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# Intensive care after minimally invasive and conventional coronary surgery: a prospective comparison

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**Abstract** *Objective*: The purpose of this study was to compare the intensive care course of patients after minimally invasive coronary surgery to conventional coronary artery bypass grafting.
*Design:* Prospective observational study.
*Setting:* Intensive care unit of a university hospital.
*Patients and participants:* One hundred and five patients with two-vessel disease consecutively scheduled for elective coronary bypass surgery were enrolled.
*Interventions:* Two techniques of revascularization were performed: the Octopus procedure via median sternotomy without cardiopulmonary bypass ($n = 52$) and conventional coronary artery bypass grafting CABG ($n = 53$).
*Measurements and results:* Three major categories describing the patients' postoperative course were defined: (1) clinical and laboratory findings, i.e., transfusion rate, catecholamine support, duration of ventilation, Simplified Acute Physiology Score II (SAPS II), serum levels of cardiac enzymes and lactic acid; (2) postoperative complications, i.e., incidence of myocardial infarction (MI), atrial fibrillation (AF), and neurological deficits; (3) this category was defined as "the extent of care" as represented by the Therapeutic Intervention Scoring System (TISS), and the length of stay in the ICU and in the hospital. In the Octopus group significantly lower figures were noted for duration of ventilation [6.1(5.5/9.5) vs 10.2(8.2/11.8) h], cardiac enzymes {CK-MB-Mass [5.1(2.0/8.3) vs 31.3(21.4/39.3) ng/ml], and lactic acid [2.0(1.5/3.3) vs 3.2(2.2/6.5) mmol/l]}, incidence of AF (2/52 vs 9/53), and neurological deficits (0/52 vs 4/53), TISS score [72(44/83) vs 84(73/93)], LOS in the ICU [2(1/2) vs 2(2/2) days], and in the hospital [6(5/9) vs 9(8/12) days]. Catecholamine support, SAPS II scores, and incidence of MI of each group did not differ significantly.
*Conclusions:* Off-pump coronary surgery via the Octopus technique was superior to conventional CABG regarding the course of patients in the early postoperative period. This implies benefits for the patients and the entire healthcare system.

**Key words** Minimally invasive coronary surgery (MICS) · Octopus · Coronary artery bypass grafting (CABG) · Postoperative period · Outcomes

## Introduction

Since its invention in the early 1980s, minimally invasive coronary surgery (MICS) gained noticeable importance [1]. A main advantage of MICS is the avoidance of cardiopulmonary bypass (CPB) with its implications and side effects, i.e., systemic heparinization, cannulation and clamping of the aorta, cardiac arrest with cardioplegia, and derangement of the hemostatic system [2]. There are two major types of MICS currently being performed: the minimally invasive direct coronary artery bypass (MIDCAB) through a small left thoracotomy, and the off-pump coronary artery bypass through a median sternotomy (OPCAB) carried out particularly with the Octopus stabilizing system. The MIDCAB approach is predominantly used to serve patients with one-vessel disease especially in the case of a proximal stenosis of the LAD. The Octopus technique is used in patients who need two or more grafts, as median sternotomy offers a more feasible surgical approach to the RCA and the RCX.

For all that, CABG, the "gold standard" of surgical coronary revascularization, is a procedure that provides excellent surgical results and is associated with a low mortality rate [3]. Thus, it is obviously difficult for novel approaches to compete with this standard technique [4]. The new procedures, therefore, should obtain similar surgical results, a lower incidence of complications, and an equivalent long-term outcome.

Diegeler et al. demonstrated that the patency rate of the grafts implanted by means of the minimally invasive techniques was comparable to the one after CABG in early postoperative angiographies [5]. To elucidate the role and the potential benefits of the new surgical techniques to the patients and the health care system, the evaluation of data from the early postoperative period is of utmost importance.

The aim of this prospective study was to compare the influence of MICS using the Octopus technique on the postoperative ICU course of patients with two-vessel disease to conventional CABG.

'Postoperative course' after coronary revascularization is obviously not a well-defined term. Thus, we chose three major features that are commonly accepted to be descriptive for this early phase of recovery:

First, we gathered a series of important clinical findings including the need for transfusions and circulatory and ventilatory support, augmented by three diagnostic parameters, i.e., postoperative Simplified Acute Physiology Score II (SAPS II), and serum levels of cardiac enzymes and lactic acid.

Second, we compared the incidence of postoperative complications such as postoperative myocardial infarction (MI), atrial fibrillation (AF), and neurological deficits.

Third, the extent of care was evaluated by means of the Therapeutic Intervention Scoring System (TISS), the length of stay (LOS) in the ICU, and the LOS in the hospital.

## Materials and methods

### Subjects

After institutional review board approval and written informed consent, 105 consecutive patients scheduled for elective coronary surgery for two-vessel disease were enrolled in this prospective observational study between April 1998 and January 2000. The diagnosis was established by a cardiologist according to standard coronary angiography. Treatment with percutaneous transluminal coronary angioplasty (PTCA) was not feasible or was unsuccessful.

The patients were allocated to the two different procedures by the unanimous decision of a team consisting of two equally highly experienced senior physicians (surgeons 1 and 2) of the department of cardiac surgery, who performed all the operations for this study. Two procedures were performed: the Octopus system [6] ($n = 52$), and conventional CABG ($n = 53$). Patients assigned for Octopus had to meet the following criteria: no combined valvular and coronary artery disease, coronary artery not less than 1.5 mm in diameter and not calcified at the proposed anastomosis site. Left main disease was an exclusion criterion for the Octopus procedure. Reduced ejection fraction was not an exclusion criterion nor were associated systemic diseases (e.g., diabetes mellitus, dialysis). To create a comparable cohort for the CABG group, only patients with two-vessel disease were prospectively identified. In addition, the patients in the CABG group had to meet the same criteria as those in the Octopus group except for the absence of left main disease. Patients with preexisting AF, which is still considered a relative contraindication for minimally invasive procedures [7], were excluded from the study.

### Surgery

Octopus: without CPB, performed through a median sternotomy using a suction device (Octopus Tissue Stabilizer Meditronic, Minneapolis, Minn., USA) for local immobilization of the myocardium, surrounding the anastomosis site. Interruption of the native coronary blood flow by clamping of the referring coronary artery was used [6].

CABG: with CPB, accomplished in mild hypothermia (31 ± 2 °C). During CPB a mean arterial pressure of > 60 mmHg was maintained by a minimal flow rate of 2.4 $l/m^2$ body surface area by means of the pump flows. Myocardial protection was provided by use of cold hyperkalemic cardioplegic solution (Brettschneider).

### Anesthesia

For premedication, patients received midazolam 0.1 mg/kg BW (body weight) 1 h before anesthesia. Induction was performed with midazolam (0.15–0.25 mg/kg BW), sufentanil (1–3 μg/kg BW), and pancuronium (0.1 mg/kg BW), and maintenance with sufentanil (1–2 μg/kg per hour) and with 0.3–1.0 vol% isoflurane. Management of postoperative pain was performed in all patients with continuous infusion of metamizol i.v. (200 mg/h) and boli of the opioid piritramide i.v. (2–5 mg) every 4–6 h if needed. For inotropic support epinephrine was used as the preferred drug.

**Table 1** Demographic data of the two study groups (*n.s.* not significant)

| Characteristics | Octopus ($n$ = 52) | CABG ($n$ = 53) | $P$ value |
|---|---|---|---|
| Age (years) | 62.0 (54.2/71/1) | 62.0 (57.0/68.0) | n.s. |
| Gender male:female *(n)* | 40:12 | 37:16 | n.s. |
| Preoperative ejection fraction (%) | > 50 | > 50 | n.s. |
| Preoperative myocardial infarction *(n)* | 13 | 17 | n.s. |
| Diabetes mellitus *(n)* | 21 | 19 | n.s. |
| Preoperative $\beta$-blockers *(n)* | 37 | 41 | n.s. |
| Duration of surgery (min) | 148 (125/156) | 133 (124/154) | n.s. |

Postoperative period

Fourteen parameters were assessed to evaluate the postoperative course of the patients in the three study groups:

- Number of packed red blood cells (PRBC) transfused. Transfusion trigger was an Hb concentration of less than 8.0 g/dl for "standard risk" patients and less than 10.0 g/dl for increased risk patients (e.g., history of ischemic cerebral event, incomplete revascularization or low cardiac output) [8]. Furthermore, the Hb concentration (g/dl) previous to the operation and at the time of discharge from the ICU was noted.
- Maximum dose of epinephrine (µg/kg per minute) to evaluate the basic inotropic support.
- Duration of ventilation in hours.
- The patients' postoperative status was assessed by means of the SAPS II score [9], and the lowest value within the first 24 h was noted.
- Maximum serum level of lactic acid was used as a marker of global tissue oxygenation [10].
- To detect cardiac ischemia, cardiac enzymes (CK-MB-mass concentration) were measured [11]. Blood samples were drawn after admission on the ICU and every 6 h until discharge from the ICU.
- Postoperative MI was detected by ECG or significant elevation of myocardial enzymes. Twelve lead ECGs were taken after admission on the ICU, after 6 h and subsequently every 12 h.
- The electrocardiographical diagnosis of postoperative MI required the presence of new Q waves lasting > 0.04 s or a reduction in R waves of more than 25 % in at least two contiguous leads, or development of new ST segment depression or elevation > 0.1 mV at 0.08 s after the J point lasting at least 24 h in at least two contiguous leads. Interpretation of the ECG was performed blinded by an independent cardiologist of the hospital. Reference values for the enzymatic diagnosis of perioperative MI after cardiac surgery were reported as CK-MB mass above 45 ng/ml [11].
- The incidence of AF, the most common arrhythmia after cardiac surgery, was evaluated by means of 12 lead ECGs [12].
- Incidence of neurological deficits (i.e., stroke and postoperative delirium) were documented by the physicians in the ICU according to a standard neurophysical examination [13]. Diagnosis of postoperative delirium was made according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM R III) [14].
- The ICU activities for each patient were documented every day based on the Therapeutic Intervention Scoring System (TISS score) [15]. The total sum of the values in each patient was recorded.
- LOS in the ICU given in days.
- LOS in the hospital given in days.
- Within 3 months after discharge from the hospital the patients' family doctors were asked to give us a brief report of their current physical status.

Statistical analysis

For statistical analysis we used the Mann-Whitney U-test for continuous variables and the chi-squared test for categorical variables. Liliefort's modifications of the Kolmogorov-Smirnov test for equality of the distributions of continuous variables were also performed. The Bonferroni-Holm test for multiple testing was applied.

All figures in this study are given as median and quartiles. A difference with a probability of $P < 0.05$ was regarded as statistically significant.

## Results

Of 105 enrolled patients, 52 underwent the Octopus procedure and 53, the CABG operation. The demographic data are depicted in Table 1. Surgeon 1 performed 24 Octopus and 29 CABG operations, while surgeon 2 performed 28 Octopus and 24 CABG operations. All patients received two grafts. A LIMA-to-LAD bypass was used in all patients. Conversion from Octopus to CABG was required in two patients (3.8 %). According to the "intention to treat" principle, they were analyzed within the group they had been assigned to. Comparison between Octopus and conventional CABG showed the following results (Table 2): perioperatively, the Octopus procedure required less transfusions (the preoperative Hb concentration did not differ significantly between the study groups). Presenting with comparable catecholamine support and SAPS II points, the Octopus group differed significantly from the CABG group in clinical and laboratory findings. More patients in the CABG group developed AF than in the Octopus group. No patient developed stroke or transitory ischemic attack, but the incidence of postoperative delirium did differ significantly between the study groups. The parameters used to represent the extent of care in the ICU showed consistently lower figures in the Octopus group. The reports of the patients' family doctors revealed the following results: none of the study patients had died and no clinical, laboratory or electrocardiographical signs of new myocardial ischemia were found in any of these patients.

**Table 2** Comparison of Octopus and CABG procedures. Values are expressed as the median (25/75 percentile). *LOS* Length of stay, *n.s.* not significant, *PRBC* packed red blood cells, *SAPS* Simplified Acute Physiology Score, *TISS* Therapeutic Intervention Scoring System

| Variable | Octopus (*n* = 50) | CABG (*n* = 53) | *P* value |
|---|---|---|---|
| PRBC *(n)* | 0 (0/1) | 0 (0/2) | < 0.05 |
| Hb at discharge (mg/dl) | 10.4 (10.2/10.8) | 10.2 (10.1/11.5) | n.s. |
| Epinephrine (μg/kg/min) | 0.0 (0.0/0.2) | 0.0 (0.0/0.4) | n.s. |
| Duration of ventilation (h) | 6.1 (5.5/9.5) | 10.2 (8.2/11.8) | < 0.05 |
| SAPS II (patients) | 24 (18.5/29) | 23 (18/30) | n.s. |
| CK-MB mass (ng/ml) | 5.1 (2.0/8.3) | 31.3 (21.4/39.3) | < 0.05 |
| Lactic acid (mmol/l) | 2.0 (1.5/3.3) | 3.2 (2.2/6.5) | < 0.05 |
| Myocardial infarction *(n)* | 0 | 1 | n.s. |
| Atrial fibrillation *(n)* | 2 | 9 | < 0.05 |
| Neurological deficits *(n)* | 0 | 4 | < 0.05 |
| TISS *(n)* | 72 (44/83) | 84 (73/93) | < 0.05 |
| LOS in ICU (days) | 2 (1/2) | 2 (2/2) | < 0.05 |
| LOS in hospital (days) | 6 (5/9) | 9 (8/12) | < 0.05 |

## Discussion

The role of minimally invasive techniques as a new option in coronary surgery is currently the focus of controversial discussion. Without doubt, it is the task of follow-up studies to find out whether the long-term outcome of minimally invasive coronary surgery will be superior to traditional surgery, but nevertheless the evaluation of short-term data should have an important impact on the ongoing discussion on this topic.

Therefore, the purpose of our study was to evaluate those aspects concerning the early postoperative period in attempt to discover whether one of the new techniques, i.e., the Octopus procedure, is of any benefit for the patients and perhaps for the entire health care system as well. This approach can be divided into three major parts:

First, is there any difference in the major clinical and laboratory findings between Octopus and CABG patients? Octopus and CABG patients did not differ according to their postoperative SAPS II score or need for catecholamine support. However, the perioperative need for transfusions was significantly lower in the Octopus group; the reason might be the avoidance of CPB and its consecutive hemostatic derangement [7]. The laboratory findings also support this hypothesis: markers of myocardial ischemia (CK-MB mass) were significantly lower in the Octopus group indicating a lesser extent of ischemic damage, despite temporary clamping of the corresponding coronary artery. Piper et al. [16] showed that reversible myocardial ischemia can cause a functional dysintegrity of the cell membranes and a consecutive release of cytosolic enzymes without subsequent cellular necrosis or a relevant decrement in function. Thus, the serum levels of the above mentioned cardiac enzymes may reflect the degree of perioperative cardiac protection even if no difference could be seen in the potential clinical sequelae, e.g., ECG changes.

Echocardiography is a more sensitive method in detecting expected temporary ventricular dysfunction, but routine TEE assessment would not have been available in all study patients during the study period.

Tissue hypoxia was attenuated in the Octopus group as demonstrated by lower levels of lactic acid. This might again be a consequence of avoiding CPB, as it is well known that inadequate perfusion of the bowel in the rewarming period during CPB is responsible for the major part of lactic acid measured in the sera of post-CABG patients [11, 17].

CABG patients had longer times on the ventilator. It has been found that CPB itself negatively affects lung function resulting in a prolonged postoperative ventilation [18]. It is certain that the earlier extubation in the Octopus group did not lead to a clinically substantially earlier discharge from the ICU which is partially caused by the fact that a step-down unit does not exist in our hospital, so that extubation does not necessarily mean discharge. However, as Higgins et al. [19] showed, the aim seems to be a reduction of the time on the ventilator to less than 10 h, as afterwards the risk of complications increases.

In addition, it has to be mentioned that "fast-tracking" was not performed in the study for several reasons: in our hospital the patients are discharged from the ICU directly to a general ward run by cardiologists, and since an intermediate care unit is not available patients have to pass strict criteria to be discharged: no chest tubes, no arterial lines, no continuous infusions or invasive hemodynamic monitoring. Based on these early clinical data, it can be assumed that applying Octopus procedures is obviously of provable benefit for the patients, presumably through the avoidance of the CPB. However, it certainly has to be discussed whether these facts could be confirmed by a lower incidence of postoperative complications.

The consecutive question was: does the minimally invasive technique influence the incidence or the extent of complications after coronary revascularization?

Roach et al. [13] described adverse neurological outcome after CABG with CPB in 6.1 %, analyzing a population of 2,417 patients. Preoperative risk factors, perioperative hypotension, cannulation of the often calcified proximal aorta, and the release of cerebral microemboli seem to play a major role. Avoiding these factors should improve neurological outcome: in the CABG group, four patients had neurological deficits (postoperative delirium) compared to none of the Octopus patients. In all patients the neurological deficits were identified to be postoperative delirium using the DSM R III. Thus, further diagnostic procedures such as CCT or EEG were not warranted. We can add that there were no more clinically detectable neurological dysfunctions in all patients at the time point of discharge from the hospital.

Another event discussed to be associated with cardiac trauma and perfusion is AF, which is a common complication after cardiac surgery with CPB [12, 20] and, as our data show, rarely occurs after Octopus. As AF is a risk factor for prolonged LOS in ICU, and thus higher costs, its avoidance favors minimally invasive procedures [21]. As the major points associated with AF, such as age, use of IABP, prolonged duration of ventilation, and withdrawal of beta-blocking agents, did not differ between the compared groups, it is again CPB that might be responsible for this result.

The third question was: is there any measurable influence of the Octopus procedure on the extent of care needed by the patients with consequences regarding cost effectiveness?

TISS scores, reflecting the extent of care in the ICU [15], differed significantly, indicating lower staff activities in the MICS patients. An obvious limitation of this statement is that the cumulative TISS score values are influenced by the LOS in the ICU, which was significantly lower in the MICS groups, too. Accordingly, we performed subgroup analysis of patients with the same LOS in the ICU. For those discharged on the first postoperative day, TISS score values were significantly lower in the Octopus group. In case of discharge on the second or third postoperative day, differences could be observed but were not significant. This could mean that less intensive care is needed in the Octopus group on the first postoperative day and that if discharge from the ICU is delayed, the successive lowering of the extent of care in the CABG group might offset the initial benefit.

The shorter LOS in the ICU in the Octopus group might be a result of all the above-mentioned factors which was additionally reflected by a shorter LOS in hospital.

Our aim was to analyze in which way two surgical techniques of coronary revascularization with and without CPB influenced the postoperative course of the patients with two-vessel disease in the ICU and whether one of those procedures should be favored. Taking into consideration the various aspects analyzed, two conclusions could be drawn: according to postoperative data in the ICU, the minimally invasive technique, i.e., Octopus, showed obvious advantages over conventional CABG, i.e., a less extensive need for care with its consequences on cost-effectiveness and a lower rate of postoperative complications. The fact that two patients scheduled for Octopus had to undergo conversion to CABG might be seen as a limitation of this procedure, but should primarily stimulate better preoperative evaluation. Further studies are needed that compare long-term outcome after these procedures to support the surgeons' decision regarding the respective one.

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