

# Off-pump coronary artery bypass with multiple arterial conduits

*Cirurgia coronária com condutos arteriais múltiplos sem circulação extracorpórea*

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## **Abstract**

**Objective:** to analyze intra-hospital results in patients undergoing elective off-pump total arterial revascularization and identify morbidity and mortality predictors using this surgical strategy.

**Methods:** From May 1999 to February 2004, 203 myocardial revascularization procedures with total arterial revascularization without cardiopulmonary bypass (off-pump) were carried out in patients with multivessel disease (three vessels 81.7 %, one vessel disease was excluded). We report pre-surgical variables and co-morbidities: average age  $63.9 \pm 9.13$  years, men 182 (89.5%), hypertension 132 (65%), smokers 125 (61%), hypercholesterolemia 152 (74.8%), previous myocardial infarction (> 30 days) 73 (35%), moderate to severe ventricular dysfunction 31 (15%), redo 5 (2.5%). Total arterial revascularization included T-grafts and sequential grafts with left internal mammary (100%), right internal mammary (56.6%) and radial (63%) arteries. The total number of distal anastomosis was 576 (mean of 3 grafts/patient), all carried

out with external mechanical stabilizers. There were no proximal aortic anastomoses. Conversion to on-pump surgery occurred in 3 patients (1.5%). 90% of the patients was extubated in the operating room. The multiple logistic regression test was used for statistical analysis.

**Results:** The postoperative incidence of atrial fibrillation was 12.8% (26), oligoanuric renal failure 3% (6), dialysis 0.49% (1), postoperative myocardial infarction 1.47% (3), low cardiac output 4% (8), Redo for bleeding 1.47% (3), mediastinitis 1.47% (3), stroke 1.47% (3). Intra-hospital mortality was 2.45% (5). The only independent 30 day morbidity predictor was age ( $p=0.033$ ; OR 1.04; IC 95%: 1-1.08).

**Conclusion:** Off-pump myocardial revascularization with arterial conduits for multiple vessel disease is feasible with a low 30-day morbidity and mortality.

**Descriptors:** Coronary surgery. Off-pump circulation. Multiple vessel disease. Arterial conduits

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**Resumo:**

**Objetivo:** Analisar os resultados, em 30 dias, em pacientes submetidos de forma eletiva à revascularização arterial total do miocárdio sem circulação extracorpórea (CEC), e identificar preditores de morbimortalidade com esta estratégia cirúrgica.

**Método:** Entre maio de 1999 e fevereiro de 2004, efetuaram-se 203 cirurgias de revascularização miocárdica (CRM) com revascularização arterial total sem CEC, em pacientes com doença de múltiplos vasos (três vasos 81,7%, doença de um vaso excluída). Reportaram-se variáveis pré-operatórias e comorbidade: média de idade 63,9 ± 9,13 anos, homens 182 (89,5%), hipertensão 132 (65%), tabagismo 125 (61%), hipercolesterolemia 152 (74,8%), infarto agudo do miocárdio prévio (mais de 30 dias) 73 (35%), disfunção ventricular moderada a grave 31 (15%), reoperação cinco (2,5%). A revascularização arterial total incluiu anastomoses em T e seqüenciais com artéria torácica interna esquerda (100%), torácica interna direita (56,6%) e artéria radial (63%). O número total de anastomoses foi 576 (média de três pontes/paciente), todas efetuadas com estabilizadores mecânicos

externos. Não foram realizadas anastomoses proximais na aorta. Cirurgia com CEC foi realizada em três (1,5%) pacientes. Noventa por cento dos pacientes foram extubados na sala de operações. Para a análise estatística, utilizou-se teste de regressão logística múltipla.

**Resultados:** A incidência de fibrilação atrial pós-operatória foi de 12,8% (26), insuficiência renal oligoanúrica 3% (seis), diálise 0,49% (um), infarto de miocárdio pós-operatório 1,47% (três), baixo débito cardíaco 4% (oito), reoperação por sangramento 1,47% (três), mediastinite 1,47% (três), acidente vascular cerebral 1,47% (três). A mortalidade intra-hospitalar foi de 2,45% (cinco). O único preditor independente de morbidade em 30 dias foi a idade ( $p=0,033$ ; OR 1,04; IC 95%: 1-1,08).

**Conclusão:** A cirurgia de revascularização miocárdica sem circulação extracorpórea utilizando condutos arteriais para a doença de múltiplos vasos é factível com baixa morbimortalidade em 30 dias.

**Descritores:** Revascularização miocárdica. Artérias mamárias. Circulação extracorpórea.

## INTRODUCTION

The use of cardiopulmonary bypass (CPB) by heart surgeons over the last 35 years has enabled coronary artery bypass grafting in more complex patients with higher surgical risk giving better results. Nevertheless, its use is associated to a certain degree of morbidity and in some clinical situations to a higher incidence of post-surgical morbidity and mortality. The undesirable effects of cardiopulmonary bypass are expressed as physiological disorders secondary to the exposure of blood to plastic tubes, oxygenators and filters, which, combined with the use of surgical field aspirators, destroy red and white blood cells and platelets. Likewise, it has been shown that this activates the inflammatory system with the release of cytokines and the increase of capillary patency and the potential threat to most of the organs [1].

Additionally, the use of CPB is associated to the manipulation of the ascending aorta during cannulation and clamping, and this has been identified as a major independent risk factor for the presence of stroke due to the embolization of atherosclerotic material and air [2]. Even though these events have been reduced, the risk of using CPB in high risk elderly patients continues to be high. Technological progress has enabled the development of state-of-the-art coronary stabilizers, suitable to carry out a correct anastomosis on all coronary territories involved without using CPB.

Another very important aspect is the type of conduit used to carry out coronary bypass grafting. In this regard LYTTLE et al. have shown a higher long-term therapeutic benefit when comparing patients using two mammary artery grafts to those using only one, thus this is becoming the first choice in arterial conduits [3].

The purpose of this paper is to: a) analyze the intra-hospital results of a group of consecutive surgical patients, undergoing off-pump coronary artery bypass grafting with multiple arterial conduits exclusively and b) to identify morbidity and mortality risk predictors using this surgical strategy.

## METHODS

From March 1999 to March 2004 a total of 1253 coronary artery bypasses (CABG) were performed. In 674 (54%) of these patients, multiple arterial conduits were used exclusively. Out of these, a subgroup of 203 patients, presenting multiple vessel disease, underwent off-pump coronary artery bypasses (OPCAB) and represent the study group of this retrospective study. The OPCAB technique had been used selectively and sporadically during the first months of 1999, from December 2001 onwards OPCAB was used routinely in coronary bypass grafting. Finally, from November 2003 onwards the decision was made to use OPCAB with multiple arterial conduits routinely for all coronary artery bypass grafting procedures using arterial

conduits as grafts. In this group, 81.7% of the patients undergoing surgery had three vessel disease, patients with one vessel disease were excluded. The average age of the patients was  $63.9 \pm 9.13$  and 89.5% were men. On analysis of the baseline characteristics of the population, high incidences of previous myocardial infarction and of diabetes mellitus appear as indicators of severe coronary disease (Table 1A).

### **Surgical technique**

All patients included in this study underwent surgery with the purpose of obtaining complete myocardial revascularization using more than one graft. The only arterial conduits used for coronary revascularization were the internal mammary arteries (right and left) and the radial artery.

Both mammary arteries were skeletonized (removal of the adipose and muscle layers) to obtain maximum length of the arterial graft and to preserve the integrity of the chest wall. The radial artery (RA) was dissected with a minimum pedicle using the conventional technique.

For total arterial revascularization, the right internal mammary artery (RIMA) was divided and its upper segment used as a free graft in a proximal T-type anastomosis to the left internal mammary artery (LIMA) and the distal segment was used as a graft to the selected coronary arteries.

In another group of patients, the RA was used as a free graft instead of the RIMA.

Using these conduits as free grafts it was possible to carry out multiple coronary anastomoses in a sequential manner. The most commonly used technical configuration was to carry out an in-situ anastomosis of the LIMA to the left anterior descending (LAD) and to use the RIMA as a sequential free graft to the circumflex and the posterior descending arteries (Figure 1).

State-of-the-art stabilizers such as the Octopus IV (Medtronic) or Expose (Guidant), intracoronary shunts and/or proximal coronary occlusion tourniquets were used when making the anastomoses. It must be stated that no proximal anastomosis of the aorta was carried out in any patient in this series.

Once coronary revascularization was completed the anastomosis was checked using Doppler with a vascular transducer of 8 MHz to measure the diastolic flow signal and velocity in each anastomosis to determine patency.

All the patients in this group were operated on with the intention of carrying out OPCAB (intention to treat) and the criteria used for conversion to on-pump CABG were: hemodynamic instability and calcified or intramyocardial coronary arteries.

Uni and multivariate multiple logistic regression analysis were carried out with the purpose of identifying variables which acted as independent predictors of postoperative morbidity and mortality.

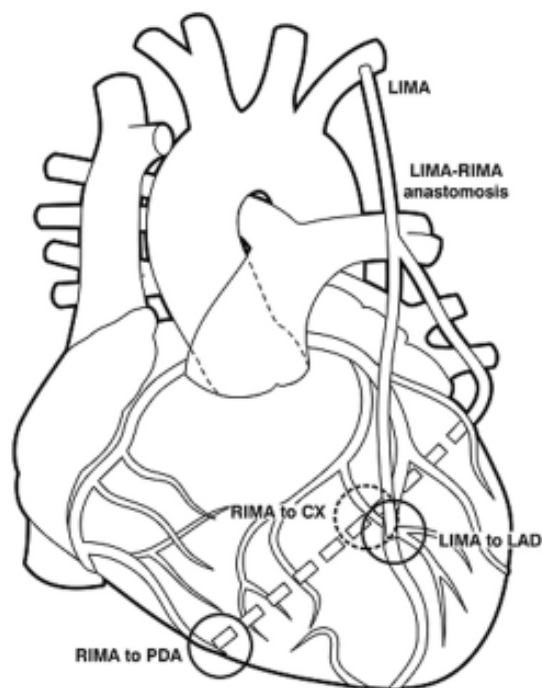


Fig. 1 - Most frequent surgical technique using only arterial conduit grafts. LIMA: left internal mammary artery. RIMA: right internal mammary artery.

A univariate analysis carried out to compare patients with or without complications considered the following variables: age, diabetes mellitus, gender, number of arteries involved, ventricular function, chronic stable angina, unstable angina, prior myocardial infarction, prior coronary bypass, high blood pressure, smoking, heart failure and cardiogenic shock. A multiple logistic regression analysis was carried out with these same variables, which although some were not significant, they are considered important in most published papers.

### **RESULTS**

The patients reported in this paper represent 42% of all off-pump coronary bypass grafting performed during this period. During 2003-2004 this percentage was over 67%, confirming the changes introduced to the surgical technique for coronary artery revascularization towards the use of off-pump coronary artery bypasses with arterial conduits and without using venous grafts.

The left internal mammary artery (LIMA) was used in 100% (203 patients) of cases, the right internal mammary artery (RIMA) in 57% (116 patients) and the left radial artery (RA) in 62% (120 patients) of the cases.

A total of 576 distal coronary anastomoses were

performed with a mean of three coronary grafts per patient (Table 1B).

Table 1. A) Baseline patient characteristics.

|                       | N   | %    |
|-----------------------|-----|------|
| Male gender           | 182 | 89.6 |
| Diabetes              | 49  | 25.1 |
| Hypertension          | 131 | 64.5 |
| Smoking               | 124 | 61   |
| AHF                   | 57  | 28   |
| Lipid disorders       | 150 | 72   |
| Previous MI           | 73  | 35   |
| Previous MRS          | 5   | 2.5  |
| Previous Stroke       | 3   | 1.5  |
| Coronary arteriogram  |     |      |
| Trunk IC              | 35  | 17.2 |
| Two vessels           | 38  | 18.8 |
| Three or more vessels | 164 | 81.1 |
| Ventricular Function  |     |      |
| Normal – Mild         | 154 | 76.2 |
| Moderate-Severe       | 31  | 15.3 |
| No Data               | 17  | 8.5  |
| Clinical status       |     |      |
| Asymptomatic          | 14  | 6.9  |
| Stable Chronic Angina | 56  | 27.7 |
| Unstable Angina       | 132 | 65.4 |

Table 1. B) Intraoperative data.

|                           | N   | %     |
|---------------------------|-----|-------|
| Arterial conduits:        |     |       |
| Left internal mammary     | 203 | 100   |
| Right internal mammary    | 116 | 57    |
| Radial artery             | 120 | 62    |
| Patients with:            |     |       |
| 2 Grafts                  | 70  | 34.4  |
| 3 Grafts                  | 99  | 48.76 |
| 4 Grafts                  | 31  | 15.2  |
| 5 Grafts                  | 3   | 1.47  |
| Grafts to:                |     |       |
| Anterior Descending       | 207 |       |
| Diagonal                  | 66  |       |
| Circumflex                | 211 |       |
| Right Coronary/Post.Desc. | 92  |       |

The rate of conversion to on-pump bypass was 1.5% (three patients) due to hemodynamic instability. The anesthetic technique used included a protocol for immediate postoperative extubation (ultra fast track) and 90% of the patients were extubated in the operating room [4].

There were no postoperative complications in 74% of the patients. Average time in intensive care was 1.4 ± 1.2 days and total postoperative hospital stay was 5.1 ± 2.4 days.

Postoperative complications were: atrial fibrillation 12.8%, renal failure 3%, dialysis in one patient, myocardial infarction in 1.47%, low cardiac output 4%, redo due to bleeding 1.47%, mediastinitis 1.47%, stroke with sequelae 1.47%. In-hospital mortality was 2.45%. Five patients died during the immediate postoperative period, three due to cardiac causes (Table 2). In the univariate analysis the only variables of statistical significance were: age (63.8 vs. 61 years) p=0.02 (T-test) and diabetes (32.5% vs. 17.1%) p=0.003 (Chi squared test). In the multivariate analysis only age (OR 1.04 95% CI 1-1.08 p= 0.03) appears to be an independent variable of higher postoperative complications after OPCAB (Table 3).

Table 2. Postoperative complications

|                          | N  | %    |
|--------------------------|----|------|
| Atrial fibrillation      | 26 | 12.8 |
| Low cardiac output       | 8  | 3.94 |
| Oliguric ARF             | 7  | 3.44 |
| Redo due to bleeding     | 3  | 1.47 |
| Perioperative MI         | 3  | 1.47 |
| Ventricular Fibrillation | 2  | 1    |
| Respiratory Distress     | 4  | 2    |
| Transient Stroke         | 1  | 0.5  |
| Stroke with sequelae     | 3  | 1.47 |
| Infection of the site    |    |      |
| Superficial              | 2  | 1    |
| Mediastinitis            | 3  | 1.47 |
| Death                    | 5  | 2.45 |

Table 3. Independent predictors of postoperative complications. Multivariate analysis.

|                    | OR   | P     | IC 95 %   |
|--------------------|------|-------|-----------|
| Age                | 1.04 | 0.033 | 1.00-1.08 |
| Diabetes           | 1.67 | 0.166 | 0.80-3.50 |
| Number of vessels  | 2.10 | 0.177 | 0.71-6.21 |
| Ventricle mod/sev. | 1.05 | 0.912 | 0.43-2.54 |
| Male gender        | 1.89 | 0.341 | 0.51-6.93 |

## DISCUSSION

The use of better medical therapy and the decrease in the incidence of coronary restenosis post-PTCA by using new devices have brought about a change in the characteristics and severity of coronary artery diseases in patients who require myocardial revascularization surgery (MRS). Currently the patients operated are older and suffer from a greater number of concomitant diseases, increasing the perioperative risk.

At the present time, coronary artery bypass grafting should have less perioperative morbidity while at the same time representing a significant clinical benefit in the long term follow-up.

This study presents a change in the strategy used for coronary revascularization based on two principles:

a) to enhance the long term therapeutic clinical effect of MRS using arterial conduits only, with proven long-term patency and

b) To simplify and maximally reduce the risks of morbidity and mortality in coronary artery bypass by using OPCAB as a routine technique.

It was proven more than 20 years ago, that internal mammary artery grafts were far superior to venous conduits for the revascularization of the anterior wall of the heart. Many surgeons tried to extrapolate this benefit to other coronary territories by using multiple arterial grafts. Due to technical difficulties and a greater incidence of complications its use did not become extensive, in spite that this technique was considered the best way to achieve myocardial revascularization. LYTLE et al [3], statistically showed that patients undergoing CABG with two mammary arteries instead of one had a longer survival and a longer period free of Redo and/or PTCA [4-5]. Therefore, on the basis of this and other experiences, it was decided to change our technique of coronary revascularization towards the exclusive use of arterial conduits, in order to obtain greater benefits in the long term. In the present series there was a low incidence of complications, especially postoperative mediastinitis, similar to that of the total group of patients undergoing MRS. Although at the beginning of this trial only those patients requiring multiple arterial conduits were selected, since January 2004 the procedure has become routine for the revascularization of all patients.

The other element which was part of the change in our strategy was the elimination of cardiopulmonary bypass to carry out coronary bypass grafting. Since the year 2000, there has been a marked increase of off-pump procedures due to better anesthetic techniques, greater surgical expertise and important technological breakthroughs, turning it into a reliable and replicable technique. When the technique was first used, there was a higher incidence of

patients with subtotal revascularization due to the technical difficulties to revascularize the lateral wall of the left ventricle. These difficulties have now been overcome. An ever increasing number of retrospective studies and a few randomized studies have been published which clearly show the benefits of OPCAB. Most of these papers underscore the results on hospital mortality, the possibility of total revascularization using arterial conduits and the incidence of stroke, loss of cognitive function, impairment of renal function, less morbidity and shorter hospital stay, all of these results according to gender [6-7].

A multicentric study of 17,969 patients undergoing off-pump surgery from the database of the American Association for Thoracic Surgery (AATS) assessed retrospectively and by statistical analysis to obtain groups with comparable risk factors (with or without cardiopulmonary bypass), showed lower in-hospital mortality in the off-pump group undergoing total revascularization [8]. MACK et al, in a study of 7,283 patients undergoing off-pump coronary bypass, showed that the use of cardiopulmonary bypass in patients over 75 years of age was a predictor for greater risk of mortality (OR 2.13 CI 95% 1.20-3.76,  $p=0.01$ ) [9]. Other authors who carried out randomized, double-blind studies in patients undergoing elective surgery were unable to demonstrate any differences in in-hospital mortality [10].

Though we personally did not carry out a comparative study, the group of patients presented in this paper was submitted to elective surgery and the in-hospital mortality was no different to that of the on-pump group reported by our Department [11].

In a meta-analysis of 53 published studies RESTON et al. included 46,621 patients undergoing OPCAB and reported a lower incidence of perioperative myocardial infarction, stroke, redo for bleeding, renal failure and early and medium-term mortality in patients undergoing off-pump versus on-pump procedures [12].

Obesity is a preoperative variable of higher post MRS mortality. ASCIONE R. et al. analyzed the effect of this variable in patients undergoing on-pump and off-pump coronary artery bypass (674 patients off-pump vs. 2,844 patients on-pump). They showed that patients who underwent off-pump surgery presented less mortality, less transfusion requirements of blood and derivatives, a lower incidence of neurological complications, and shorter hospital stay [13].

Another important issue to take into consideration is the possibility to carry out coronary artery bypass grafting with the same level of quality, that is to say total revascularization, when using OPCAB. This is worth mentioning, because most of the papers which had been published at the beginning presented a smaller number of grafts per patient than those operated with the conventional

cardiopulmonary bypass, and therefore are populations which cannot be compared. PUSKAS et al. carried out a randomized trial comparing both techniques with complete revascularization (approximately 3.4 grafts per patient in both groups) and showed that patients undergoing elective off-pump coronary artery bypass presented lower levels of myocardial injury, less transfusion requirements and shorter hospital stays [14]. In our series, we carried out total revascularization with the exclusive use of multiple arterial conduits and obtained the same results with regards to technical feasibility and procedural morbidity and mortality as the ones presented by SINGH et al. [15]. Not manipulating the ascending aorta could be one of the factors which explain the low incidence of postoperative cerebral problems. From the beginning, off-pump coronary bypass grafting was considered the ideal solution to avoid the presence of postoperative stroke. After several studies were published, factors associated to a higher incidence of postoperative stroke were identified.

Among them the use of cardiopulmonary bypasses, the manipulation of the ascending aorta (clamping or proximal anastomosis), and age (> 75 years) were identified as factors with the highest incidence of cerebral problems post cardiopulmonary bypass. JOHN et al. [2], after analyzing a multicentric trial of 19,244 patients, identified the use of cardiopulmonary bypass as one of the risk predictors for stroke ( $p = 0.0004$ ; OR 1.27 per 60 minutes) post coronary artery bypass grafting. Another study in favor of a lower incidence of stroke in off-pump bypass grafting is presented by LEE JD et al., after randomizing a large number of patients conclude that patients undergoing off-pump bypass showed a significant reduction in intraoperative cerebral stroke (transcranial Doppler) better postoperative cerebral perfusion (SPECT) and better neurocognitive functioning at two weeks and one year post-op [16].

Nevertheless, SABIK et al. did not find significant differences in the presence of postoperative stroke when comparing two well selected populations [17]. In our series, in spite of being a group undergoing elective coronary bypass grafting, without manipulation of the ascending aorta, the incidence of stroke was not zero, which indicates that there are multiple causes related to this type of complication. Even though the controversy still exists, there are clinical situations as in the elderly (>75 years) and ascending aorta with calcium plaques and/or former history of stroke, in which off-pump coronary artery bypass grafting shows better results [18]. Off-pump bypass has been associated to a lesser impairment of the postoperative renal function expressed as lower reduction in glomerular filtration and a better preservation of the albumin/creatinine in the first 48 hours of coronary revascularization, especially in high-risk patients [19].

Finally, if we compare the results obtained in a group of patients undergoing on-pump coronary surgery, there is no difference in hospital mortality. Nevertheless, a detailed analysis proves that with this new coronary bypass grafting technique, total revascularization is possible with more grafts per patients without using venous conduits. It is also noted that in spite of the fact that two internal mammary arteries are used, and that it is a complex technical procedure, there were no differences in the incidence of mediastinitis, low cardiac output, renal failure and stroke. There was a lower incidence of atrial fibrillation and recovery was faster with intraoperative extubation of most of the patients, as well as shorter length of stay [20].

#### CONCLUSION

Off-pump coronary artery bypass grafting with multiple arterial conduits, in a series of consecutive patients, enabled total arterial revascularization with a low mortality and a low incidence of major postoperative events (stroke, renal failure, myocardial infarction, mediastinitis). The routine use of this new surgical strategy simplified the surgical procedure enabling intraoperative extubation and a shorter hospital stay. These results were possible after a complete re-engineering process of the team as a whole, which is an essential element to approach this new coronary artery bypass grafting modality.

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