) · 2013 · pp 58-66
DOI: 10.2478/v10039-012-0046-2

ABSTRACT

Purpose: To compare cardiac function assessed by intraoperative transesophageal echocardiography in patients undergoing cardiac revascularization with or without cardiopulmonary bypass.
Material and methods: Forty-one patients scheduled for elective, isolated cardiac revascularization (21 on-pump and 20 off-pump) were prospectively analyzed. Patients were matched for demographic (age and gender), anthropometric (BMI), clinical (co-morbidities, EuroScore) and laboratory variables (blood counts, renal function, left ventricular function). Transesophageal echocardiography was performed after induction of anesthesia, protamine sulfate administration, and chest closure. Left ventricular wall motion score index, end-diastolic area, fractional area change, right ventricular area change and end-diastolic area were assessed. Troponin I and C-reactive protein concentrations were measured.
Results: Regarding echocardiographic parameters of left and right ventricular function no significant differences between on-pump and off-pump groups at any point-of-time measurements were found. Troponin I and C-reactive protein were higher in on-pump as compared to off-pump group ($p=0.001$ and $p=0.002$; $p=0.003$ and $p=0.001$, respectively).
Conclusions: In elective patients scheduled for cardiac revascularization there were no difference in cardiac performance assessed by intraoperative echocardiography regardless of surgical method used.

Keywords: intraoperative transesophageal echocardiography; conventional coronary artery bypass grafting; off-pump coronary artery bypass grafting; myocardial function.

INTRODUCTION

Intraoperative transesophageal echocardiography (IOTEE) has become now a recommended and routinely employed tool for every cardiac open heart and thoracic aortic surgical procedure [1]. In patients undergoing coronary artery bypass grafting (CABG) IOTEE enables to modify and confirm surgical plan, as well as helps to evaluate cardiac function after induction of anesthesia and after surgical procedure, before leaving operating room (OR). IOTEE is the most accurate technique to detect intraoperative myocardial ischemia, hypovolemia or the reason of unexplained hemodynamic worsening during operation [2].

Perioperative complications of the on-pump CABG (i.e. conventional coronary artery bypass grafting, CCABG) are mainly related to the use of cardiopulmonary bypass (CPB). Cardioplegic cardiac arrest and extracorporeal circulation (ECC) result in systemic inflammation, cardiac damage, myocardial stunning, hemodynamic instability, tissue edema, bleeding diathesis and finally multiorgan dysfunction [3,4].

Off-pump CABG (OPCAB) offers better preservation of cardiac function, due to the avoidance of cardiac arrest, the lack of ECC, as well as shorter operation time [5]. However, the procedure is technically more demanding, may induce hemodynamic instability due to the heart displacement and temporary occlusion of coronary arteries [2].

Our aim was to verify hypothesis that OPCAB surgery is superior to CCABG in terms of preservation of the left and right ventricular function estimated by IOTEE. We performed a prospective case-controlled study to compare perioperative myocardial function assessed by IOTEE in patients undergoing CCABG versus OPCAB. Moreover, we aimed to compare laboratory variables – biomarkers of cardiac necrosis and systemic inflammation – in the respect to the surgical method. No study has systematically investigated this subject.

MATERIAL AND METHODS

Patients population

The study design was compliant with the Helsinki Declaration and it was approved by the Local Bioethics Committee of Medical University (approval number R-I-002/343/2009). Written informed consent from all participants was obtained before enrolment.

It was prospective, case-control study, where patients were adjusted with regard to demographic (age and gender), anthropometric (BMI) clinical (co-morbidities, EuroScore) and laboratory variables (blood counts, renal function, left ventricular function) due to minimize selection bias. Forty-one patients qualified for the first, elective isolated coronary artery revascularization between February 2008 and August 2009 in Department of Cardiac Surgery, were prospectively enrolled to the study. Patients were selected out of a cohort of 822 patients operated on during this period of time The inclusion criteria were as follows: feasibility of both either off-pump or on-pump CABG, I or II NYHA class before operation, baseline left ventricle ejection fraction (LVEF) ≥40% and preserved sinus rhythm. Patients with concomitant valvular diseases and other cardiac co-morbidities requiring additional surgical procedures were excluded from the study. Twenty-one patients who undergone on-pump CABG (CCABG group), and twenty patients off-pump CABG with midline full sternotomy (OPCAB group) were included to the study.

Anesthesia

Patients were premedicated with oral midazolam 7.5-15 mg. Induction was obtained with the following medications: sulfentanyl 0.005 mg/kg i.v., etomidate 0.3 mg/kg i.v. and parcuronium bromide 0.1 mg/kg i.v. Anesthesia was maintained with Sufentanil and pancuronium. Sevoflurane 0.4-2 vol% was used as an inhaled agent. Patients were ventilated with 50-60% oxygen in air. Patient monitoring and intraoperative fluid balance was achieved by means of following parameters: continuous hear rate assessment, invasive blood pressure measurement and capillary blood oxygen saturation measurement, central venous pressure and hourly diuresis. Body temperature was measured in the esophagus. All patients were operated on in normotermia.

Cardiopulmonary bypass

A standardized for the institution protocol was used. Priming consisted of 1000 ml Ringer lactate, 500 ml 6% hydroxyethyl starch (HAES), 250 ml 20% Mannitol solution, 20 ml 8.4% Sodium Bicarbonate and 10000 units of unfractionated heparin. Nonpulsatile flow (2.4 l/min x m^2) was performed with a roller-pump, membrane oxygenator with temperature exchanger applied. Aortic root was cannulated with an arterial cannula and right atrium was cannulated with 2-stage venous cannula. Heparin coated circuit was employed. Cardioprotection was obtained with anterograde warm (36.6 °C) blood cardioplegia according to Calafiore method [6]. Individual dose was delivered into aortic root every 10-15 minutes.

Surgical technique

The patients were operated by two surgeons, both experienced in on- as well as off-pump CABG. Expertise was defined as follows: > 5 years of experience with both procedures and completing > 100 operations of each kind. Operation method (CCABG with CPB or OPCAB) was left at the discretion of the operator. Arterial and venous grafts were performed as a single anastomosis to one coronary artery or sequential to two or three coronary arteries.

Echocardiography

Baseline transthoracic echocardiography (TTE) as well as IOTEE was performed using General Electric Healthcare Vivid i^2 equipment.

TTE was done the day before surgery by the same cardiologist. For the purpose of the study left ventricular wall motion score index (WMSI) was calculated using 16 segment model. LVEF was estimated by visual method currently utilized in our laboratory and widely accepted as a screening tool [7].

IOTEE was performed after induction of anesthesia. Omniplane 6T-RS (2.9 – 9 MHz) probe was inserted into esophagus and stayed on during whole procedure. The following views were obtained: mid esophageal 4 and 2-chamber, long axis with special attention to the apex visualization and transgastric short axis at the papillary muscles level. IOTEE was performed 3 times during procedure: after induction of anesthesia (before sternotomy), at the end of surgery after protamine sulfate administration and after chest closure. For the purpose of this study we have selected three distinct time-periods during operation which were the same in both types of procedure. This ensured the most similarity of the results. Echocardiographic images were digitally stored in a cine loop format for off-line analysis by 2 experienced, independent echocardiographers. Global and regional left and right ventricular functions (LV, RV) were assessed according to the echocardiographic recommendations [7,8]. The following parameters were analyzed: LV wall motion score index (WMSI) calculated using 16 segment from the midesophageal views, as well as LV end-diastolic area (LVEDA), LV end-systolic area (LVESA), fractional area change (%FAC) from transgastric view measured at the midpapillary level, RV area change (%RVAC) for global systolic function, RV end-diastolic area (RVEDA) and RV end-systolic area (RVESA) were assessed from midesophageal 4 chamber view [9] Estimation of preload was provided by LVEDA and RVEDA [10].

Concentration of troponin I and C-reactive protein (CRP) were measured from venous blood samples collected at baseline – before cardiac surgery, immediately after transferring patient to the Intensive Care Unit (day 0), next morning (day 1), and at the day of discharge.

Statistical analysis

Descriptive statistics (percentages for discrete variables and mean ± SD for continuous variables) was done for baseline characteristics. Parameters distribution was assessed using Shapiro-Wilk test. Continuous variables between groups were compared using two-tailed independent-samples Student's t-test or U Man-Whitney test (respectively to parameter's distribution) and the χ^2 test was used for categorical variables. Analysis between repeated measurements of the same subject was performed using paired Student-t test or paired Wilcoxon test. A p value ≤0.05 was considered statistically significant. Commercially available statistic software SPSS for Windows 12 computer package was applied.

RESULTS

The characteristics of baseline parameters is summarized in *Tab. 1* and *2*. Two groups were similar in respect to demographic parameters, medical history, co-morbidities, EuroScore, baseline laboratory results as well as preoperative LV function assessed in TTE. The only significant difference was clopidogrel cessation time, which was significantly longer in CCABG patients than in OPCAB group (*Tab. 1*). Moreover, among CCABG patients there was a prevalence of multivessel disease as compared to OPCAB patients (95% vs 62% p=0.012) (*Tab. 2*). Perioperative details are shown in *Tab. 3*. A complete revascularization was performed in all patients. In OPCAG group 21 arterial anastomosis (19 single and 1 sequential) and 30 venous grafts (16 single and 7 sequential) were performed, with 23 top ends to the aorta. In CCABG group there were 29 arterial anastomosis (15 single and 7

Table 1. **Baseline characteristics of patients undergoing conventional coronary artery bypass grafting and off-pump coronary artery bypass grafting: demographic and clinical history. Values are mean (SD) or number (proportion).**

	CCABG*	OPCAB†	p value
Age, yrs	66.3 ± 8.65	65.38 ± 7.29	ns
Gender (male)	15 (75%)	16 (76.2%)	ns
Height, m	1.69 ± 0.08	1.68 ± 0.09	ns
Weight, kg	81.05 ± 14.91	77.18 ± 13.86	ns
BMI, kg/m^2‡	28.21 ± 3.75	27.25 ± 4.23	ns
Euro-score	3.2 ± 2.17	2.38 ± 1.66	ns
NYHA class§	1.85 ± 0.81	1.95 ± 0.59	ns
History of angina	7 (35%)	4 (19%)	ns
History of MI¶	9 (45%)	12 (57.1%)	ns
History of PCI**	10 (50%)	7 (33.3%)	ns
History of diabetes type 2	8 (40%)	4 (19%)	ns
Hypertension	19 (95%)	18 (85.7%)	ns
Peripheral vascular disease	12 (60%)	13 (61.9)	ns
Hyperlipidemia	18 (90%)	19 (90.5%)	ns
Current smoker	12 (60%)	13 (61.9%)	ns
Aspirin cessation, days	7.45 ± 4.33	7.43 ± 4.03	ns
Clopidogrel cessation, days	15.3 ± 10.2	5.28 ± 2.67	0.017

**CCABG, conventional coronary artery bypass grafting; †OPCAB, off-pump coronary artery bypass grafting; SD, standard deviation; ‡BMI, body mass index; §NYHA, New York Heart Association classification; ¶MI, myocardial infarction; **PCI, percutaneous coronary intervention.*

Table 2. **Baseline characteristics of patients undergoing conventional coronary artery bypass grafting and off-pump coronary artery bypass grafting: laboratory, echocardiographic parameters and coronary angiography results. Values are mean (SD) or number (proportion).**

	CCABG*	OPCAB†	p value
Creatinine, mg/dL	1.00 ± 0.17	0.96 ± 0.14	ns
Glucose, mg/dL	109.70 ± 31.03	118.81 ± 45.85	ns
WBC, $10^3/\mu L$‡	7.19 ± 1.79	7.49 ± 2.08	ns
HGB, g/dL§	13.05 ± 1.04	13.61 ± 1.10	ns
PLT, $10^3/\mu L$¶	243.35 ± 65.48	228.14 ± 60.41	ns
Preoperative echocardiography (TTE)**			
LVEF, % ††	53.75 ± 7.97	55 ± 6.83	ns
WMSI‡‡	1.19 ± 0.26	1.25 ± 0.21	ns
Coronary angiography			
1-vessel disease	0 (0%)	4 (19%)	0.059
2-vessel disease	1 (5%)	4 (19.1%)	ns
Multivessel disease	19 (95%)	13 (61.9%)	0.012

**CCABG, conventional coronary artery bypass grafting; †OPCAB, off-pump coronary artery bypass grafting; ‡WBC, white blood cells; §HGB, hemoglobin; ¶PLT, platelets; **TTE, transthoracic echocardiography; ††LVEF, left ventricle ejection fraction; ‡‡WMSI, wall motion score index.*

Table 3. **Surgical outcome and perioperative data of patients undergoing conventional coronary artery bypass grafting and off-pump coronary artery bypass grafting. Values are mean (SD).**

	CCABG*	OPCAB†	p value
Operation time, min.	175.15 ± 37.35	94.95 ± 32.61	0.001
No of arterial grafts	1.4 ± 0.99	1.0 ± 0.32	ns
No of venous grafts	2.2 ± 1.06	1.48 ± 1.12	0.044
Total No of grafts	3.6 ± 2.05	2.48 ± 1.44	ns
The type of coronary artery grafted, n (%):			
LAD§	20 (28)	22 (44)	ns
RCA¶	14 (20)	8 (16)	ns
Cx**	6 (8)	2 (4)	ns
Other	31 (44)	18 (36)	ns
Mechanical ventilation time, h	23.25 ± 56.83	11.95 ± 5.18	ns
ICU‡ stay, h	38.9 ± 55.94	26 ± 16.44	ns
Hospital stay, days	12.15 ± 5.40	11.95 ± 4.18	ns
Drainage during first 24 h, mL	848.75 ± 334.47	934.52 ± 386.37	ns
Total drainage, mL	1429 ± 589.71	1379.29 ± 566.73	ns

**CCABG, conventional coronary artery bypass grafting; †OPCAB, off-pump coronary artery bypass grafting; ‡ICU, Intensive Care Unit; §LAD, left anterior descending; ¶RCA, right coronary artery; **Cx, left circumflex.*

sequential) and 42 venous grafts (23 single and 9 sequential). In this group there were 32 top ends to the aorta.

None of the patients died. Postoperative period was uneventful. Perioperatively, none of the patients needed infusion of catecholamines or cardiac pacing. Time of the operation was significantly longer in CCABG group as compared to OPCAB group (*Tab. 3*). In CCABG group the number of venous grafts per patient was significantly higher as compared to OPCAB group (*Tab. 3*). There were no differences in the number of arterial anastomoses per patient, time of mechanical ventilation, blood transfusion, and duration of the hospital stay.

Laboratory parameters

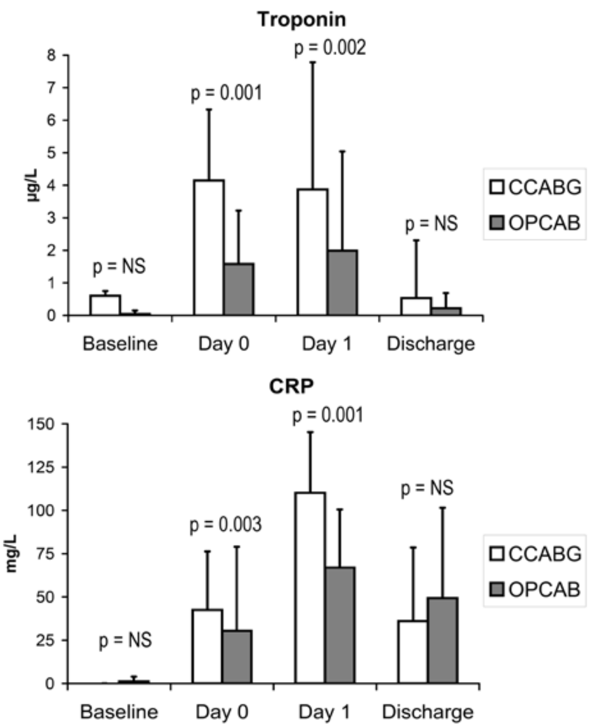
There were no significant differences between the groups regarding baseline troponin I as well as CRP concentrations (*Fig. 1*). Significant rise of troponin I occurred in both groups at day 0 and day 1. In CCABG group the peak of troponin I concentrations appeared earlier–at day 0, while in OPCAB group within next day (day 1). In CCABG patients troponin I levels were significantly higher than in OPCAB group (*Fig. 1*). Significant rise of CRP concentrations occurred at day 0 and day 1 in both groups, with a peak value at day 1. In CCABG patients CRP concentrations were significantly higher than in OPCAB group (*Fig. 1*).

Echocardiographic assessments

No significant differences between CCABG and OPCAB groups at any point-of-time measurements during procedure regarding echocardiographic parameters of left and right ventricular function were found (*Tab. 4*). Within each of the group there were significant changes of analysed echocardiographic parameters at different stages of the operation.

Wall motion score index (WMSI)

Figure 1. **The comparison of troponin I and C-reactive protein (CRP) concentrations during perioperative period in patients undergoing conventional coronary artery bypass grafting and off-pump coronary artery bypass grafting. Values are mean (SD). CCABG − conventional coronary artery bypass grafting; OPCAB − off-pump coronary artery bypass grafting.**



There was a tendency to an improvement of LV contractility assessed by WMSI in both groups following consecutive IOTEE evaluations. However, only in OPCAB patients WMSI after chest closure was significantly lower comparing to the first and second examinations (WMSI 1 vs WMSI 3, p=0.001; WMSI 2 vs WMSI 3, p=0.047).

Fractional area change (%FAC)

In OPCAB group %FAC consecutively improved (%FAC 1 vs %FAC 2, p=0.003; %FAC 1 vs %FAC 3, p=0.004). In CCABG group after protamine injection %FAC 2 decreased

Table 4. **Parameters of the left and right ventricular function determined by intraoperative transesophageal echocardiography after induction of anesthesia (1), post operation after protamine infusion (2), after chest closure (3) in patients undergoing conventional coronary artery bypass grafting and off-pump coronary artery bypass grafting. Values are mean (SD).**

	CCABG*	OPCAB†	p value
WMSI 1‡	1.19 ± 0.26	1.25 ± 0.21	ns
WMSI 2	1.15 ± 0.2	1.21 ± 0.22	ns
WMSI 3	1.12 ± 0.15	1.14 ± 0.15	ns
%FAC 1§	0.55 ± 0.11	0.49 ± 0.13	ns
%FAC 2	0.53 ± 0.15	0.56 ± 0.18	ns
%FAC 3	0.59 ± 0.13	0.58 ± 0.17	ns
LVEDA, cm^2 1¶	22.27 ± 6.79	25.78 ± 7.45	ns
LVEDA, cm^2 2	22.86 ± 5.35	26.27 ± 6.46	ns
LVEDA, cm^2 3	20.4 ± 4.54	23.27 ± 7.95	ns
LVESA, cm^2 1**	10.22 ± 4.51	13.48 ± 5.99	ns
LVESA, cm^2 2	11.05 ± 4.89	12.18 ± 6.93	ns
LVESA, cm^2 3	8.55 ± 3.45	10.63 ± 7.29	ns
%RVAC 1††	0.45 ± 0.12	0.46 ± 0.13	ns
%RVAC 2	0.49 ± 0.13	0.53 ± 0.12	ns
%RVAC 3	0.51 ± 0.11	0.56 ± 0.09	ns
RVEDA, cm^2 1‡‡	19.76 ± 6.08	20.22 ± 4.63	ns
RVEDA, cm^2 2	19.8 ± 5.5	19.68 ± 6.46	ns
RVEDA, cm^2 3	18.16 ± 6.35	18.40 ± 5.51	ns
RVESA, cm^2 1§§	10.47 ± 3.46	10.93 ± 3.34	ns
RVESA, cm^2 2	9.81 ± 2.69	9.05 ± 3.5	ns
RVESA, cm^2 3	8.67 ± 3.5	7.94 ± 2.21	ns

**CCABG, conventional coronary artery bypass grafting; †OPCAB, off-pump coronary artery bypass grafting; ‡WMSI, wall motion score index; §%FAC, fractional area change; ¶LVEDA, left ventricular end-diastolic area; **LVESA, left ventricular end-systolic area; ††%RVAC, right ventricle area change for global systolic function; ‡‡RVEDA, right ventricle end-diastolic area; §§RVESA, right ventricle end-systolic area.*

(the difference was not significant), while after chest closure significantly increased (%FAC 3 vs %FAC 2, p=0.039).

Left ventricular area

After protamine injection LVEDA not significantly increased in both groups. The smallest LVEDA value was found after chest closure. The only significant difference of LVEDA reduction was observed in OPCAB group between second and third measurement (p=0.025).

In CCABG population LVESA had a tendency to increase after weaning from CPB. The only significant difference in LVESA was found between weaning from CPB and chest closure (p=0.016). After chest closure in both groups LVESA was the smallest. In OPCAB group there was a significant drop in LVESA between induction of anesthesia and protamine injection (p=0.003) and between induction and chest closure (p=0.004) (*Fig. 2*).

Figure 2. **The comparison of left ventricular end-systolic area at three stages of procedures in patients undergoing conventional coronary artery bypass grafting (black squares) and off-pump coronary artery bypass grafting (grey diamonds). LVESA − left ventricular end-systolic area; CCABG − conventional coronary artery bypass grafting; OPCAB − off-pump coronary artery bypass grafting.**

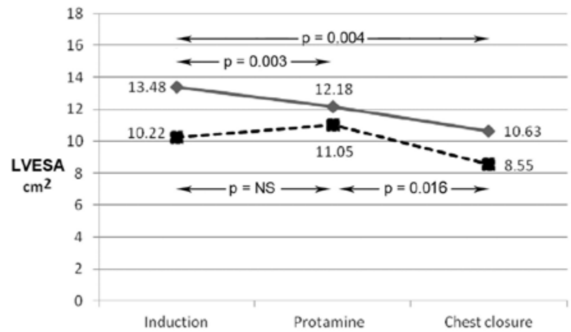
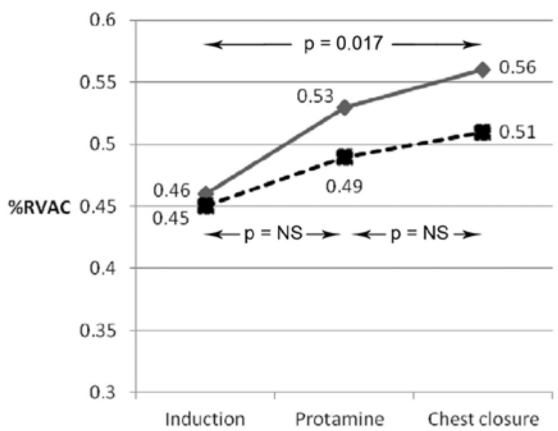


Figure 3. **The comparison of right ventricle area change for global systolic function at three stages of procedures in patients undergoing conventional coronary artery bypass grafting (black squares) and off-pump coronary artery bypass grafting (grey diamonds). %RVAC − right ventricle area change for global systolic function; CCABG − conventional coronary artery bypass grafting; OPCAB − off-pump coronary artery bypass grafting.**



Right ventricular area change (%RVAC)

In both groups gradual improvement of %RVAC was found (*Fig. 3*). However statistical significance was found only in OPCAB patients between the first and third registrations (p=0.017) (*Fig. 3*).

Right ventricular area

There were no changes in RVEDA between groups as well as among three stages of operation within the groups. In CCABG group significant RVESA reduction was noticed between first and third registrations as well as between second and third examinations: p=0.034 and p=0.044, respectively. In OPCAB group significant reduction of RVESA was detected between first and second as well as first and third registrations: p=0.016 and p= 0.001, respectively.

DISCUSSION

The main finding of the study is that in patients scheduled for elective cardiac revascularization, regardless of surgical method – with or without CPB – myocardial function assessed by IOTEE is comparable. In our study, off-pump surgery was not superior to the CABG with extracorporeal circulation. Although the duration of surgical procedure, as well as, the release of cardiac troponin and CRP concentrations were significantly higher in CCABG group, such difference was not was associated with a decrement in cardiac function.

Growing interest in OPCAB operations has raised many controversies, whether this surgical technique is superior to the conventional CABG. The release of cardiac biomarkers of necrosis as well as inflammation is quite common circumstance during the on-pump CABG [11]. The usage of ECC as well as cardioplegic arrest seem to be responsible for this effect. OPCAB operations are related to shorter duration of operation, decreased peak of postoperative troponin levels, decreased dose of noradrenaline infusion as well as decrease need for red blood cell transfusion [12]. On the other hand, after OPCAB operations late thrombin generation, reduced fibrinolysis and still functioning platelets may contribute to adverse thromboembolic events [13]. Moreover, OPCAB surgeries are related to more frequent myocardial ischemia due to the temporary occlusion of coronary arteries, hemodynamic instability caused by cardiac manipulation, the risk of suboptimal graft anastomoses and the possible emergency conversion to an on-pump technique [2]. Short-term outcome was compared between off-pump and on-pump CABG in patients randomly enrolled to ROOBY and CORONARY trials. There were no differences in regard of death and composite end-point between two techniques [14,15]. However in both trials in off-pump population fewer grafts were implanted and early repeated revascularization was more frequent than in on-pump CABG patients.

Echocardiography is the main and mostly used imaging tool for daily practice at bedside. Hemodynamic monitoring by means of Doppler technique has an impact on management of critically ill patients in the setting of ICU or OR [10]. Application of IOTEE for monitoring of the LV function was published in the early 1980s, however introduced into clinical practice in the late 1970s [16,17]. In patients undergoing elective CABG indications for IOTEE were confined to high risk group or acute hemodynamic deterioration at the OR [18]. In the majority of studies concerning application of IOTEE in surgical cardiac revascularization, investigators concentrated on new findings which resulted in changes of the surgical plan, need for graft revision, intra-aortic balloon implantation or major modification in anesthetic procedure [17,19]. Moreover, IOTEE allows continuous monitoring of important parameters, such as left and right ventricular function, the contraction of both ventricles as well as cardiac preload. We thought, it might be interesting to compare these variables in stable, low risk patients qualified for elective CABG operations. Based on the available data, we supposed that OPCAB would better preserve perioperative myocardial function. According to our knowledge, the current study is the first to compare perioperative myocardial function assessed by IOTEE between two surgical techniques: on the beating heart and with the usage of heart/lung machine.

From the anesthesiologist's point of view, perioperative care of the patients undergoing OPCAB differs from the on-pump CABG. Heart displacement and temporary occlusion of coronary arteries during OPCAB procedure may result in hemodynamic instability. Mishra *et al*. [20], studied 500 patients operated without CPB. They observed statistically significant deterioration of LV function due to the decrease of mean arterial pressure, stroke volume or the increase of central venous pressure. Other investigators reported the development or deterioration of pre-existing mitral regurgitation as a consequence of manipulations on the beating heart during OPCAB [21]. Like in our study, the assessment of regional and global LV function was provided by WMSI and %FAC and LVEDA was used for the estimation of preload. However, the main limitation of their study was a single, transgastric short axis plane used for the measurements. In OPCAB operations quality of IOTEE, particularly transgastric views, may be affected while the heart is vertically elevated. In our study for the consecutive measurements transgastric view as well as midesophageal 4-chamber views were used. In analyzed populations slight, but comparable LV regional contractility disturbances and global LV dysfunction as expressed by WMSI and %FAC were found. There were no significant differences between the study groups, however the improvement of LV contractility and function were more evident in OPCAB group. Interestingly, in CCABG group finally %FAC increased, suggesting normalization of LV function, but with a slight delay. Moreover, in both groups LVESA similarly decreased, which suggested gradual improvement of LV function, again more evident in OPCAB group. The indices of preload – LVEDA and RVEDA – suggested that loading conditions of left and right ventricle were comparable in CCABG and OPCAB patients at every stage of surgical procedure. LVEDA decrease was more evident after OPCAB, probably due to better left ventricle filling during off-pump procedure *per se*.

The data comparing conventional CABG and OPCAB surgery considering RV function estimated by IOTEE is sparse. Michaux *et al*. [22], compared RV systolic and diastolic function in 50 patients randomized to on-pump versus off-pump operation. They did not find any significant differences between analyzed echocardiographic parameters. The only significance was found regarding biochemical parameter – troponin I, which was higher measured 24 h after surgery in conventional CABG patients. We obtained the same results in similar patient population. In our patients we found no differences in RVESA and %RVAC, but these parameters shown significant improvement at the consecutive stages of procedure in both – CCABG and OPCAB patients.

Higher release of cardiac biomarkers and inflammatory parameters among on-pump CABG patients in comparison with OPCAB is well known [23]. In our low risk population we observed the same effect. It might be suggested that the degree of myocardial injury assessed by troponin I elevation and the degree of inflammation estimated by CRP release are higher in CCABG patients due to more invasive procedure. The significant changes in biomarkers of myocardial injury and inflammation were not parallel to the significant changes in echocardiographic variables suggesting left and right ventricular dysfunction. The results of our study suggest that concerning perioperative LV and RV function CCABG is not inferior to OPCAB . Perhaps investigated parameters were not sensitive enough, but until now novel technologies such as Doppler Tissue Imagining or Speckled-Tracking Echocardiography, have not been introduced in IOTEE technique. On the other hand, perhaps lack of differences in cardiac function between the groups could be explained by counterbalance of the destructive effect of CPB and cardioplegia in CCABG as compared to myocardial ischemia induced by temporary occlusion of coronary arteries during OPCAB operation.

Limitation of the study

The main limitation of this study was the lack of randomization and relatively small number of patients enrolled, which was related to strict inclusion and exclusion criteria. We have focused on a homogenous low-risk patients due to establish baseline comparable groups in terms of clinical variables and surgical difficulty of both procedures. Our matching process allowed us to create comparable groups for the most perioperative variables except the number of stenosed coronary arteries which was higher in CCABG patients.

Another limitation of our study is an application of the 16-segment model for the regional LV contractility assessment instead of currently recommended 17-segment model. However, in our opinion for contractility estimation 16-segment model may be admitted. Moreover, in TEE examination, due to a risk of the LV long axis foreshortening, "apical cap" visualization sometimes may be hazardous.

Furthermore it must be recognized that the differences in cardiac function may also be seen when the patient is outside of the OR. This is highlighted by the fact that troponin (reflecting myocardial damage) or CRP did not peak until day 0-1 post-op. They were not taken at the same time point as IOTEE. Potential impact was not investigated until a day or so later. While in our low risk population perioperative period was uneventful and catecholamines were not employed, we interpret the difference in troponin I level and CRP concentrations between the groups as a pure effect of different surgical techniques (particularly CPB usage as well as longer operation time in CCABG patients). Obviously a post-op or pre-discharge TTE would have bring new information concerning cardiac function, but our intention was to investigate if there is an influence of the two different operative methods on cardiac function evaluated immediately in the OR. IOTEE was used as a diagnostic tool and the patients were examined by the same anesthesiologist due to avoid an interobserver variability. Moreover, we decided not to compare analyzed parameters of RV and LV function assessed by different echocardiographic techniques performed by different investigators. There are only a few studies in the literature regarding the use of IOTEE in assessment of LV function [22,24,25]. However, none of them compared cardiac function between CCABG and OPCAB groups. The studies were provided on a small, similar number of patients, but while were prospective, the authors considered the results as being representative.

CONCLUSIONS

In low risk patients off-pump elective surgery is not superior to conventional CABG regarding perioperative myocardial function assessed by IOTEE.

ACKNOWLEDGEMENTS

No external funding and no competing interests declared.

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