Myocardial oxidative stress, and cell injury comparing three different techniques for coronary artery bypass grafting

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Abstract

Objective: Oxidative stress as a result of reperfusion injury is a known causative factor of cardiac muscle injury. In the peripheral blood as well in the coronary sinus, oxidative stress parameters and cardiac biomarkers were measured to investigate the different levels of oxidative stress during three different CABG techniques; MCABG (with minimal prime volume and warm blood cardioplegia) that was newly introduced in our hospital, versus OPCAB, versus our current standard, conventional CABG (CCABG, consisting of high volume prime and cold crystalloid cardioplegia). Concomitantly, cardiac biomarkers were measured to detect myocardial cell injury. Methods: Thirty patients scheduled for CABG with the intention to treat three-vessel disease were randomly assigned for CCABG, MCABG or OPCAB. Perioperatively, plasma levels of malondialdehyde (MDA) as a marker of oxidative stress, and the allantoin/uric acid ratio (A/U ratio) as a marker of antioxidant activity were measured in the ascending aorta (Aa), and in the coronary sinus (Cs), simultaneously. Additionally peripheral (Aa) blood levels of heart fatty acid binding protein (HFABP), troponin T, CPK and CKMB as markers of myocardial injury were obtained. Results: The MCABG group had significantly lower MDA levels in the Cs compared to the CCABG group, respectively, to the OPCAB group (p = 0.04 and p = 0.03). At all time points the A/U ratio in the CCABG group remained significantly higher in the Cs as well in the Aa samples compared to the MCABG and the OPCAB group (p < 0.001, respectively, p < 0.001, for both groups). HFABP and troponin T showed consistent curves compared to the CPK figure over time in all groups. Conclusion: In this study coronary sinus blood levels of oxidative stress parameters were consistently higher compared to peripheral blood levels. The levels were lowest in the MCABG study group. In this group also the lowest levels cardiac biomarkers of myocardial injury were found.

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Keywords: Oxidative stress; Antioxidant capacity; CABG; Heart enzymes

1. Introduction

Despite improvements in surgical techniques, anesthesia, and intensive care, cardiac surgery with use of extra corporeal circulation (ECC) is associated with an inflammatory response [1]. Various mechanisms are known to release mediators that initiate and prolong systemic inflammation. Complement activation by contact of blood with foreign material has always been addressed as an important initiator of this inflammatory cascade. However, studies comparing on- and off-pump surgery have shown few differences, indicating that blood-tubing surface contact may be a less important contributor [2]. Morbidity associated with these mechanisms may involve multiple organs, such as the heart, brain, lung, liver, kidney, and gastro-intestinal tract [3,4]. In poorly managed myocardial protection more cytokines are released [5]. Furthermore, prolonged cardioplegic arrest can result in myocardial dysfunction resulting in hypoperfusion [6,7]. Although the heart is protected during CABG, a certain level of reactive oxygen species (ROS) production still occurs. This effect in itself is an important contributor of inflammatory response [8]. Regimens for myocardial protection have been developed in order to reduce ROS generation [9,10].

Recently a mini extra corporeal circuit (MECC) has been introduced. Besides known technical achievements such as closed circuits (reducing blood air contact) and heparin coating, active venous drainage was introduced. This circuit enables perfusionists to reduce their priming volumes

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propofol (1.5—2 mg kg⁻¹). Induction took place by means of infusion of a balanced opiate-based general anesthesia orally 2—3 h before the procedure started. Anesthesia consisted of a conventional cardiopulmonary bypass (CCABG), using the membrane oxygenator (Maquet GmbH, Rastatt, Germany) and a Quadrox² membrane oxygenator (Maquet GmbH, Rastatt, Germany). Priming volume of the system was 500 ml of sodium chloride 0.9% (this solution contains 14.4% HES). Depending on the patient’s hemostability the amount of prime will be returned to zero by starting MECC. When MECC starts, the nasopharyngeal temperature will be maintained at 33—34 °C. Acid—base management during mild hypothermia was monitored with alpha-stat and the cardiac index was kept between 2.0 and 2.4 l min⁻¹. Preservation of the heart was performed using a modified Calafiore-technique (warm blood cardioplegia with 30 ml potassium chloride 2 mol l⁻¹ and 6 ml magnesium sulfoxide 1 mol l⁻¹); [10].

2.4. Perfusion technique MCABG

The MECC system consisted of a closed system, containing a Rotaflow centrifugal pump (Maquet GmbH, Rastatt, Germany) and a Quadrox² membrane oxygenator (Maquet GmbH, Rastatt, Germany). Via short tubings, the venous line was directly connected to a centrifugal pump, which passes the oxygenator and, via the arterial line, returned to the patient. All components were from tip-to-tip Biolene coated (Maquet GmbH, Rastatt, Germany). Priming volume of the system was 500 ml of sodium chloride 0.9% (this solution contents 14.4% HES). Depending on the patient’s hemostability the amount of prime will be returned to zero by starting MECC. When MECC starts, the nasopharyngeal temperature will be maintained at 33—34 °C. Acid—base management during mild hypothermia was monitored with alpha-stat and the cardiac index was kept between 2.0 and 2.4 l min⁻¹. Preservation of the heart was performed using a modified Calafiore-technique (warm blood cardioplegia with 30 ml potassium chloride 2 mol l⁻¹ and 6 ml magnesium sulfoxide 1 mol l⁻¹); [10].

2.5. Surgical procedure

In the groups, median sternotomy and harvesting of the internal mammary artery were followed by full exposure of the coronary artery branches to be revascularised. All patients in the groups were placed in the Trendelenburg position less than 20° tilt. The revascularization in the OPCAB group was performed on the beating heart using the Medtronic Octopus device (Medtronic³⁸, Minneapolis, USA). Temporary coronary occlusion was achieved using Acland clamps (S&T Marketing Limited, Neuhausen am Rheinfall, Switzerland), while no shunts were used. For the MCABG and CCABG patients received standardized postoperative care. Propofol was stopped and tracheal extubation is accomplished when the patient was hemodynamically stable, responsive and cooperative, Fio₂ 50%, PaO₂ > 11 kPa, pH 7.3, core temperature 36 °C and without excessive chest tube drainage. Postoperative pain relief was achieved with intravenous morphine (0.5 mg kg⁻¹ h⁻¹) and paracetamol, 1000 mg administered rectally three times daily.

2.3. Perfusion technique CCABG

The ECC circuit was composed of a roller pump (Sarns, USA), a hollow fiber polypropylene oxygenator with an incorporated cardiotorax reservoir (Cobe Optima Xp², Cobe Cardiovascular Inc., Arvada, USA) and plasticized polyvinyl chloride tubing. The pump was primed with 1.5—2 l of 50% homemade primer solution. The heart was protected with topical cooling, together with 1000 ml of cold cardioplegic solution based on hydroxyethyl starch (HES: 60 g l⁻¹; Fresenius AG) and containing 2 mmol l⁻¹ D-l-magnesium aspartate, 4 mmol l⁻¹ procaine hydrochloride, 0.5 mmol l⁻¹ calcium hydrochloride, 25 mmol l⁻¹ sodium chloride, 5 mmol l⁻¹ potassium chloride, 10 mmol l⁻¹ glucose, 200 mmol l⁻¹ mannitol and 20 mg dexamethasen per liter with an osmolarity of 320 mosm l⁻¹, pH 7.4 [19].

2.2. Anesthetic technique

Premedication consisted of temazepam (10 mg), given orally 2—3 h before the procedure started. Anesthesia consisted of a balanced opiate-based general anesthesia technique. Induction took place by means of infusion of propofol (1.5—2 mg kg⁻¹), pancuronium (0.1 mg kg⁻¹) and fentanyl (7 mg kg⁻¹). Anesthesia was maintained with nitrous oxide in oxygen and continuous propofol infusion (10—20 ml h⁻¹), remifentanil (0.25—1 mg kg⁻¹) and pancuronium as required. Hypertension was treated with vasodilators (nitroglycerin and nitroprusside). A mean arterial pressure of 60 mmHg or higher and a heart rate less than 70 beats per min was maintained. Heparin was administered at 300 IU kg⁻¹ for the on-pump CABG group and 150 IU kg⁻¹ for the off-pump CABG group. After all anastomoses were completed, heparin was neutralized with protamine chloride 120 IU/150 IU. All

significantly. As a consequence reducing volume shifts can be accomplished. Using MECC a reduced systemic inflammation and oxidative stress have already been reported [11,12].

Also off-pump CABG has become a well accepted and safe technique. Short-term and mid-term angiography follow-up studies of off-pump constructed grafts show comparable results to the conventional technique [13]. Temporary occlusion of a coronary artery however, induces regional ischemia, and whether the damage is mild or moderate depends on the existence or ability to develop coronary collateral circulation and further technical aspects, e.g. the use of coronary occlusion or shunts.

Measurements of parameters for oxidative stress and antioxidant activity are well accepted methods to detect the extent of ROS generation [14,15]. Their involvement is known to be substantial when the CCABG is used [16]. Oxidative stress studies show a significant reduction of malondialdehyde levels during OPCAB and MCABG as compared to the CCABG technique [14].

There are only few data that show the myocardial contribution of oxidative stress in elective CABG in a prospective setting [17,18]. In this study we want to investigate the influence of the use of three different techniques of CABG in the occurrence of oxidative stress in the heart. Furthermore we studied the relationship between myocardial oxidative stress and myocardial cell injury by measuring cardiac biomarkers.

2. Materials and methods

2.1. Patients

Thirty patients, 22 men and 8 women undergoing elective coronary bypass surgery were consecutively enrolled and randomized in three equal groups of 10 patients between conventional cardiopulmonary bypass (CCABG), using the MECC system (MCABG) and off-pump surgery (OPCAB). Exclusion criteria were: age < 65 years, redo CABG or less then three-vessel disease. The medical ethical committee of the Sint Antonius Hospital approved this study and written informed consent was obtained. The study had a prospective design.

2.2. Anesthetic technique

Premedication consisted of temazepam (10 mg), given orally 2—3 h before the procedure started. Anesthesia consisted of a balanced opiate-based general anesthesia technique. Induction took place by means of infusion of propofol (1.5—2 mg kg⁻¹), pancuronium (0.1 mg kg⁻¹) and fentanyl (7 mg kg⁻¹). Anesthesia was maintained with nitrous oxide in oxygen and continuous propofol infusion (10—20 ml h⁻¹), remifentanil (0.25—1 mg kg⁻¹) and pancuronium as required. Hypertension was treated with vasodilators (nitroglycerin and nitroprusside). A mean arterial pressure of 60 mmHg or higher and a heart rate less than 70 beats per min was maintained. Heparin was administered at 300 IU kg⁻¹ for the on-pump CABG group and 150 IU kg⁻¹ for the off-pump CABG group. After all anastomoses were completed, heparin was neutralized with protamine chloride 120 IU/150 IU. All
groups standard cannulation with a DLP (Medtronic®, Minneapolis, USA) arterial cannula in the ascending aorta and a DLP two stage cannula in the right atrium were used. Postoperatively, patients were weaned from the ventilator as soon as possible (between 0 and 4 h for the OPCAB group, and between 4 and 8 h for the MCABG and CCABG groups). In all patients a standard retrograde cardioplegia cannula (Edwards Life Sciences®, Irvine, California, USA) was positioned in the coronary sinus for sampling blood.

In all techniques blood was collected from the surgical field in a cell-saving device (Cobe BRAT2®) and re-infused after washing and centrifugation.

2.6. Sample collection and analyses

Samples were obtained from a retrograde cardioplegia catheter, placed in the coronary sinus (Cs) representing the myocardium and from the arterial line (ascending aorta (Aa)), representing the global body, collected in tubes containing EDTA or lithium.

Time points for collecting blood samples

T0: induction of anesthesia
T1: start ECC/first anastomose (OPCAB)
T2a: reperfusion 1 min (clamp off, in OPCAB, last distal finished)
T2b: reperfusion 5 min
T2c: reperfusion 10 min
T3: arrival at ICU
T4: 6 h ICU
T5: 8:00 a.m. first day postoperative

The samples were immediately placed on ice and delivered to the laboratory within 15 min after collection. Plasma was obtained by centrifugation (lithium heparin blood) at 2200 × g for 10 min and the samples were kept frozen at −80°C until analysis. Routine analyses were performed within 1 h.

Pre- and postoperatively echocardiography was performed in all study patients with regard to LV function.

2.7. Assays

Malondialdehyde and allantoin measurements were performed as described by Gerritsen et al. [21]. Hemoglobin, hematocrit, platelets and leukocytes were determined on a Coulter STKS (Beckman Coulter Nederland B.V., Mijdrecht, the Netherlands). Uric acid, creatinine kinase, creatinine kinase MB-iso-enzyme and troponin T were determined according to the manufacturer’s instructions on a Cobas Integra 700 analyzer (Roche, Kayseraugst, Switzerland). CK-MB was measured only in case of CPK higher 185 IU.

HFABP measurements were performed as described by Morariu et al. [22] ELISA (Hycult Biotechnology, Uden, The Netherlands). All samples were adjusted for hemodilution [23].

2.8. Data analysis and statistical considerations

Data analyses were performed using SPSS software version 14.0. Results were reported as mean (±SD or SEM). Areas under curves (AUC) were calculated using the trapezium method. Significant changes within or between groups (p < 0.05) were determined by ANOVA followed by the post-hoc Tamhane’s T2 test. Comparisons between groups were carried out using the Fisher’s exact tests or Pearson chi-square test if appropriated.

3. Results

3.1. Patients

The patients included were admitted for elective coronary revascularization of the heart. The preoperative clinical and surgical data are presented in Tables 1 and 2 which show no significant differences with respect to gender, age, severity of coronary disease, diabetes mellitus, NYHA functional class, left ventricle function extent of vessel disease, and preoperative laboratory analysis. For the surgical data, the groups were also similar with respect to the number and distribution of distal anastomoses. In all study groups, no hospital mortality, neurological accidents, myocardial infarction or acute renal failure occurred. No ECG changes were revealed. There was no significant difference in use of inotropic support, ventilation times or intensive care stay.

3.2. Malondialdehyde assay

The MDA levels in the OPCAB group, plotted as AUC, were higher for the Cs samples compared to the Aa samples (p = 0.02, Fig. 1A and B). The AUC MDA—Cs were significantly higher in case of CPK higher 185 IU.

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>CCABG</th>
<th>MCABG</th>
<th>OPCAB</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>n.s.</td>
</tr>
<tr>
<td>Male/female</td>
<td>6/4</td>
<td>6/4</td>
<td>9/1</td>
<td></td>
</tr>
<tr>
<td>Age (year)</td>
<td>70.9 ± 9.6</td>
<td>69.5 ± 8.0</td>
<td>70.9 ± 8.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>Hypertension</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>n.s.</td>
</tr>
<tr>
<td>Diabetes I or II</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Angina class</td>
<td></td>
<td></td>
<td></td>
<td>n.s.</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>X—VD</td>
<td></td>
<td></td>
<td></td>
<td>n.s.</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>LV-function</td>
<td></td>
<td></td>
<td></td>
<td>n.s.</td>
</tr>
<tr>
<td>Good</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>1.0 ± 0.0</td>
<td>1.0 ± 0.0</td>
<td>1.2 ± 0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Euro score</td>
<td></td>
<td></td>
<td></td>
<td>n.s.</td>
</tr>
<tr>
<td>≤3</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>&gt;3 ≤5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>&gt;5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Data are presented as mean ± standard deviation; LV-function: left ventricle, X—VD: n vessel disease.
lower for the MCABG group compared to the CCABG and the OPCAB group \((p = 0.04, \text{ respectively}, p = 0.03; \text{ Fig. 1A})\).

Besides this, the CCABG group had significantly higher MDA levels in the Cs as well as in the Aa compared to the MCABG group respectively to the OPCAB group \((p = 0.02 \text{ and } p < 0.001, \text{ respectively}, p = 0.19 \text{ and } p < 0.001; \text{ Fig. 1})\).

### 3.3. Allantoin/uric acid (A/U) ratio

In the OPCAB and MCABG groups the ratio in all specimens was not measurable. Within the CCABG group, there was a significant increase in both Cs and Aa during reperfusion \((p < 0.001 \text{ and } p < 0.001).\) During all time points the A/U ratio for Sc and Aa remained significant increased compared to the OPCAB and MCABG \((p < 0.001; \text{ Fig. 1C and D})\).

### 3.4. Heart enzymes

#### 3.4.1. CPK and CK-MB

From baseline till 6 h ICU and day 2 the CPK increased significantly within the MCABG and the OPCAB group \((p = 0.02 \text{ and } p = 0.01, \text{ respectively}, p < 0.001 \text{ and } p = 0.005).\) Thereby from arrival to the ICU until 6 h in the ICU and to day 2 the CPK increased significantly within the OPCAB group \((p = 0.005 \text{ and } p = 0.01).\) However, at all time points the highest CPK levels were measured in the CCABG group \((\text{Fig. 2A})\).

For CK-MB there was no significant difference between or within the groups at consecutive time points. However, from arrival ICU until day 2 the highest CK-MB levels were measured in the CCABG group \((\text{Fig. 2B})\).

#### 3.4.2. HFABP

From baseline until reperfusion the HFABP increased significantly within the MCABG and OPCAB group \((p = 0.03, \text{ respectively}, p = 0.01).\) However, at reperfusion and arrival ICU the highest levels were measured in the CCABG group \((\text{Fig. 2C})\).

#### 3.4.3. Troponin T

In the OPCAB group there were significant increases from arrival ICU until 6 h ICU \((p = 0.04).\) Between the groups we found no significant different levels; however after arrival at ICU and at 6 h ICU stay the highest levels were found in the CCABG group \((\text{Fig. 2D})\).

### 4. Discussion

In this prospective randomized study consisting of three-vessel CABG patients we measured oxidative stress and the myocardial contribution to it, stated as myocardial oxidative stress. Additionally we measured myocardial cell injury by means of heart enzymes (CPK, CK-MB, HFABP, and troponin T) during three different techniques for coronary artery bypass surgery.

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**Table 2**

<table>
<thead>
<tr>
<th>Variable</th>
<th>CCABG</th>
<th>MCABG</th>
<th>OPCAB</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBP time (min)</td>
<td>100.5 ± 25.6</td>
<td>85.1 ± 17.6</td>
<td>6.0 ± 0.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cross-clamp time (min)</td>
<td>65.5 ± 14.1</td>
<td>61.5 ± 13.0</td>
<td>0.0 ± 0.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Grafts per patients</td>
<td>4.3 ± 1.1</td>
<td>3.9 ± 0.7</td>
<td>3.9 ± 1.0</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Data are presented as mean ± standard deviation.
Results showed consistently higher oxidative stress parameters in the coronary sinus when compared to samples taken from the peripheral blood during early reperfusion indicating that the heart is an important contributor to oxidative stress. Significantly lower parameters of oxidative stress parameters were observed in the MCABG group. In patients undergoing off-pump CABG as compared to patients with CCABG a reduction of oxidative stress has been reported before [14]. However in these studies, parameters of oxidative stress measured either in plasma or in the urine only gave an impression of global body ischemia and cell injury [14,16]. By taking blood samples out of the coronary sinus perioperatively, myocardial oxidative stress was studied.

4.1. Myocardial injury and heart enzymes

In this study postoperatively the lowest CPK levels were measured in the MCABG group compared to both other study groups. As a consequence of cell injury caused by oxidative stress heart enzymes can leak through the cell membrane and can be detected in the peripheral bloodstream. The increase of heart enzymes caused by myocardial damage, is consistent with the extent of oxidative stress found in the study groups.

Consistent with these findings similar curve shapes are found for the other heart enzymes, e.g. CK-MB, HFABP, and troponin T only differing in release over time, showing lowest non-significant levels in the MCABG group as compared to the OPCAB and CCABG group.

4.2. The important differences between the techniques

Either local or systemically different effects of the techniques used can explain the differences found. The study results showed that the myocardial protective protocols are important contributors to oxidative stress.

Fig. 2. Peri- and postoperative CPK levels (A), and CK-MB levels (B), and HFABP levels (C), and troponin T levels (D) represented as mean ± SEM.

Firstly, in the CCABG group myocardial protection is based on ischemic hypothermic reduction of cell metabolism whereas in both other techniques myocardial protection is based on more physiologic strategies [24].

Secondly, the composition of the extracorporeal circuit differs:

- in coating. The tubings of the CCABG circuit are not coated with heparin in contrast to the MCABG circuit. It is well known that heparin coated tubings cause less inflammation [24]. Furthermore, it was found by our group that avoiding conventional ECC significantly reduces oxidative stress [14,16].

- in volume. The volume of the CCABG circuit is larger. Hemodilution is substantially increased in the CCABG group in contrast to the MCABG and OPCAB group. It appears that the main advantage of MCABG is the reduction of the blood surface contact area due to a shorter circuit [25].

Thirdly, the use of roller pumps versus centrifugal pumps or an open reservoir versus closed circuit or type of oxygenator does interfere with inflammation and hemostasis. Especially the mechanic trauma caused by the roller pump, used in the CCABG technique, initiates hemolysis and activation of hemostasis [26].

Finally, considering all techniques presented in this study myocardial protection seems to be the most important factor causing oxidative stress which correlates with an increase in biomarkers of myocardial injury which correlates with an increase in biomarkers of myocardial cell injury.

The following pathophysiological pathway can mainly explain ischemia of the myocardium caused by cross-clamping of the ascending aorta in the conventional CABG technique. Despite the cold crystalloid cardioplegia an anaerobe degradation of ATP into hypoxanthine takes place in the heart. During
the MCABG and OPCAB techniques myocardial protection was based on intermittent oxygenation. During reperfusion, oxygen is delivered and the xanthine oxidoreductase pathway is activated metabolizing hypoxantine into xanthine and uric acid thereby generating ROS. The concentration of uric acid, (an end product of the purine metabolism), increases during reperfusion after an ischemic period [27] and is a parameter of oxidative stress and can act as an antioxidant. When this process takes place uric acid is converted into allantoin.

In this study mildest myocardial oxidative stress indicated by the lowest MDA levels was measured in the Cs of the MCABG group. Thereby concentrations of allantoin and uric acid expressed as A/U ratio were not detected during reperfusion in the MCABG and the OPCAB group. On the contrary the A/U ratio in the CCABG group was significantly increased. As a consequence of this result the ROS generation was also markedly increased. This amount of ROS attacks the polyunsaturated fatty acids of the cell membrane generating MDA. Our study result confirms this pathway by the measurement of highest levels of MDA in the CCABG group.

4.3. Clinical findings

In the small groups studied no significant differences were found in ECG and echocardiographic results. We are well aware that the ischemic insult in these relatively low risk patients is only mild and that ECG findings are a very rough parameter to detect mild myocardial cell injury. A transesophageal echocardiogram on the first postoperative day can detect major myocardial damage. To detect contractile dysfunction more accurately it would be better to perform transesophageal echocardiography (TEE) to look for real-time changes in absolute segmental wall motion using the transgastric short axis plane [28].

The clinical consequences of our findings remain uncertain. We only found biochemical differences between three different CABG techniques. The small sample size and the fact that only low risk patients for elective CABG were included make it even more difficult to draw conclusions. Furthermore to detect differences in contractility we should have used more sensitive monitoring. However the biochemical differences found justify more future research to evaluate if in more vulnerable patients and or in patients with more complex surgery the biochemical differences found could have clinical implications.

5. Conclusions

Performing CABG using minimized extracorporeal circuit with blood cardioplegia (MCABG) showed significantly lower levels of global and myocardial oxidative stress as well as cell injury. Caution has to be taken for the small sample size and further research has to be done with larger groups, evaluating morbidity and mortality.

6. Limitations

We are well aware that the use of blood cardioplegia can have contributed to the observed differences found. Also we liked to compare the MCABG with the CCABG technique as is routinely used with very good results in our clinic.

References


