Comparative Costs between Myocardial Revascularization with or without Extracorporeal Circulation

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Summary

Background: Surgical techniques of myocardial revascularization without the use of extracorporeal circulation (ECC) have raised hopes of attaining operative results with less systemic damage, lower occurrence of clinical complications and shorter hospital stay duration, generating expectations of lower hospital costs.

Objective: To evaluate the hospital costs in patients submitted to myocardial revascularization with and without ECC and in those with stable multiarterial coronary disease with preserved ventricular function.

Methods: The hospital costs were based on the existing governmental reimbursement. The costs included that of ortheses and prostheses and clinical complications. The time and costs of ICU stay and hospital stay duration were considered.

Results: Between January 2002 and August 2006, 131 patients were randomized to surgery with ECC (SECC), whereas 128 were randomized to surgery without ECC (WECC). The basal characteristics were similar for both groups. The costs of surgical complications were significantly lower ($p < 0.001$) in patients from the WECC when compared to the SECC group (606.00 ± 525.00 vs. 945.90 ± 440.00), as well as ICU costs: 432.20 ± 391.70 vs. 717.70 ± 257.70, respectively. The duration of the operating room stay were 4.9 ± 1.1 h vs. 3.9 ± 1.0 h, $p < 0.001$; at the ICU it was 48.2 ± 17.2 h vs. 29.2 ± 26.1h) ($p < 0.001$), with intubation time of 9.2 ± 4.5 h vs. 6.4 ± 5.1h, $p < 0.001$ for patients from the group with and without ECC, respectively.

Conclusion: The present study allowed us to conclude that the myocardial revascularization surgery without extracorporeal circulation results in the decrease of operational costs and duration of the stay in each section related to the surgical treatment. (Arq Bras Cardiol 2008;91(6):340-346)

Key words: Hospital costs; extracorporeal circulation/economic/adverse effects; coronary artery bypass, off pump; myocardial revascularization; coronary arteriosclerosis.

Introduction

The commencement of the use of the extracorporeal circulation (ECC) circuit in cardiac surgery after the 50s, allowed the surgeons to perform a large variety of heart procedures that were technically impossible. However, due to its non-physiological nature, this circuit generated a series of adverse events, such as the activation of systemic inflammatory responses, hemostasis alterations and multiple dysfunctions in organs such as the heart, brain and kidneys[1-4]. These effects seem to be more perceptible in elderly patients[5].

Recently, with the use of less invasive techniques in myocardial revascularization surgeries that suppressed the need for the use of this circuit[6] and with the help of heart stabilizers[7], we have observed an increasing utilization of this alternative. In theory, with the elimination of these circuits, many of these adverse events can be suppressed.

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Additionally, with the perspective of a better clinical evolution, we can expect a faster recovery and shorter duration of hospital stay for those patients submitted to myocardial revascularization surgery (MRS) without extracorporeal circulation (WECC).

The interest for this technique has motivated by several researchers to evaluate the clinical and economic benefits of this type of intervention[8-11]. In fact, there was a perspective that, with the decrease in the adverse events caused by the MRS with ECC (SECC), the duration of the operating room stay, ICU stay, with shorter orotracheal intubation time[12] and shorter hospital stay duration, the direct and indirect costs would also markedly decrease. Additionally, this gain related to the hospital costs can directly contribute to the clinical and quality of life improvement of the patients.

Objectives

This study aims at evaluating the comparative costs at the hospital phase in patients with stable multiarterial coronary disease with preserved ventricular function submitted to myocardial revascularization surgery with and without ECC.

Methods

Patients with multiarterial coronary disease documented by angiogram and visually graded arterial stenosis ≥ 70%, stable angina and preserved ventricular function were considered eligible for the present study. These patients were included in the study when there was a concordance between two surgeons to perform the MRS through both techniques. All angiograms were revised by the surgeons and a surgical plan was documented before the randomization. The patients were eligible for randomization if the procedure were technically feasible and safely performed, without the help of extracorporeal circulation. Patients previously submitted to a MRS, those with ventricular aneurysm or valvulopathy that needed correction, unstable angina that needed emergency revascularization or myocardial infarction that had occurred less than 3 months before, were excluded from the study. Additionally, patients with compromised ventricular function due to left ventricular (LV) ejection fraction (EF) < 40% were also excluded from the study, as well as patients who refused to sign the free and informed consent form. This study was carried out according to the principles of the Declaration of Helsinki and was approved by the scientific commission of Instituto do Coração, protocol #2622/05/042 and under #415/05 of the Ethics Committee for the Analysis of Research Projects (CAPPesq) of the Clinical Board of Hospital das Clínicas of FMUSP.

Anesthetic and surgical techniques

The surgeons were asked to perform the revascularization procedure according to best surgical practice and safety. The procedure was carried out by surgeons that were experienced in both techniques, with and without ECC. In surgeries with ECC, a cold cardioplegic solution was administered for more effective myocardial protection. In surgeries without ECC, an Octopus™ (Medtronic, Inc. Minneapolis, MN) stabilizer was used, as described[13]. IN summary, the distal part of the two suction arms of the stabilizer is placed on the heart, on both sides of the artery that will undergo correction. The proximal part is fixed on the rib spreader. Through a negative pressure, the intervention site is sufficiently immobilized to allow a safe anastomosis of the graft with the receptor artery.

The anesthetic technique and the ECC circuit, standardized at the Instituto do Coração (The Heart Institute) of HCFMUSP, were applied throughout the study. The ECC circuit was used as it is regularly used, together with a membrane oxygenator and spiral pump. The heart was exposed through a median incision in the sternum. During the surgery with ECC, the patients were cooled to a temperature close to 32º Celsius, whereas, in the surgery without ECC, the patients were kept warm, to maintain a core temperature, never below 35º Celsius. Myocardial infarction will be admitted as the appearance of Q waves at the surface ECG, together with a 5-fold increase in the CK-MB enzymes above the normal levels.

Hospital mortality will be considered as the 3-day period, which is necessary to stay at the hospital.

Hospital Costs

The costs of the surgical interventions were obtained from the hospital financial administration, based on the reimbursement that the government offers for the surgical treatment of this disease. The myocardial revascularization has a fixed reimbursement per patient, regardless of the type and number of grafts. As it is a high-complexity and high-cost procedure, the cardiac surgery receives a differentiated reimbursement for additional resource used in the intervention, either in the operating room, or in the intensive care unit. Therefore, the additional costs, effectively applied to each step of the procedure, will be calculated. The Octopus™ stabilizer will be used and disposed of, after the use, in all patients that undergo the surgery without ECC. The direct hospital costs were calculated according to the mean current prices while the manuscript was being written, using the national monetary currency values. Blood transfusion will be considered when indicated by the medical team and the costs calculated according to the number of transfused units.

Regarding indirect costs, such as building administration costs, maintenance costs, water consumption, electricity, telephone, laundry, food costs, among others and that of material depreciation, considering that they are common to both techniques and presumably included in the costs, they won't be considered.

- **Patient admission:** during the patient preparation for the intervention, the expenses related to the hospital stay, nursing care, physical therapy, medications and preoperative examinations were not considered, as they are the same for both techniques.

- **Patient transportation:** the costs related to patient transportation, special gurneys, transportation staff including nurses, medications, pre-anesthetic medication, arrival at the operating room and anesthesia preparation were not considered as they are similar procedures for both techniques.

- **Operating room:** The depreciation of the operating room, permanent material and the salaries of the circulating professionals were not considered. However, the salaries of the perfusion team were considered for both techniques. That was necessary because, during the surgery without ECC, the perfusion team professionals remained in the room in case the use of this resource would be indicated. The costs of the medical team and of the anesthesia were calculated according to the fixed reimbursement established by the institution, based on the Public Health System (Sistema Único de Saude - SUS), which is similar for both techniques. This same criterion was used to consider the costs of surgical instrumentation professionals.

The extracorporeal circulation circuit, with all materials, either disposable or not, used in the operation, including those operating the equipment, are included in the fixed reimbursement paid by the SUS. For patient submitted to the surgery without ECC that received the stabilizer, here called Octopus™, the value of this procedure is added to the final price of the surgery. This resource resulted in an increase of the operation costs when compared to the surgery with ECC. The duration of the operating room stay was calculated in hours and its cost in monetary currency values. The administration of blood and blood products, both in the operating room and at

the ICU or infirmary, was calculated for both techniques. The surgical instrument box, as it is common to both techniques, was not considered.

• **Intensive Care Unit:** similarly to the preoperative costs, the cost of the transporting the patient from the operating room to the ICU were not considered. However, the time and cost of the ICU stay were calculated, as well as the costs of the necessary artificial ventilation time and the use of high-complexity and high-cost resources.

These resources were available for postoperative complications: intra-aortic balloon, hemofiltration circuit and Swan-Ganz catheter. The reoperations, when necessary, were calculated similarly to a new operation.

All the complications observed in the postoperative period, from the moment the patient left the operating room until the hospital discharge, such as cerebrovascular accidents, acute myocardial infarction, respiratory and surgical wound infections, among others, were considered and calculated according to the values reimbursed by the Public Health System (SUS).

Statistical analysis

Initially, all variables were analyzed descriptively. For the quantitative variables, this analysis was carried out based on minimum and maximum values, using mean, median and standard deviation (SD) calculations. For the qualitative variables, the absolute and relative frequencies were calculated. To compare the means of two groups, the Student's *t* test was used. When the supposition of normality was rejected, the non-parametric Mann-Whitney test was used. To evaluate homogeneity between proportions, the Chi-square method or Fisher's exact test were used, when expected frequencies lower than 5 occurred[14].

Results

Patients' data

Between January 2002 and August 2006, 261 patients were randomized for surgical treatment. Of these, 2 patients were excluded due to death in the operating room. As the treatment was not completed, the patients were excluded from the cost assessment, but not from the clinical results. Of the remaining 259 patients, 131 were submitted to surgery with ECC (SECC group) and the other 128 were submitted to surgery without ECC (WECC group). During surgery, two patients from the WECC group underwent ECC, as they presented hemodynamic instability. In this case, the costs of the additional interventions were added to the total cost. Additionally, the patients remained in the original group due to methodological reasons (intention to treat). The mean age of the patients referred to surgery with ECC was 60.3 years, whereas it was 61.4 years in the group without ECC. The distribution of patients with symptoms of angina graded by the Canadian Cardiovascular Association was similar in both groups. In the studied population, 67 patients (26%) had diabetes and 99 (38%) reported they had previously suffered an acute myocardial infarction. The distribution of the number of affected arteries and the degree to which the arteries were affected were similar in both groups. The other demographic, clinical, laboratory and angiographic characteristics are summarized in Table 1.

Clinical data

During the hospitalization period, two patients from the WECC group died. Still during this period, 43 patients (33.6%) from the WECC and 5 patients (3.8%) from the SECC groups presented atrial fibrillation ($p < 0.001$). Blood transfusion was necessary in 65 patients (49.6%) from the SECC group and in only 43 patients (33.6%) in the WECC group ($p < 0$,

.001). Myocardial infarction, respiratory infections, need for Swan-Ganz catheter use and other complications are shown in Table 2.

Surgical data

The time necessary to perform the operation was significantly shorter for the patients from the WECC group, when compared to the SECC group (3.9 ± 1.0 h *vs*. 4.9±1.1 h) ($p < 0.001$). The number of distal anastomoses was of 3.6 arteries per patient in the SECC group and 2.8 arteries in the WECC group, with a statistically significant difference ($p < 0.001$); thus, there was an incomplete revascularization in this group. However, the percentage of grafts performed with the mammary artery was similar in both groups: 92.3% and 94.5%, for the SECC and WECC groups, respectively. Table 3 shows the other surgical data.

Intensive care data

The ICU stay duration was significantly shorter for the patients from the WECC group, when compared to the SECC group: 29.2 ± 26.1 hrs *vs*. 48.2 ± 17.2 hrs ($p < 0.001$), respectively. This result contributes to a lower cost per patient in the WECC group. The time for artificial ventilation weaning was significantly lower in the WECC group, when compared to the SECC group: 6.4 ± 5.1 hrs *vs*. 9.2 ± 4.5 hrs ($p < 0.001$), respectively. Table 4 shows the other ICU data.

Hospital cost data

The costs resulting from medical complications of the surgical intervention were significantly lower in patients from the WECC group, when compared to the SECC group: 606.00 ± 525.00 *vs*. 945.90 ± 440.00 ($p < 0.001$), respectively. The costs reimbursed by the Public Health System, for each clinical complication, are shown in Table 5. These patients' longest ICU stay also contributed to the increase in costs: 717.70 ± 257.70 *vs*. 432.20 ± 391.70 ($p<0.001$), respectively. Table 6 shows the other data on hospital costs.

Discussion

The present study, carried out at a single institution, evaluated the comparative costs that were estimated for two techniques in routine myocardial revascularization surgery, based on the governmental resources paid by the Public Health System (SUS). This system reimburses for rendered services and for professionals and institutions through defined programs of fixed payment agreed between the parts. Based

Table 1 – Basal characteristics of patients at hospital admission

Characteristics	W/t ECC (n = 128)	With ECC (n= 131)	p
Demographic profile			
Age (yrs)	61.41	60.38	0.837
Age ≥ 65 yrs (%)	40.35	39.12	0.975
Male sex (%)	78.42	79.64	0.886
Smokers/ex-smokers (%)	67.39	68.13	0.932
Clinical history			
Myocardial infarction (%)	37.20	38.80	0.912
Hypertension (%)	36.60	34.15	0.831
Diabetes mellitus (%)	24.94	27.06	0.769
Angina class II or III (%)	34.56	34.06	0.967
Laboratory (mg/dl)			
Total cholesterol	224 ± 6	226 ± 4	0.918
LDL cholesterol	140 ± 12	138 ± 14	0.878
HDL cholesterol	38 ± 8	39 ± 7	0.911
Triglycerides	166 ± 10	170 ± 8	0.832
Glucose	102 ± 15	100 ± 12	0.981
Stress-induced ischemia (%)	82	80	0.885
Angiographic data			
Biarterial stenosis (%)	26.18	24.16	0.745
Triarterial stenosis (%)	73.82	75.84	0.856
Ejection fraction (mean)	65.68	64.58	0.908

W/t - without; ECC - extracorporeal circulation; p - statistical level of significance.

Table 2 – Perioperatory data and hospital complications

Variables	W/t ECC (n = 128)	With ECC (n= 131)	p
Surgical complications [n] (%)			
Ventricular Arrhythmia	[3] (2.4)	[4] (3.1)	0.898
Bleeding	[5] (3.9)	[6] (4.6)	0.889
Hemodynamic Instability	[6] (4.7)	[5] (3.8)	0.879
Intra-aortic balloon	[1] (0.8)	[1] (0.8)	1
Intraoperative death	[2] (1.6)	0	0.573
Inotropic drugs	[14] (11.0)	[16] (12.2)	0.913
Blood transfusion	[43] (33.6)	[65] (49.6)	<0.001
Atrial fibrillation	[43] (33.6)	[5] (3.8)	<0.001
Wound infection	[3] (2.3)	[2] (1.5)	0.757
Mediastinitis	[2] (1.6)	[2] (1.5)	0.984
Hemodialysis	[1] (0.8)	[1] (0.8)	1
Myocardial infarction	[6] (4.7)	[16] (12.2)	<0.003
Encephalic vascular accident	[2] (1.6)	[4] (3.1)	0.564
Bronchopneumonia	[6] (4.7)	[6] (4.6)	0.984

W/t - without; ECC - extracorporeal circulation; p - statistical level of significance.

Table 3 – Surgical data

Variables	W/t CEC (n = 128)	With CEC (n = 131)	p
Distal Anastomoses /patients	2.76	3.64	<0.001
Grafts/patients	2.55	3.15	<0.001
Types of grafts, number and (%)			
LITA	121 (94.5)	121 (92.3)	0.898
RITA	45 (36.0)	44 (35.5)	0.916
RADIAL	25 (20.1)	27 (21.0)	0.944
GEA	10 (7.8)	8 (6.1)	0.989
Venous grafts	114 (89.2)	126 (95.4)	0.899
Sequential grafts	26 (21.0)	24 (18.2)	0.621
Revascularized area (%)			
ADA area	96.49	98.23	0.844
CXA area	66.31	82.03	<0.001
RCA area	76.18	79.26	0.856

W/t - without; ECC - extracorporeal circulation; p - statistical level of significance; LITA - left internal thoracic artery; RITA - right internal thoracic artery; GEA - gastroepiploic artery; ADA - anterior descending artery; CXA - circumflex artery; RCA - right coronary artery.

Table 4 – Perioperative time

Variables	W/t CEC n = 128	With CEC n = 131	p
Time at the operating room (hours)	3.9 ± 1.0	4.9 ± 1.1	<0.001
ECC time (min)	NA	61.5 ± 28	NA
Change to ECC (n)	2	NA	NA
Clamping time (min)	NA	48.4 ± 10	NA
ICU time (hrs)	29.2 ± 26.1	48.2 ±17.2	<0.001
Time to extubation (hours)	6.4 ± 5.1	9.2 ± 4.5	<0.001

W/t - without; ECC - extracorporeal circulation; p - statistical level of significance; ICU - intensive care unit; NA - non-applicable.

Table 5 – Public health system payment refund

Variable	Monetary values in Reais (R$)	
Intensive care	(Daily cost)	363.31
Nursing care	(Daily cost) #	20.00
Blood transfusion	(Unit)	17.00
Atrial fibrillation	(Event)	200.00
Encephalic vascular accident	(Event)	430.00
Respiratory infection	(Event)	550.00
Acute myocardial infarction	(Event)	464.00
Swan-Ganz catheter	(Unit)	520.00

 # Reimbursements from the seventh day of hospitalization without ECC and tenth day with ECC.

Table 6 – Hospital costs

Variables (R$)	W/t CEC (n = 128)	Com CEC (n= 131)	p
Revascularization	6,271.26	4,358.70	(#)
Intensive Care	432.20 ± 391.70	717.70 ± 257.70	<0.001
All complications	606.00 ± 525.00	945.90 ± 440.00	<0.001

W/t - without; ECC - extracorporeal circulation; p - statistical level of significance; # Fixed payment made by the Public Health System for each surgery carried out in the absence of complications.

on this model, the payment for a myocardial revascularization surgery (MRS) depends on the type of technique employed and the extra resources applied by the surgical team and on the occurrence or absence of complications. Thus, considering the special nature of the governmental reimbursement that contemplates differentiated values for the same procedure, the comparative calculations among the types of payment have become complex. Additionally, this system arbitrates an additional payment: a percentage is defined for auxiliary teams that work in the operating room and also at the ICU. This picture routinely includes the surgical instrumentation professionals, professionals circulating in the operating room, perfusionists, nurses and physical therapists, for any type of cardiac surgery.

As a MRS with no complications results in expenses with little cost variation, it is possible to consider that both techniques can basically differ according to the use of additional disposable materials. On the other hand, the comparative costs of this surgery can increase if high-complex and high-cost resources are employed for one or the other type of technique used in the surgery.

Thus, to evaluate the comparative costs between the two techniques under these conditions, it is reasonable to consider that the shorter hospital stay, observed in one of the techniques, can directly lower the costs and, indirectly, protect the patients from hospital complications.

Therefore, the decrease in the duration of the operating room stay reduces operational costs, which include the use of catheters and aspirators or other resources that are pertinent to the employed technique. This assessment also applies to the ICU, when the aim is a shorter time of use of artificial ventilators and vasoactive drugs. A prolonged stay at the ICU facilitates the onset of hospital infections, with all the consequences generated by this condition. In addition to high-cost medications, necessary for controlling the events, it is necessary to consider the occasional use of Swan-Ganz catheters, intra-aortic balloons and hemodialysis circuit, among others, to appropriately manage a clinical complication. Our results, similar to those observed by Kobayashi et al[15], showed.

That the patients submitted to the surgery without ECC presented a significantly shorter operating room stay when compared to the patients that underwent the surgery with ECC ($p < 0.001$). Additionally, the duration of the ICU stay for patients submitted to the surgery without ECC was significantly shorter than for patients that underwent the surgery with ECC, similarly to that observed by another study[11]. Other results, concerning the cost analysis, did not show a decrease in the ICU stay for patients without ECC; however, all of them showed a shorter intubation time[16-18].

Our data also showed a shorter intubation time and ICU stay ($p < 0.001$ and $p < 0.001$, respectively). These results are supported by the fact that, in the present study, the ICU physicians were blinded to the research protocol and the extubation and ICU discharge criteria were maintained according to the operational routine.

The importance of the patients' extubation time in the mentioned studies[17,19] received a higher clinical attention, rather than an economical one. Furthermore, these authors did not consider, for the economic analysis, the ICU stay duration. Methodological and also administrative issues of these centers might have been considered at the analysis of such costs. In fact, studies performed to assess this strategy showed a significant decrease in costs in patients that underwent early extubation[19-21]. Additionally, the increased intubation time with a consequent increase in ICU stay, in patients without ECC, was observed in female patients when compared to male patients[22]. It was also observed a higher need for blood transfusion and hemoderivatives among women, with consequent increase in costs[22]. Although our study did not aim at this subanalysis, the number of women in our sample would not have statistical power to answer that question.

In our study, the data related to the need of blood transfusion showed a higher need of this resource in patients without ECC, when compared to the ones with ECC ($p = 0.006$). These data were frequently observed as being cost-reducing in other studies[5,10]. However, the comparative costs of blood transfusions in our sample took into account the fact that the Brazilian laws prevent the reimbursement of blood transfusions and use of hemoderivatives. Similar conditions were observed in a study carried out in Canada, from which the calculations were excluded, considering that the distribution of blood by the governmental organs is free of cost[11].

The payment of qualified personnel, at the operating room and ICU, is another item with a relevant weight at the calculation analysis of each procedure[8]. In our study, the calculation of the payment received by professionals that belong to the Public Health System was not carried out, as the values pertinent to each activity were already part of the governmental reimbursement contracts. However, only the professionals involved with the ECC circuit had their costs considered separately, as this resource was not used for patients that underwent surgery without ECC.

Although the resources for the ECC circuit were not used in these patients, contributing to the cost decrease, these patients needed stabilizers in all interventions. Thus, the use of these additional resources resulted in cost increase related to this topic and were, therefore, reimbursed by the government.

Several studies did not use stabilizers in all patients and, in many of them the equipment is re-usable[8-18]. The criteria for these procedures have not been discussed in depth; however, to ensure our patients' safety, especially those in whom the procedure involved the revascularization of latero-posterior wall of the left ventricle, the use of stabilizer was considered mandatory for all the patients in this group.

Final considerations

As the surgical procedures, due to their interventionist nature, involve predictable and unpredictable clinical complications, not only for the patients, but also for the hospitals, as well as the increase in costs of the public or private finance organs, it is justifiable to research which mechanisms can contribute to decrease clinical complications, as well as costs of these interventions.

In this context, the medical interventions directed at the treatment of ischemic cardiopathy have contributed to this objective. The progress in the modernization of percutaneous

interventions and, now, with surgical interventions without the extracorporeal circulation circuit, follows such model. Furthermore, although this search is little measureable from an economic point-of-view, the clinical benefits can be clearly observed.

It is incontestable that a shorter stay at the operating room, shorter intubation time, shorter stay at the ICU and, finally, shorter hospital stay contribute to minimize the patient's suffering and prevent postoperative clinical complications.

Following the same line of thought, although these data are not mathematically measurable, the decreased stay in these units leads to the decrease in intuitively accepted hospital costs.

Transporting this interpretation to tertiary hospitals, of which objective is focused on elective procedures, the decrease in hospital stay duration has a social and economic nature.

Thus, considering that in our hospital, the number of elective myocardial revascularization procedures is close to 1,000 interventions/year, for a period of 220 working days/year, the decrease in the hospital stay duration by 25% would increase the capacity of receiving new patients by 250 patients/year.

These data alone would support seeking safer procedures, with shorter hospital stay duration and at a lower social cost.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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