Eur J Med Res (2005) 10: 218-226

Impact of Intraoperative Myocardial Cellular Damage on Early Hemodynamics after Off-pump versus On-pump Coronary Artery Bypass Surgery

M. Thielmann, P. Massoudy, G. Marggraf, E. Assenmacher, P. Kienbaum, J. Piotrowski, H. Jakob

Department of Thoracic and Cardiovascular Surgery (M.T.,P.M.,G.M.,J.P.,H.J.),
and the Department of Anesthesiology and Intensive Care Medicine (E.A., P.K.),
West-German Heart Center Essen, University Clinic of Essen, Germany

Abstract
Background: Due to the surgical trauma a small amount of myocardial cellular damage is inherent during coronary artery bypass grafting (CABG). The purpose of the present study was to assess the degree of myocardial cellular damage after off-pump (OPCAB) and on-pump CABG (ONCAB) as measured by cardiac troponin I (cTnI), creatine kinase (CK), its MB isoenzyme (CK-MB) and myoglobin (Myo) and to examine its impact on early hemodynamics after surgery.
Methods: Ninety-nine consecutive OPCAB patients, operated between 01/1999 and 01/2004, were enrolled in the present study and compared to 99 ONCAB patients operated during the same period of time, who were matched for baseline data and mean number of grafts per patient. Early hemodynamics, cTnI, CK/CK-MB and Myo were measured preoperatively and at 1, 6, 12, 24 and 48 hours (h) postoperatively. Perioperative inotropic support, clinical data and potoperative outcome were recorded prospectively.
Results: The two groups were similar concerning preoperative characteristics. The mean number of distal grafts/patient was 2.1 ± 1.0 in OPCAB and 2.1 ± 0.8 in ONCAB patients (mean ± SD). There was no significant difference among the groups regarding early hemodynamics in terms of cardiac index (CI), systemic vascular resistance index (SVRI), and left ventricular stroke work index (LVSWI), and inotropic support. However, cTnI, CK/CK-MB but not Myo levels were significantly lower in OPCAB compared to ONCAB patients at 1, 6, 12, 24, 36 and 48 h postoperatively ($P < 0.05$).
Conclusions: Off-pump surgery results in equal early hemodynamics despite a significantly lower release of cTnI and CK, suggesting a reduced myocardial cell damage as compared to ONCAB surgery.

Key words: Coronary artery disease; beating heart surgery; cardiopulmonary bypass; myocardial cellular necrosis; cardiac troponin I; perioperative hemodynamics; outcomes

Abbreviations: CABG = coronary artery bypass grafting; CI = cardiac index; CK = creatine kinase; CK-MB = creatine kinase MB; CPB = cardiopulmonary bypass; cTnI = cardiac troponin I; ICU = intensive care unit; LVSWI = left ventricular stroke work index; Myo = myoglobin; OPCAB = off-pump coronary artery bypass; ONCAB = on-pump caronary artery bypass; SVRI = systemic vascular resistance index

Introduction

There is increasing evidence, that patients with coronary artery disease undergoing coronary artery bypass grafting (CABG) may benefit from beating heart surgery without extracorporeal circulation due to the 'less' invasive operative technique, which may be associated with lower morbidity and mortality rates (Angelini et al. 2002; Legare et al. 2004; Puskas et al. 2004). The possible clinical benefits for off-pump coronary artery bypass (OPCAB) surgery are related to various concerns (Ascione et al. 2000; Bowles et al. 2001; Lee et al. 2003; Puskas et al. 2003), however, the potential myocardial benefit of reducing or even avoiding perioperative myocardial cellular injury, which is inherent with conventional CABG surgery (Alpert et al. 2000), has not been fully understood.

To date, the occurence of new Q-waves in the electrocardiogram (ECG) as well as elevated serum levels of cardiac biomarkers for myocardial damage are used to establish the diagnosis of perioperative myocardial infarction (Alpert et al. 2000; Jain 1992). Cardiac isoforms of troponins, most notably cardiac troponin I (cTnI) and T (TnT), have recently been supposed to be more specific and sensitive biomarkers, particularly as indicators for the extent of irreversible myocardial necrosis in the postoperative period after cardiac surgery (Selvanayagam et al. 2004; Steuer et al. 2004; Thielmann et al. 2004). Furthermore, several clinical studies could clearly demonstrate that a strong relationship exists between the postoperative release of cardiac troponins and the patients short- and long-term outcome following cardiac surgery (Lasocki et al. 2002; Lehrke et al. 2004). Moreover, there is recent evidence that the postoperative rise of cardiac troponins is significantly lower after OPCAB surgery compared to conventional CABG with cardiopulmonary bypass (CPB). Whether these postoperative lower levels of cardiac troponins are acutally associated with an improved recovery of hemodynamics in the early postoperative period after surgery is uncertain.

The purpose of the present study was therefore to assess the postoperative degree of myocardial injury, as

measured by cardiac troponin I (cTnI), creatine kinase (CK) and myoglobin (Myo) release following OPCAB surgery compared to conventional on-pump coronary artery bypass grafting (ONCAB). Furthermore, we sought to examine the possible relationship between the postoperative release of cardiac biomarkers for myocardial damage and the early postoperative hemodynamic situation following OPCAB and ONCAB surgery.

Methods

Patient Population and Data Management

Between September 1999 and January 2004, the first 99 consecutive patients undergoing elective primary off-pump coronary artery bypass surgery were studied (OPCAB group). We compared this OPCAB group with another 99 patients, randomly selected from the population who underwent a conventional elective isolated CABG procedure within the same time period, matched for preoperative characteristics and the number of distal grafts per patient (ONCAB group). All preoperative, intraoperative, and postoperative data were prospectively recorded with more than 1800 variables per case and retrospectively reviewed for the present study using the institutional database according to the 'Heidelberger Verein zur Multizentrischen Datenanalyse e.V.' (HVMD) (Vahl et al. 1990). Patiens were excluded from the study, if any of the following preoperative criteria were present: (1) Emergency surgery, (2) previous myocardial infarction (<4 weeks), (3) concomitant open heart surgery. The study was performed with local ethics committee and institutional approval, all patients gave their informed consent.

Intraoperative Management

Cardiac anaesthesia was standardized for both groups. All patients underwent complete median sternotomy for access and the conduits used included left and right internal thoracic artery and saphenous veins. Fine monofilament polypropylene 7-0 suture was used for all distal anastomoses. Proximal anastomoses were performed with 6-0 suture for venous anastomoses and 7-0 suture for arterial anastomoses. Mean flow of each individual graft was assessed in both groups just before sternal closure by Doppler transit time flowmetry (Cardiomed, MediStim, Oslo, Norway).

OPCAB technique: Temperature maintenance was accurately considered during the last two years in the OPCAB group using a combination of techniques, including range of operating theatre temperature (20-24 °C), warm water blanket, warm air blanket and humidification of the anaesthesia circuit. Hemodynamic stability was maintained with adequate volume loading, optional use of the Trendelenberg position and administration of intravenous inotropes, as required to maintain a systolic mean blood pressure of 60-70 mmHg. Positioning of the heart was achieved by using the pericardial deep stich technique and the Octopus I (January 1999-March 1999) Octopus II (March 1999-December 2000) and III (December 2000-December 2003) stabilizer and optionally the Starfish I (Medtronic, Minneapolis, MN, USA) stabilizer. During coronary artery bypass grafting the coronary artery was occluded proximal to the anastomotic site using a small bulldog clamp. An intracoronary shunt was only used, if a prolonged coronary occlusion time was assumed in cases when coronaries were heavily calcified. A humidified carbon dioxide blower (Medtronic, Minneapolis, MN, USA) was used to disperse blood from the anastomotic site.

ONCAB technique: Conventional CABG was performed using standard CPB technique with ascending aortic and two-stage venous cannulation. Heparin was administered in order to achieve an activated coagulation time above 400s. CPB was conducted with hemodilution, mild hypothermia (>32 °C) and membrane oxygenation. Myocardial protection was achieved using antegrade cold cristalloid (Bretschneider; Custodiol®) cardioplegia supplemented by topical cooling, and single aortic cross-clamping for all distal anastomoses.

Hemodynamic Measurements

Heart rate, central venous pressure, mean pulmonary artery pressure, pulmonary capillary wedge pressure, and cardiac output were monitored. Cardiac output was measured in triplicates by thermodilution using a Swan-Ganz-catheter and a Siemens SC-7000 monitor computer system. The hemodynamic measurements were performed (1) during anesthesia before surgery (preoperative), (2) just after sternal closure (intraoperative), at 1 hour (h) after arrival on the ICU, and at 6, 12, and 24 h after surgery. Derived cardiovascular variables, including cardiac index (CI), left ventricular stroke work index (LVSWI), and systemic vascular resistance index (SVRI), were calculated. Pharmacologic therapy with inotropic support was used to keep the CI above 2.0 L/min/m^2. Intravenous epinephrine and noradrenaline were used as the inotropic agents and therapy was not interrupted when hemodynamic data were determined.

Postoperative Management

Patients were hemodynamically monitored as mentioned above. A 12-lead ECG was recorded preoperatively, immediately after arrival on the intensive care unit (ICU) and at 12, 24, 36 and 48 hours postoperatively. A medication of 500 mg acetylsalicylic acid was administered intravenously within the first 6 hours after surgery in the absence of significant bleeding. Postoperative bleeding was measured from the time at arrival on the ICU until they were removed or on the morning of the second postoperative day. Hospital mortality was defined as any death that occurred during the same hospital admission.

Determination of Cardiac Biomarkers

Blood samples were drawn preoperatively, and at 1, 6, 12, 24, 36, and 48 hours after aortic unclamping and analyzed separately for cTnI, CK, and CK-MB isoenzyme activity and myoglobin. A 2-site immunoassay specific for cTnI and myoglobin was used (Dimension-Flex®, Dade Behring, Newark, DE, USA), respectively, with a cTnI detection range of 0.1–50 ng/ml, requiring further dilutions if necessary. CK and CK-MB catalytic

concentrations were measured at 25 °C using an inhibiting immunoassay (Granutest®, Merck KG, Darmstadt, Germany). A perioperative myocardial infarction (PMI) was considered to have occurred, if one of the following diagnostic criteria were present: (1) A postoperative cTnI serum level above 10.5 ng/ml within the first 24 hours after CABG, as previously described (Thielmann et al. 2003) or elevated values of CK-MB 2 times above the upper normal limit. (2) The appearance of ST-segment deviations at the J point in two or more contiguous leads with cut-off points ≥0.2 mV in leads V1, V2, or V3 and ≥0.1 mV in other leads or T-wave abnormalities in two or more contiguous leads or the development of new Q-waves (Alpert et al. 2000). LOS was present, if high-dose inotropic support was neccessary in the postoperative course during hospital stay with or without the need of intraaortic ballon couterpulsation (IABP).

Statistical Analysis

Continuous variables are reported as mean ± SD or SEM as indicated, and categorical variables as number (%). Comparisons of categorical variables between groups were performed by Pearson´s Chi-square test, for expected frequencies <5 by Fisher´s exact test. Comparisons of continuous variables between groups were performed by two-sided Student´s t-test. Perioperative time courses of cTnI, Myo, CK and CK-MB as well as the perioperative hemodynamic data were analyzed by two-way ANOVA for repeated measurements and post-hoc comparisons by Tukey´s honest significance difference test. For all statistical tests, a two-tailed P value <0.05 was considered as statistically significant. All statistical analyses were performed the SPSS software package version 10.0 (SPSS, Chicago, IL, USA).

Results

Demographics

Patient characteristics like demographics, risk factors, comorbidities, and preoperative data are outlined in Table 1.

Table 1. Baseline characteristics.

	OPCAB (n=99)	**ONCAB (n=99)**	**P value**
Demographics			
Age, y	63 ± 10	62 ± 10	0.10
Gender, female	28 (28)	30 (30)	0.88
Body weight, kg	80 ± 16	81 ± 13	0.23
Cardiovascular risk factors			
Diabetes mellitus	26 (26)	26 (26)	1.00
Hypertension	73 (74)	69 (70)	0.64
Hyperlipidemia	75 (76)	80 (81)	0.49
Family history	26 (26)	29 (29)	0.75
Smoking history	40 (40)	39 (39)	1.00
Obesity*	29 (29)	31 (31)	0.88
Comorbidities			
History of stroke	3 (3)	3 (3)	1.00
COPD	25 (25)	11 (11)	0.02
PVD	12 (12)	6 (6)	0.14
Renal disease**	4 (4)	8 (8)	0.23
Cardiac history			
Previous MI***	41 (41)	36 (36)	0.47
Previous PCI	33 (33)	43 (43)	0.14
CCS III-IV	53 (53)	53 (53)	1.00
Extent of CAD			
One-vessel disease	31 (31)	34 (34)	0.65
Two-vessel disease	30 (30)	321 (32)	0.76
Three-vessel disease	38 (38)	33 (33)	0.55
LV function			
LV-EF <30%	5 (5)	0 (0)	0.06
LV-EF 30(49%	28 (28)	33 (33)	0.44
LV-EF >49%	66 (66)	66 (66)	1.00

Data are presented as mean ± SD or number (%); COPD: Chronic obstructive pulmonary disease; PVD: Peripheral vascular disease; MI: Myocardial infarction; PCI: Percutaneous coronary intervention; CCS: Canadian Cardiovascular Society; CAD: Coronary artery disease; LV: Left ventricle; EF: Ejection fraction.*:BMI ≥30; **: Serum Creatinine >0.2µmol/l; ***: MI >4weeks. For comparisons between the groups Pearson´s Chi-square test, Fisher´s exact test and two-sided Student´s t-test were applied.

Table 2. Intra- and postoperative characteristics.

	OPCAB (n = 99)	ONCAB (n = 99)	P value
Intraoperative data			
ACC time, min	–	72 ± 23	–
CPB time, min	–	110 ± 33	–
Skin to skin time, min	159 ± 51	175 ± 35	0.04
Cardioplegia, ml	–	1579 ± 445	–
Reperfusion time, min	–	34 ± 14	–
Conversion	6 (6)	0 (0)	–
Grafts per patient, n	2.1 ± 1.0	2.1 ± 0.8	0.36
Grafts, arterial.	102 (63)	111 (68)	–
Grafts, venous	60 (37)	54 (32)	–
Postoperative data			
Ventilation time, h	8.9 ± 8.9	8.8 ± 6.8	0.45
Blood loss, mL	763 ± 673	910 ± 505	0.18
Blood transfusion, units	1.0 ± 1.2	1.2 ± 1.6	0.29
Inotropic support	31 (31)	32 (32)	0.88
Inotropic support, h	4.5 ± 4.2	5.7 ± 6.3	0.12
IABP support	0 (0)	0(0)	1.00
ICU stay, d	1.8 ± 1.4	1.8 ± 0.8	0.14
Hospital stay, d	5.8 ± 2.4	7.0 ± 2.8	<0.01
Major adverse events			
Death in OR	0 (0)	0 (0)	1.00
Death in hospital (≤30d)	2 (2)	0 (0)	0.50
LOS	0 (0)	0 (0)	1.00
PMI	4 (4)	3 (3)	1.00
New Q-wave MI	2 (2)	1 (1)	1.00
Stroke	0 (0)	0 (0)	1.00
Other complications			
Major bleeding	2 (2)	1 (1)	1.00
Rethoracotomy	3 (3)	2 (2)	1.00
Atrial fibrillation	9 (9)	12 (12)	0.65
Ventricular fibrillation	1 (1)	0 (0)	1.00
Renal failure (dialysis)	1 (1)	2 (2)	1.00
Sternal instability	1 (1)	1 (1)	1.00
Peripheral thrombectomy	1 (1)	0 (0)	1.00
Bowl ischemia	1 (1)	0 (0)	1.00

Data are presented as mean(SD, median (25% – 75% Interquartile) or number (%); ACC: Aortic cross-clamp; CPB: Cardiopulmonary bypass; IABP: Intraaortic ballon counterpulsation; ICU: Intensive care unit; LOS: Low cardiac output syndrome; PMI: Perioperative myocardial infarction; OR: odds ratio and 95% confidence interval between group 1 and 2.For comparisons between the groups Pearson´s Chi-square test, Fisher´s exact test and two-sided Student´s t-test were applied.

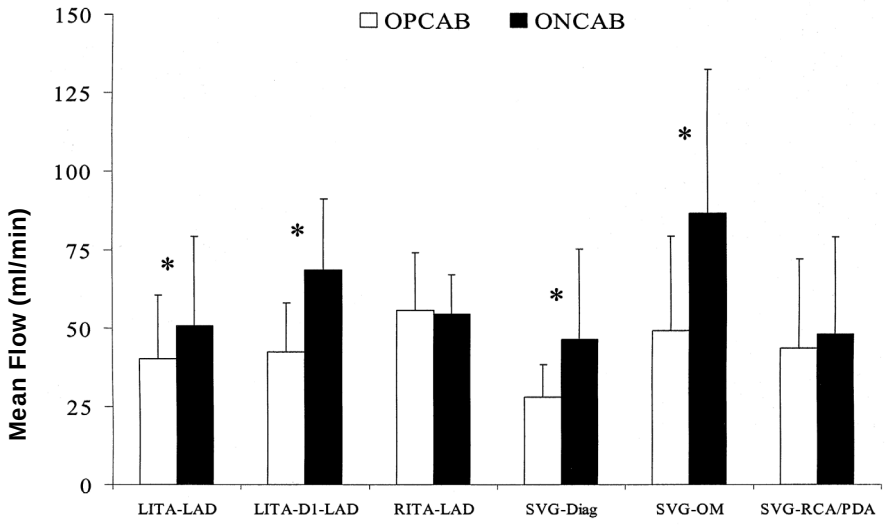


Fig. 1. Doppler mean graft flow (± SD) to different target vessels in patients following ONCAB versus OPCAB surgery. LITA, Left internal thoracic artery; LAD, left anterior descending artery; RITA, right internal thoracic artery; SVG, saphenous vein graft; RD, diagonal branch; OM, obtuse marginal branch; RCA, right coronary artery; PDA, posterior descending artery. *: P<0.05 (Two-sided Student´s t-test).

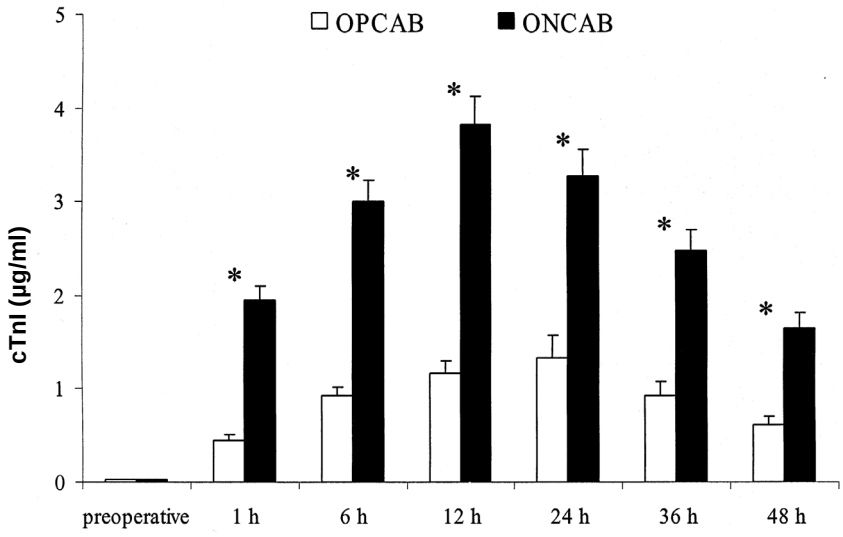


Fig. 2. Mean (±SEM) serum levels of cardiac troponin I (cTnI) in patients undergoing ONCAB versus OPCAB surgery. *: P<0.05 between the groups (2-way ANOVA).

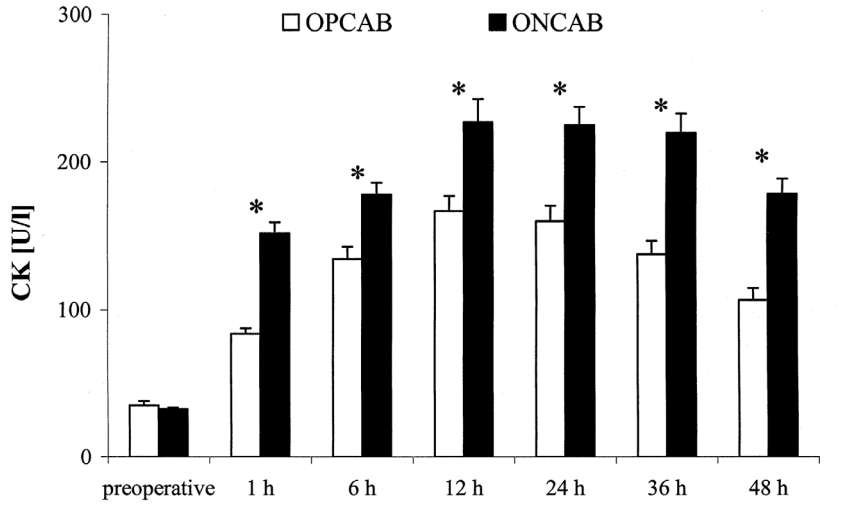


Fig. 3. Mean (±SEM) serum levels of myoglobin (Myo) in patients undergoing ONCAB versus OPCAB surgery. *: P<0.05 between the groups (2-way ANOVA).

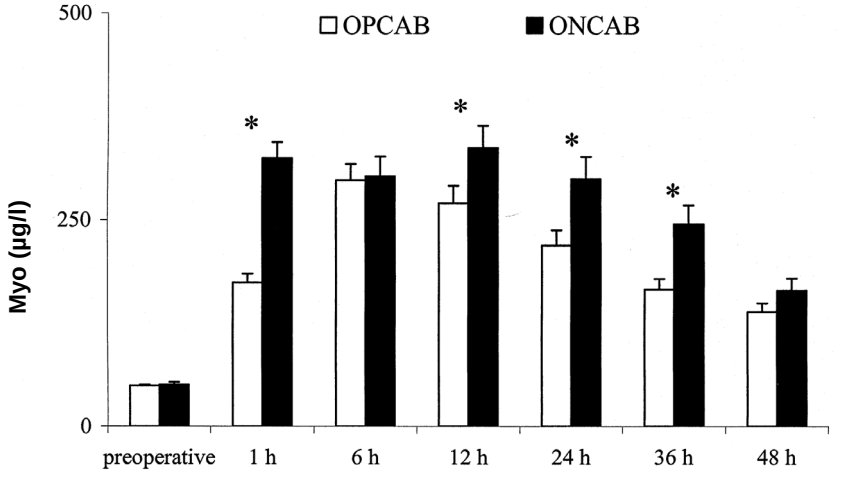
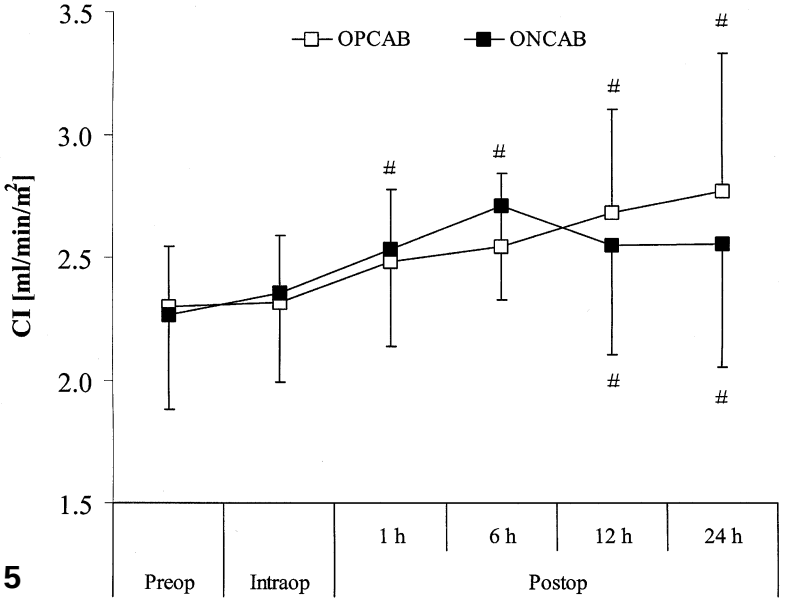


Fig. 4. Mean (±SEM) serum activity of creatine kinase (CK) in patients undergoing ONCAB versus OPCAB surgery. *: P<0.05 between the groups (2-way ANOVA).

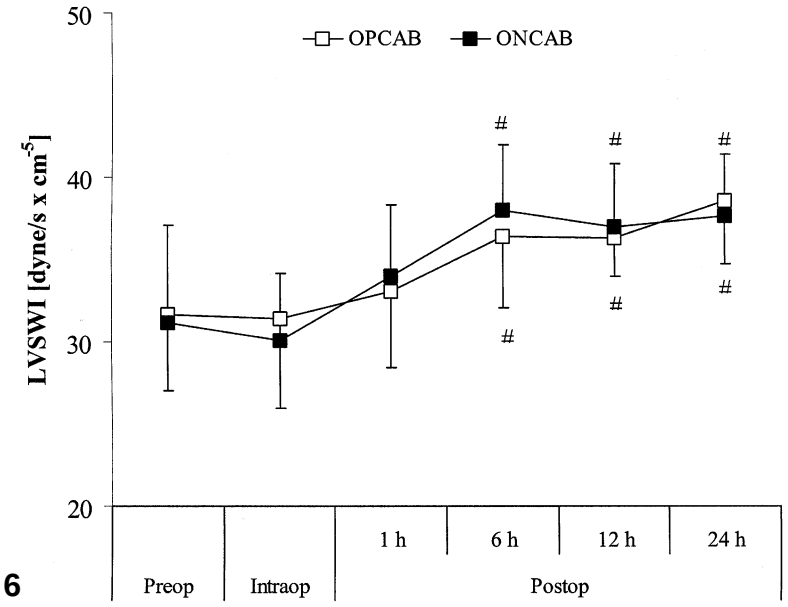
Both groups had similar profiles, except that the OPCAB group had significantly more patients with a COPD (P<0.02). Both groups had approximately the same extent of coronary artery disease, but the OPCAB group tended to have more patients with impaired left ventricular function below 30% ejection fraction (P<0.06).

Bypass Grafting and Graft Flow

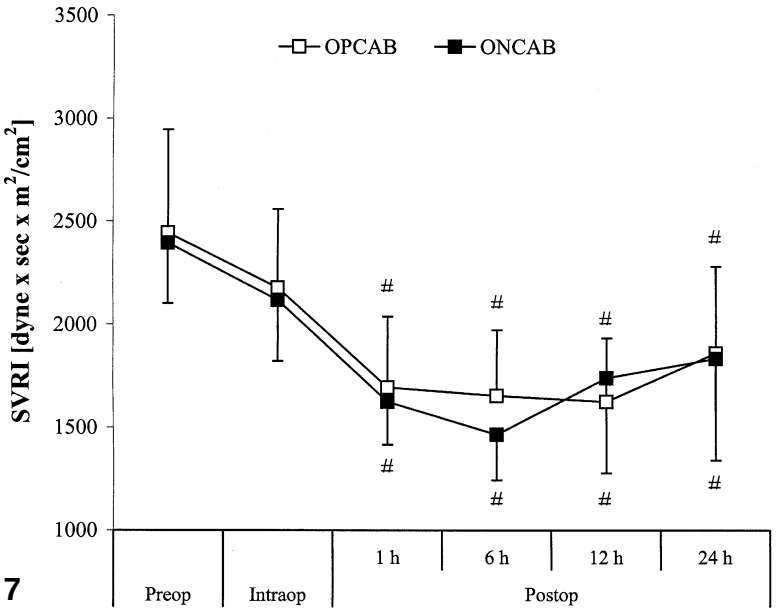
The OPCAB group received an average of 2.1 ± 1.0 grafts per patient, compared with 2.1 ± 0.8 grafts for the ONCAB group (P = NS). As outlined in Table 2, the total numbers of grafts performed in the OPCAB and ONCAB groups were 162 and 164, in which 63%



5



6



7

Figs. 5-7. Perioperative course of mean (±SEM) cardiac index (CI), left ventricular stroke work index (LVSWI), and systemic vascular resistance index (SVRI) in patients undergoing OPCAB versus ONCAB surgery. #: $P<0.05$ versus preoperative values. There were no significant difference between the groups (2-way ANOVA).

and 68% were grafted with arterial conduits (P = NS), respectively. Skin to skin time did not differ between the groups. As shown in Table 2., 6 patients had to be converted from OPCAB to ONCAB surgery due to hemodynamic instability during surgery or an unsatisfying quality of the anastomosis. By using the Doppler flowmeter (MediStim AS, Oslo, Norway) routinely, intraoperative graft flow rates could be determined for each target vessel in all patients prior to chest closure under stable and comparable hemodynamic conditions. As shown in Figure 1. almost all target vessel areas had a significant lower mean graft flow rate in the OPCAB patients compared to the ONCAB patients.

Perioperative Hemodynamics

No statistically significant differences could be found according to the perioperative hemodynamic status, as measured by CI, LVSWI, and SVRI, between the two study groups at any time point of measurement. Mean CI as well as LVSWI tended to increase slightly within the study groups from baseline (preop) to 24 h after surgery, whereas SVRI tended to decrease within the observation period in both groups (Figs. 5-7).

Cardiac Biomarkers

Preoperative serum values of biomarkers for myocardial damage, as measured by cTnI, CK/CK-MB, and Myo, did not differ between the two groups. Postoperative serum levels of cTnI, CK/CK-MB were significantly lower at 1, 6, 12, 24, 36 and 48 h ($P<0.05$) and Myo was lower at 1, 12, 24 and 36 h ($P<0.05$) in the OPCAB compared to the ONCAB group (Figures 2-4). Maximum peak cTnI, CK, and Myo occurred at 12 h in both groups. Maximum values of cTnI (1.7 ± 1.3 versus 4.1 ± 2.3 ng/mL), CK (177 ± 85 versus 263 ± 105 IU/l) and CK-MB (5.1 ± 2.8 versus 10.9 ± 5.7 IU/l), but not Myo (387 ± 316 versus 377 ± 257 μg/mL) were significantly lower in OPCAB as compared to ONCAB surgery.

Postoperative Data and Clinical Outcome

All postoperative data and clinical outcome of the patients are shown in Table 2. No difference was observed between OPCAB and ONCAB patients according to postoperative ventilation time, postoperative blood loss, and requirement for packed red blood cells, neccessity for inotropic support, duration of inotropic support or neccessity for intraaortic balloonpump support. The mean stay on ICU did not differ, whereas hospital stay was significantly different between the groups ($P<0.02$). Two patients died during hospital stay in the OPCAB group, 1 patient on the first and another on the 29th postoperative day due to sudden cardiac death. There were 4 patients with PMI, defined as mentioned above, in the OPCAB group compared to three patients in the ONCAB group. A Q-wave MI was identified in 2 OPCAB patients compared to 1 ONCAB patient, there was no patient with LOS or postoperative stroke in the entire study population. As shown in Table 2., there were no differences according to postoperative major bleeding and retho-racotomy, postoperative arrhythmias or sternal instability. Acute renal failure with temorary renal replacement therapy was necessary in 1 patient in the OPCAB group and in 2 patients in the ONCAB group. In one OPCAB patient, a thrombectomy of the lower left extremity and I another patient a laparatomy due to acute bowl ischemia had to be carried out postoperatively (Table 2).

Discussion

The present study demonstrates that beating heart coronary artery bypass surgery without CPB results in a lower release of cardiac biomarkers, as measured by cardiac troponin I, creatine kinase, its MB isoform, and myoglobin, indicating a lower degree of perioperative myocardial cellular damage compared to patients undergoing conventional coronary artery bypass surgery with CPB. Furthermore, we could show that the intraoperatively determined transit time graft flow rates were significantly lower in almost all vessel territories with OPCAB compared to ONCAB surgery. However, neither the lower intraoperatively measured graft flow rates on the one hand, nor the lower postoperative release of cardiac biomarkers in patients undergoing OPCAB surgery, had actually any significant impact on the early postoperative hemodynamics and clinical outcome.

Our findings that OPCAB surgery results in significantly lower release of serum myocardial biomarkers than ONCAB surgery confirms the findings of several previous studies (Puskas et al. 2003; Puskas et al. 2004; Selvanayagam et al. 2004; Wan et al. 1999). Myocardial cellular damage in association with cardiac surgery and coronary artery bypass surgery in particular, is caused by various pathological mechanisms, including direct myocardial trauma due to surgical manipulation, focal cellular damage caused by inadequate myocardial cellular protection and inadequate cardioplegic perfusion, myocardial cellular damage due to intraoperative distal coronary microembolization, leading to myocardial inflammatory respone and progressive myocardial contractile dysfunction (Thielmann et al. 2002). These numerous etiologies of myocardial cellular damage may all result in myocardial necrosis and therefore, all lead to the elevation of cardiac biomarkers. An elevation of cardiac troponins, most notably cardiac troponin I and T, was found to be most sensitive and specific, indicating even 'minor' amounts of irreversible myocardial cellular necrosis (Galianes 1998; Heidenreich et al. 2001; Newman 2001). Previous studies have shown that there is a strong correlation between the extent of release of cardiac troponins and the amount of irreversible myocardial cellular damage after CABG with (Steuer et al. 2004) and without CPB (Selvanayagam et al. 2004). In OPCAB surgery, however, several ethiologies and risk factors concerning the intraoperative myocardial cellular damage (e.g. less surgical manipulation to the myocardium, omission of inadequate myocardial protection due to inadequate cardioplegic perfusion, omission of epicardial defibrillation) are simply negligible.

The value of intraoperative assessment of bypass graft flow using the Doppler technique has been

demonstrated by several clinical studies, in which mean graft flow could be correlated with patient outcome following coronary artery bypass grafting (Louagie et al. 1998). However, the mid- or long-term prognostic value of bypass graft flow rates measured intraoperatively still remains an issue of controversial discussion and has not yet been defined. While there is evidence that bypass anastomoses can stay patent even with low initial graft flow rates, high graft flow rates are more correlated with patent anastomoses than low graft flow rates (Gurne et al. 1995; Hirotani et al. 2001). In patients undergoing CABG with CPB, the postischemic heart is in a hyperemic state, therefore mimicking the application of vasodilating drugs such as adenosine, which provokes a hyperaemic flow velocity reserve (Wieneke et al. 2000); this mechanism caused by ischemia/reperfusion during CABG with CPB and aortic cross clamping does not exist in OPCAB surgery. Therefore, mean graft flow rates are generally seen to be lower on average in comparison to CABG with CPB (Schmitz et al. 2003).

Despite the considerable differences in the release of cardiac biomarkers for myocardial damage, we neither found a significant difference in the early postoperative hemodynamic performance as measured by CI, LVSWI, and SVRI, nor a significant difference of the duration or need of inotropic support, which is contrary to several recently published studies where a better postoperative hemodynamic performance and/or a lower inotropic support has been reported in favor of OPCAB surgery (Ascione et al. 1999; Louagie et al. 2002; Vedin et al. 2003). These results may be related to an earlier extubation in OPACB patients, associated with higher endogenous catecholamine release and, therefore, lower need for inotropic support.

Limitations of the Study

There are several limitations of the present study. One limitation is that the study was not randomized, but matched for some preoperative data and the number of distal anastomosis performed per patient. In addition, the small study size is underpowerd to identify differences in endpoints occuring infrequently like patient morbidity and mortality, which is also a limitation applicable for randomized trials. The low number of cases within the last four years as well as the low mean number of distal grafts per patient reflects our low case load and the preference to perform CABG on the pump. Moreover, the present study only presents short-term outcome. Intermediate and long-trem outcome has not yet been adequately addressed in any OPCAB study.

Conclusions

In summary the present study suggests that off-pump coronary artery bypass grafting results in a significantly lower release of cardiac troponin I and creatine kinase, indicating a reduced myocardial cellular damage as compared to conventional CABG with CPB. The reason for the reduced cellular damage is unclear and has to be further explored. Moreover, OPCAB surgery without CPB results in lower graft flow rates measured intraoperatively. None of these differences seem to have an impact on early hemodynamic recovery and patient outcome.

References

Alpert JS, Thygesen K, Antman E, Bassand JP. Myocardial infarction redefined - a consensus document of The Joint European Society of Cardiology/American College of Cardiology Committee for the redefinition of myocardial infarction. J Am Coll Cardiol 2000;36:959-969.

Angelini GD, Taylor FC, Reeves BC, Ascione R. Early and midterm outcome after off-pump and on-pump surgery in Beating Heart Against Cardioplegic Arrest Studies (BHACAS 1 and 2): a pooled analysis of two randomised controlled trials. The Lancet 2002;359:1194-1199.

Ascione R, Lloyd CT, Gomes WJ, Caputo M, Bryan AJ, Angelini GD. Beating versus arrested heart revascularization: evaluation of myocardial function in a prospective randomized study1. Eur J Cardio-Thoracic Surg 1999;15: 685-690.

Ascione R, Lloyd CT, Underwood MJ, Lotto AA, Pitsis AA, Angelini GD. Inflammatory response after coronary revascularization with or without cardiopulmonary bypass. Ann Thorac Surg 2000;69:1198-1204.

Bowles BJ, Lee JD, Dang CR, Taoka SN, Johnson EW, Lau EM, Nekomoto K. Coronary Artery Bypass Performed Without the Use of Cardiopulmonary Bypass Is Associated With Reduced Cerebral Microemboli and Improved Clinical Results. Chest 2001;119:25-30.

Galianes M. In search of a reliable marker of tissue injury during heart surgery. Heart 1998;80:317-318.

Gurne O, Chenu P, Polidori C, Louagie Y, Buche M, Haxhe JP, Eucher P, Marchandise B, Schroeder E. Functional evaluation of internal mammary artery bypass grafts in the early and late postoperative periods. J Am Coll Cardiol 1995;25:1120-1128.

Heidenreich PA, Alloggiamento T, Melsop K, McDonald KM, Go AS, Hlatky MA. The prognostic value of troponin in patients with non-ST elevation acute coronary syndromes: a meta-analysis. J Am Coll Cardiol 2001;38: 478-485.

Hirotani T, Kameda T, Shirota S, Nakao Y. An evaluation of the intraoperative transit time measurements of coronary bypass flow. Eur J Cardio-Thoracic Surg 2001;19:848-852.

Jain U. Myocardial infarction during coronary artery bypass surgery. J Cardiothorac and Vasc Anesth 1992;6:612-623.

Lasocki S, Provenchere S, Benessiano J, Vicaut E, Lecharny J, Desmonts J, Dehoux M, Philip I. Cardiac troponin I is an independent predictor of in-hospital death after adult cardiac surgery. Anesthesiology 2002;97:405-411.

Lee JD, Lee SJ, Tsushima WT, Yamauchi H, Lau WT, Popper J, Stein A, Johnson D, Lee D, Petrovitch H, Dang CR. Benefits of off-pump bypass on neurologic and clinical morbidity: a prospective randomized trial. Ann Thorac Surg 2003;76:18-26.

Legare JF, Buth KJ, King S, Wood J, Sullivan JA, Friesen CH, Lee J, Stewart K, Hirsch GM. Coronary Bypass surgery performed off pump does not result in lower in-hospital morbidity than coronary artery bypass grafting performed on pump. Circulation 2004;109:887-892.

Lehrke S, Steen H, Sievers HH, Peters H, Opitz A, Muller-Bardorff M, Wiegand UKH, Katus HA, Giannitsis E. Cardiac troponin T for prediction of short- and long-term morbidity and mortality after elective open heart surgery. Clin Chem 2004;50:1560-70.

Louagie Y, Jamart J, Broka S, Collard E, Scavee V, Gonzalez M. Off-pump coronary artery bypass grafting: a case-matched comparison of hemodynamic outcome. Eur J Cardio-Thoracic Surg 2002;22:552-58.

Louagie YAG, Brockmann CE, Jamart J, Schroeder E, Buche M, Eucher PM, Schoevaerdts JC. Pulsed Doppler intraoperative flow assessment and midterm coronary graft patency. Ann Thorac Surg 1998;66:1282-87.

Newman MF. Troponin I in cardiac surgery: Marking the future. American Heart Journal 2001;141:325-326.

Puskas JD, Williams WH, Duke PG, Staples JR, Glas KE, Marshall JJ, Leimbach M, Huber P, Garas S, Sammons BH. Off-pump coronary artery bypass grafting provides complete revascularization with reduced myocardial injury, transfusion requirements, and length of stay: A prospective randomized comparison of two hundred unselected patients undergoing off-pump versus conventional coronary artery bypass grafting 1. J Thorac Cardiovasc Surg 2003;125:797-808.

Puskas JD, Williams WH, Mahoney EM, Huber P, Block PC, Duke PG, Staples JR, Glas KE, Marshall JJ, Leimbach M, MacCall SA, Petersen RJ, Bailey LL, Weintraub WS, Guyton RA. Off-pump vs conventional coronary artery bypass grafting: early and 1-year graft patency, cost, and quality-of-life outcomes: a randomized trial. JAMA 2004; 291:1841-1849.

Schmitz C, Ashraf O, Schiller W, Preusse CJ, Esmailzadeh B, Likungu JA, Fimmers R, Welz A. Transit time flow measurement in on-pump and off-pump coronary artery surgery. J Thorac Cardiovasc Surg 2003;126:645-650.

Selvanayagam JB, Petersen SE, Francis JM, Robson MD, Kardos A, Neubauer S, Taggart DP. Effects of off-pump versus on-pump coronary surgery on reversible and irreversible myocardial injury: A randomized trial using cardiovascular magnetic resonance imaging and biochemical markers. Circulation 2004;109:345-350.

Steuer J, Bjerner T, Duvernoy O, Jideus L, Johansson L, Ahlstrom H, Stahle E, Lindahl B. Visualisation and quantification of peri-operative myocardial infarction after coronary artery bypass surgery with contrast-enhanced magnetic resonance imaging. Eur Heart J 2004;25:1293-1299.

Thielmann M, Dorge H, Martin C, Belosjorow S, Schwanke U, van de Sand A, Konietzka I, Buchert A, Kruger A, Schulz R, Heusch G. Myocardial dysfunction with coronary microembolization: signal transduction through a sequence of nitric oxide, tumor necrosis factor-alpha, and sphingosine. Circ Res 2002;19:807-813.

Thielmann M, Massoudy P, Marggraf G, Kamler K, Herold U, Piotrowski J, Schmermund A, Erbel R, Jakob H. Diagnostic discrimination between early graft failure and non-graft related perioperative myocardial infarction with cardiac troponin I following coronary artery bypass surgery. Circulation 2003;108 (Suppl S):391-392.

Thielmann M, Massoudy P, Marggraf G, Knipp S, Schmermund A, Piotrowski J, Erbel R, Jakob H. Role of troponin I, myoglobin, and creatine kinase for the detection of early graft failure following coronary artery bypass grafting. Eur J Cardio-Thoracic Surg 2004;26:102-109.

Vahl CF, Tochtermann U, Gams E, Hagl S. Efficiency of a computer network in the administrative and medical field of cardiac surgery. Concept of and experience with a departmental system. Eur J Cardio-Thoracic Surg 1990;4: 632-638.

Vedin J, Jensen U, Ericsson A, Bitkover C, Samuelsson S, Bredin F, Vaage J. Cardiovascular function during the first 24 hours after off pump coronary artery bypass grafting-a prospective, randomized study. Interact Cardiovasc Thorac Surg 2003;2:489-494.

Wan S, Izzat MB, Lee TW, Wan IYP, Tang NLS, Yim APC. Avoiding cardiopulmonary bypass in multivessel CABG reduces cytokine response and myocardial injury. Ann Thorac Surg 1999;68:52-56.

Wieneke H, Haude M, Ge J, Altmann C, Kaiser S, Baumgart D, von Birgelen C, Welge D, Erbel R. Corrected coronary flow velocity reserve: a new concept for assessing coronary perfusion 1. J Am Coll Cardiol 2000;35:1713-1720.

Received: January 26, 2005 / Accepted: April 18, 2005

Address fo correspondence:
PD Dr. med. Parwis Massoudy
Department of Thoracic and Cardiovascular Surgery
West-German Heart Center Essen
University Clinic of Essen
Hufelandstraße 55
D-45122 Essen, Germany
Tel.: +49-201-723-4901
Fax: +49-201-723-5451
e-mail: parwis.massoudy@uni-essen.de