Off-pump revascularization of multivessel coronary artery disease has a decreased myocardial infarction rate

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Abstract

Background: The advent of new mechanical stabilization devices allows complete coronary artery revascularization on the beating heart without extracorporeal circulation (ECC). Objectives: To compare retrospectively the short-term outcomes of 40 patients operated without ECC or cardiopulmonary arrest (group 1) with 40 consecutive patients operated with ECC (group 2) by the same surgeon in the period immediately prior to starting the beating-heart technique. Results: The two groups were similar in terms of age (group 1: 64 ± 8 vs. group 2: 62 ± 10), male/female ratio (group 1: 31/9 vs. group 2: 32/8), presence of unstable angina prior to surgery (group 1: 72.5% vs. group 2: 77.5%), reoperative surgery (group 1: 1.5% vs. group 2: 7.5%), and perioperative risk factors. Group 1 had an average of 2.8 ± 0.7 grafts compared to 3.3 ± 0.9 grafts in group 2 (P < 0.01). Postoperative myocardial infarction rate (CK-MB > 50 IU) was 12.5% following ECC and 2.5% with the beating-heart technique (P < 0.001). Maximum perioperative CK-MB level was also decreased in group 1 (group 1: 14 ± 17 vs. group 2: 46 ± 53, P < 0.001). Postoperative arterial lactate dosage (group 1: 3.1 ± 1.2 vs. group 2: 3.9 ± 1.6, P = 0.02) and a significant increase in creatinine (>50 mM) (group 1: 5% vs. group 2: 18%, P = 0.06) were also decreased less frequent in patients operated on without ECC. A decrease in transfusion needs was also observed (group 1: 40% vs. group 2: 58%). Similar results were obtained for atrial fibrillation, stroke, postoperative use of intra-aortic balloon pumping (IABP), and pulmonary complication rate. Conclusions: We conclude from our experience with a multivessel coronary disease population, that a decrease in perioperative myocardial infarction and renal damage can be achieved by using the beating-heart technique.

Keywords: Coronary bypass surgery; Beating-heart technique; Myocardial infarction

1. Introduction

Although the use of extracorporeal circulation (ECC) has been seen as the ‘obligatory artifice’ for coronary artery revascularization over the last 25 years, its use has lately been questioned again. Increased health-care cost, an aging patient population, and technological advances have urged the quest for less-invasive cardiac interventions and shorter surgical outcome. Numerous advantages have been achieved with the avoidance of ECC in coronary artery revascularization. Decreased operative mortality, improved perioperative outcome, reduced perioperative myocardial infarction incidence, and shorter hospital stay are the most commonly reported [1–3]. The use of ECC has been linked to a severe inflammatory response, as well as the systemic release of microthrombi which can adversely affect a patient’s coagulation system and cognitive performance [4,5]. Keeping the heart beating during the surgical procedure virtually eliminates myocardial edema related to the cardioplegic arrest, and avoids the hazard of suboptimal myocardial preservation. However, the procedure itself is technically more demanding due to the heart motion and the remoteness of the circumflex territory. This has made surgeons reluctant to adopt the beating-heart approach on a large scale. With the advent of coronary artery stabilizers, it is now feasible to perform coronary artery bypass on the beating heart with satisfactory technical results. We present the short-term outcome with our first 40 patients, with multivessel coronary disease operated off-pump on the immobilized beating heart. The coronary stabilizer system that we utilized was especially-designed to achieve multi-vessel access. This cohort has been compared to a similar cohort operated on with ECC, a year prior to the off-pump cohort.
2. Materials and methods

2.1. Off-pump revascularization (group 1)

Patients operated on without extracorporeal circulation were initially selected according to specific anatomic criteria. These patients were those displaying double or triple coronary artery disease with no intramyocardial, heavily-calcified, or diffusely-atheromatous coronary vessels. Patients who needed more than one bypass on the circumflex artery territory were not rejected. However, the last 15 patients included in the series were consecutive patients regardless of their anatomy. All surgical procedures were performed by the same surgeon (RC) under general anesthesia, maintained by continuous infusion of narcotics and benzodiazepines and intermittent administration of pancuronium, to provide muscle relaxation. Coronary-artery stabilization was achieved through a mechanical specially-designed stabilizer system to access all coronary territories (patent pending), see Fig. 1.1 To ensure a bloodless surgical field during grafting, silastic bands attached to blunted needles (‘retractotape’, Canadian Cardiovascular, Quest, Allen, TX) were used for proximal and distal hemostasis of the arteriotomy. Heart beat was initially lowered to 50–60 beats/min with an intravenous bolus injection of

Fig. 1. Picture of the coronary stabilizers used for immobilization of the left anterior descending (A) and circumflex (B).
esmolol or cardizem, to help perform the procedure and decrease myocardial oxygen consumption. Later, with increasing experience, the surgery could be easily performed with a heart-rate averaging between 70 and 80 beats/min. The use of mechanical stabilization allows bypass surgery to be performed with the same facility as the conventional technique using cardioplegic arrest and extracorporeal pressure above 100 mmHg when necessary. Intravenous nitroglycerin infusion was also added whenever an increase in pulmonary pressure was observed during immobilization or coronary artery flow interruption. A cross-clamping test (1 min) was always performed before proceeding to vessel revascularization, to evaluate patient tolerance to local ischemia. No patient had to be converted to the ECC procedure.

2.2. Revascularization with extracorporeal circulation (group 2)

All ECC cases were performed under moderate hypothermia (33–34°C). The extracorporeal circuit was primed with lactate Ringer’s, with or without albumin 25% (100–200 ml). Patients were maintained under anesthesia by continuous infusion of narcotics and benzodiazepines, and muscle relaxation was provided by intermittent administration of pancuronium.

2.3. Statistics

Results are expressed as mean ± SD. For categorical variables, groups were compared using the chi-square test or the Fischer exact test. For continuous variables, unpaired t-test was used. Statistical significance was adjusted for a P-value of <0.05.

3. Results

Demographic data are presented in Table 1. Both groups were similar, except for the number of bypass grafts performed per patient (Fig. 2). In group 1, there were two single, ten double, 23 triple and five quadruple bypasses, for an average of 2.8 ± 0.7 grafts/patient. The single internal thoracic artery (ITA) was used as a conduit in 38 patients, the bilateral internal thoracic artery in seven patients. In one patient, a sequential bypass was performed with the left ITA. Vein grafts were used in 65 bypasses.

![Fig. 2. Graft distribution per patient.](image-url)
Only two patients did not benefit from ITA conduit for revascularization.

In group 2, there were one single, six double, 18 triple, 11 quadruple and four quintuple bypasses, for an average of 3.3 ± 0.9 grafts/patient. Single ITA was used in 39 patients, and double ITA in ten. Vein grafts were used as conduits in 80 bypasses, and only one patient was revascularized with vein grafts alone. The graft distribution as a function of coronary artery territory, for both groups is presented in Table 2.

Myocardial infarction, defined as either an increase in CK-MB enzyme levels above 50 IU/L or Q-wave on the postoperative ECG, was present in 2.5% of group 1 versus 12.5% of group 2 (P = 0.09). The maximum postoperative CK-MB level was also significantly lower in the group operated without ECC: group 1: 14 ± 17 U/I versus group 2: 46 ± 53 U/I (P = 0.0005). CK-MB stratifications according to the number of grafts performed in each patient are reported in Table 3. Postoperative lactate levels were also decreased in group 1: 3.1 ± 1.2 mM versus group 2: 3.9 ± 1.6 mM (P = 0.02).

The incidence of atrial fibrillation was similar in both groups, although a trend towards a decreased frequency was observed in group 1 (group 1: 20% vs. group 2: 27.5%, n.s.). There was a significant difference between pre- and postoperative creatinine level in group 2 (100 ± 23 vs. 123 ± 54, P = 0.02) which was not observed in group 1 (97 ± 20 mM vs. 104 ± 41 mM, n.s.). The incidence of patients having significant postoperative renal impairment (defined as an increase in creatinine level of more than 50 mM) was 5% in group 1 compared to 18% in group 2 (P = 0.06).

Cerebrovascular accident with permanent neurological impairment was seen only in group 2. Similarly, the use of a postoperative intra-aortic counterpulsation balloon pump was only necessary in group 2. The rate of pulmonary complications (pneumonia and bronchospasms) requiring prolonged mechanical support was equal in both groups (7.5%).

Total perioperative blood loss was not different between the two groups (Table 4). However, the operative blood loss was decreased in off-pump patients (group 1: 376 ± 241 ml vs. group 2: 470 ± 220 ml, P = 0.07), as well as a decreased need for blood transfusion (P = 0.1). Among patients requiring blood transfusion, the total amount transfused was similar in the two groups.

### Table 3

| CK-MB stratification according to the number of grafts performed per patient in each group |
|---------------------------------------------|-----------------------------|
|                                             | Group 1 (IU) | Group 2 (IU) |
| Single                                     | 7 ± 2        | 12*          |
| Double                                     | 13 ± 5       | 26 ± 2       |
| Triple                                     | 16 ± 4       | 48 ± 11      |
| Quadruple                                  | 14 ± 6       | 60 ± 28      |
| Quintuple                                  | 0            | 31 ± 3       |

*Only one patient.

### Table 4

<table>
<thead>
<tr>
<th>Hematological event</th>
<th>Group 1</th>
<th>Group 2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beating heart</td>
<td>Cardiopulmonary bypass</td>
<td></td>
</tr>
<tr>
<td>Total blood loss (ml)</td>
<td>993 ± 605</td>
<td>1139 ± 687</td>
<td>n.s.</td>
</tr>
<tr>
<td>Pariop. blood loss (ml)</td>
<td>376 ± 241</td>
<td>470 ± 220</td>
<td>0.07</td>
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<tr>
<td>Transfusion rate (%)</td>
<td>40</td>
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<td>0.11</td>
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<tr>
<td>Re-sternotomy for bleeding (%)</td>
<td>5</td>
<td>7.5</td>
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### 3.2. Perioperative mortality

The only perioperative death was reported in group 1 and was secondary to multiorgan failure. Autopsy revealed that all three grafts performed were patent.

### 4. Discussion

The purpose of this report was to evaluate the morbidity and mortality associated with the coronary artery revascularization technique, performed on a beating heart with the use of a mechanical stabilization system. This retrospective study compared the early postoperative course of multivessel coronary patients operated off-pump with patients operated with the conventional cardiopulmonary bypass under cardioplectic arrest. Direct myocardial revascularization can be done successfully without stabilization, but it requires a significant learning curve [1–3]. The introduction of a
mechanical coronary stabilization in minimally invasive coronary artery surgery, has considerably contributed to advancing the beating-heart procedure [7,8]. As we previously reported, the stabilization designed and used in this study can be adapted to a standard sternotomy retractor, and can be used on any coronary artery territory [9]. We performed an average of 2.8 grafts/patient, which is comparable to other surgical series of patients operated on by conventional techniques in our institution [10]. The higher number of grafts/patient found in the control group of our study (3.3 grafts/patient vs. 2.8 grafts/patient) can be explained by a higher percentage of patients needing four and five grafts (Fig. 2). As reported by others, we observed evidence that the avoidance of ECC better preserves the left ventricular function. This is shown by reduced myocardial damage, as quantified by the CK-MB, in the group operated on without ECC [2,11,12]. This observation was maintained even when the CK-MB were stratified according to the ratio grafts/patient, thus confirming the benefits of off-pump surgery. This is in accordance with recent work from Benetti who reported a marked reduction of mitochondrial and myofibril damage following revascularization, in a high-risk subset of patients revascularized without ECC [13]. A significant increase in postoperative creatinine level was also detected in the patients operated under conventional technique, whereas no significant increase was seen in the off-pump group suggesting that the renal function was also better preserved. This is in accordance with the lower level of lactate observed, during and after surgery in this group, thereby strongly suggesting that a better systemic perfusion was also maintained.

As we previously reported, direct revascularization on the mechanically-stabilized beating heart can be performed with excellent angiographic results. We found the main limitation of the procedure is related to the anatomy and the quality of the vessel itself. Diffuse atheromatous disease, necessitating long arteriotomy or even endarterectomy, are relative contraindications to this technique. The circumflex territory remains the more challenging part of the surgical procedure, but with experience and proper stabilization, all circumflex branches can be revascularized. This is confirmed by the fact that in our beating-heart group cohort, more than 70% had at least one graft performed on this posterior territory.

In conclusion, direct coronary revascularization on the beating heart can be done with less perioperative morbidity than with the standard cardiopulmonary bypass technique. Myocardial and renal function seem to be better preserved. Long-term follow-up and angiographic studies, however, are mandatory to confirm the benefits of this surgical procedure.

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