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Minimized Cardiopulmonary Bypass Combined with a Smart Suction Device: The Future of Cardiopulmonary Bypass?

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ABSTRACT

Objective. The standard heart-lung machine is a major trigger of systemic inflammatory response and the morbidity attributed to conventional extracorporeal circulation (CECC) is still significant. Reduction of blood–artificial surface contact and reduction of priming volume are principal aims in minimized extracorporeal circulation (MECC) cardiopulmonary bypass systems. The aim of this paper is to give an overview of the literature and to present our experience with the MECC–smart suction system.

Methods and Results. At our institution, 1799 patients underwent isolated coronary artery bypass grafting (CABG) surgery, 1372 with a MECC–smart suction system and 427 with CECC. All in-hospital data were assessed and the results were compared between the 2 groups. Patient characteristics and the distribution of EuroSCORE risk profile in our collective were similar between both groups. Average age in the MECC collective was 67.5 ± 11.4 years and average EuroSCORE was 5.0 ± 1.5. Average number of distal anastomoses was similar to the average number encountered in patients undergoing CABG surgery with CECC (3.3 ± 1.0 for MECC versus 3.2 ± 1.1 for CECC; P = ns). Myocardial protection is superior in MECC patients with lower postoperative maximal cTnI values (11.0 ± 10.8 µmol/L for MECC versus 24.7 ± 25.3 µmol/L for CECC; $P < .05$). Postoperative recovery was faster in patients operated on with the MECC–smart suction system and discharge from the hospital was earlier than for CECC patients (7.4 ± 1.9 days for MECC versus 8.8 ± 3.8 days for CECC; $P < .05$).

Conclusions. The MECC–smart suction system is a safe perfusion technique for CABG surgery. In patients operated on with this system, the clinical outcome seems to be better than in patients operated on with CECC. This promising and less damaging perfusion technology has the potential to replace CECC systems in CABG surgery.

INTRODUCTION

Conventional extracorporeal circulation (CECC) is state of the art in cardiac surgical procedures. Potential side effects related to the use of CECC, mainly stimulation of a global inflammatory response and induction of coagulation cascade, are still a matter of debate [Roach 1996; Chang 2002; Levy 2003], despite the fact that CECC is a safe and established technique with a low mortality rate [Gundry 1998; Pentilä 2001].

Several minimized extracorporeal circulation (MECC) systems are available on the market. Most of these systems are combined with a cell-saver unit, which may partly affect inflammatory response and coagulation cascade [Liebold 2006; Remadi 2006]. However, several studies have also shown that in the setting with a cell-saver unit, myocardial damage can be reduced [Skrabal 2006], inflammatory response is less pronounced [Remadi 2006], intrinsic endothelial damage is diminished [Skrabal 2006], and cerebral tissue oxygenation is preserved and cerebral microembolization is reduced [Liebold 2006]. Despite these observations in small collectives, the clinical benefits of minimized extracorporeal bypass systems are still controversial [Wiesenack 2004; Abdel-Rahmann 2005]. As outlined by Remadi and colleagues [2006], surgical exposure in MECC patients is similar to CECC patients, despite a volume-constant perfusion.

Priming volume reduction leads to a significant decrease in intraoperative transfusion requirement. This aspect is of increasing interest, as it has been shown that transfusion of red blood cell units after coronary artery bypass grafting (CABG) surgery adversely affects postoperative outcome.

At our institution, MECC consists of a centrifugal pump, a membrane oxygenator, and an integrated optoelectrical suction system. Coronary procedures with the MECC system are performed without a cell-saver system. The circuit has a very short tubing length and the cardiotomy reservoir and the conventional suction device have been eliminated. These simplifications in the perfusion circuit have helped to decrease the priming volume from 1800 mL to 600 mL, reducing the associated negative effects. We have recently shown that

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myocardial markers are significantly lower in patients who underwent CABG surgery with the MECC–smart suction system [Immer 2005] in comparison to patients operated on with the CECC system. One may assume that the smart suction device affects coagulation cascade and inflammatory response less, as blood-air contact is reduced in this setting, where suction is applied, only when the optoelectrical tip of the device detects blood.

The aim of the present paper is to give an overview from the literature and to present our clinical experience with the MECC–smart suction system.

MATERIALS AND METHODS

Patients

At our institution, 1799 patients underwent primary isolated CABG surgery using the MECC–smart suction or the CECC system and were prospectively studied. All other CABG operations (combined with valve surgery and/or aortic surgery) and redo CABG were excluded except for selected patients who underwent a closure of a patent foramen ovale or an atrial septal defect, which is safely feasible with the MECC–smart suction system. In our study, 1372 consecutive patients (76.3%) underwent CABG surgery with the MECC–smart suction system and were compared to 427 patients (23.7%) operated on with CECC.

All in-hospital data for patients undergoing CABG at our institution have been assessed, and data from the MECC–smart suction system collective have been compared to patients who underwent surgery with the CECC system.

Operative Technique

The priming volume of the MECC is 600 mL. The minimized cardiopulmonary bypass (MECC, Jostra, Hirrlingen, Germany) is driven by a centrifugal pump without a cardiotomy reservoir. In our setting, air is detected by an ultrasound probe, placed at the highest level of the venous cannula. If air is detected within the MECC, perfusion stops immediately. Until now, this system detected 1 air emboli in 1372 patients operated on with the MECC system and removal of the air was successful. To prevent additional damage to blood cells in the MECC group, a new suction device Cardiosmart (Cardiosmart, Muri, Switzerland) was integrated in the system. Aspiration of blood is controlled by an optoelectrical sensor at the tip of the suction cannula and the suction mechanism is only started when the tip of the suction cannula is in direct contact with blood. The aspirated blood is directly retransfused into the venous line of the circuit and therefore no additional suction pump or reservoir is required.

Surgery was performed through median sternotomy. After low-dose heparinization (MECC, 200 iU/kg; CECC, 400 iU/kg), cardiopulmonary bypass was conducted with an arterial cannula in the ascending aorta, and a 2-stage venous cannula was inserted through the right atrium or bicaval cannulation was performed in case of a patent foramen ovale or an atrial septal defect. For MECC perfusion, the venous cannula was secured with 2 snares to ensure proper fixation and stabilization of the cannula and to minimize air aspiration. One hundred mL of crystalloid cardioplegia (Cardioplex) were injected after cross clamping the aorta and only repeated when mechanical activity of the heart was observed, which was the case in only 3 patients.

Statistical Analysis

Data are presented as mean values ± their first standard deviation. A Mann-Whitney U test and χ^2 test were used for comparison between groups of continuous and nominal variables, respectively. A P value less than .05 was considered significant.

RESULTS

Patient characteristics and outcomes are shown in the Table. In the MECC group, the average age was 67.5 ± 11.4 years and 78% of the patients were male. The number of distal anastomosis was 3.3 ± 1.0 (range, 1 to 6). The average EuroSCORE was 5.0 ± 1.5. Twenty-seven patients died within 30 days after surgery, which leads to an overall mortality of 2.0%, compared to 2.8% in the CECC group (P = ns). Morbidities are displayed in the Table. Perioperative cerebrovascular incidents with a persistent neurological deficit were encountered in 10 patients (0.7%), compared to 10 patients (2.3%) in the CECC group (P ± .07).

DISCUSSION

CABG with CECC is an established and safe procedure; however, off-pump myocardial revascularization has gained some popularity in the last decade. Nevertheless, despite some advantages, off-pump myocardial revascularization is controversial, mainly because of less optimal surgical conditions, which may result in incomplete revascularization or unsatisfactory procedures. In a large trial, Remadi and colleagues outlined that surgical exposure in patients undergoing CABG surgery with the MECC system is excellent and allows surgeons to perform surgery similar to that for patients operated on with CECC [Remadi 2006]. An optimal exposure in an arrested heart in MECC patients allows surgeons to perform distal anastomoses safely and with high quality, which is one of the aspects of controversy concerning patients undergoing beating heart surgery. Several positive effects on inflammatory markers, transfusion requirements, myocardial protection, and cerebral perfusion in small collectives of patients undergoing MECC surgery in comparison to CECC have been reported [Abdel-Rahmann 2006; Liebold 2006; Remadi 2006; Skrabal 2006]. However, a clear clinical benefit could not be documented until now by comparing MECC with CECC surgery [Wiesenack 2004; Abdel-Rahmann 2005]. Our clinical experience now includes data for 1799 consecutive patients who underwent isolated CABG surgery, of which 1372 (76.3%) underwent surgery with the MECC– smart suction system. As reported previously [Immer 2005], patient characteristics do not differ between the 2 collectives. Mortality is similar in both groups. Assessed morbidities were not different in the 2 collectives; however, there was a trend toward a decrease in cerebrovascular incidents with persistent neurological deficit in patients operated on with the

Data of Patients Who Underwent Coronary Artery Bypass Grafting Surgery with Conventional Extracorporeal Circulation (CECC) Cardiopulmonary Bypass (n = 427) or Minimal Extracorporeal Circulation (MECC) Cardiopulmonary Bypass (n = 1372)*

	CECC	MECC	*P*
No. of patients	427 (23.7%)	1372 (76.3%)	
Mean age, y	68.2 ± 9.5	67.5 ± 11.4	ns
Preoperative ejection fraction, %	54.8 ± 16.8	55.8 ± 15.5	ns
EuroSCORE	4.7 ± 1.3	5.0 ± 1.5	ns
Intraoperative			
No. of distal anastomoses	3.2 ± 1.1	3.3 ± 1.0	ns
Duration of ACC, min	50.6 ± 22.2	44.2 ± 20.1	ns
Postoperative			
Duration of ventilation, h	17.4 ± 24.9	11.8 ± 7.3	<.05
ICU stay, h	30.9 ± 35.2	22.6 ± 6.3	<.05
Postoperative weight increase, %	4.4 ± 2.6	2.9 ± 2.4	<.05
Transfusion of EC	119 (31.9%)	98 (9.3%)	<.05
Average EC/patient	2.79	0.27	<.05
Inotropic support, 6 to 12 h off ECC	100 (23.3%)	145 (8.0%)	<.05
In-hospital mortality	12 (2.8%)	27 (2.0%)	ns
Atrial fibrillation	169 (39.4%)	159 (11.6%)	ns
Cerebrovascular accident	10 (2.3%)	10 (0.7%)	ns
Length of stay, d	8.8 ± 3.8	7.4 ± 1.9	<.05
Myocardial Markers†			
cTnI, 6 h	18.8 ± 21.9	7.9 ± 6.1	<.05
cTnI, 12 h	19.9 ± 15.3	10.2 ± 7.8	<.05
cTnI, 24 h	24.7 ± 25.3	11.0 ± 10.8	<.05

*Data are displayed as absolute values or mean values ± 1 SD. ns indicates not significant; ACC, aortic cross-clamping time; ICU, intensive care unit; EC, erythrocyte concentrate (400 mL); cTnI, cardiac troponin I; ECC, extracorporeal circulation time.

†Patients with preoperative cTnI elevation and/or perioperative myocardial infarction have been excluded.

MECC system, compared to patients who underwent surgery with the CECC system. This observation is probably related to the higher perfusion pressure during the on-pump period in MECC patients and to the fact that, in MECC surgery, cerebral tissue oxygenation is preserved and cerebral microembolizations are reduced, as described by Liebold and colleagues [2006]. The higher perfusion pressure is probably related to the fact that the patient acts as one reservoir and therefore perfusion physiology is different than in a CECC system.

Reduction of myocardial markers, as described by our study group and others [Pentilä 2001; Immer 2005], and less pronounced inflammatory response [Skrabal 2006] may finally contribute to the general observation in our collective that the early postoperative course in MECC patients is improved, compared to CECC patients. In our setting, cardiac arrest on-pump is achieved with crystalloid cardioplegia in both groups. In the CECC group, crystalloid cardioplegia is combined with cold blood cardioplegia, as mechanical activity occurs much earlier in CECC patients.

We are aware that these data are obtained in a nonrandomized collective. However, preoperative and intraoperative data are similar in both groups and the distribution of EuroSCORE risk stratification revealed no differences between the 2 collectives. However, clear benefits in transfusion requirement, incidence of atrial fibrillation, and myocardial markers could be confirmed in this large collective, and these aspects may contribute to the improved clinical outcome observed in daily routine in patients undergoing CABG surgery with the MECC system.

Minimal cardiopulmonary bypass using the MECC–smart suction system is a very promising technique because it reduces the transfusion requirement and maintains central and peripheral perfusion, which combines the advantages of on-pump surgery (complete revascularization, safe anastomoses, and maintained central and peripheral perfusion) with reduced pump-related systemic side effects that result in an improved clinical outcome in patients undergoing CABG surgery.

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