Original Article

Myocardial Revascularization Surgery without Extracorporeal Circulation Minimizes Postoperative Bleeding and the Need for Transfusion

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Objective

To compare myocardial revascularization (MR) with and without extracorporeal circulation (ECC) in regard to postoperative bleeding and the need for blood and hemoderivate transfusion.

Methods

From November 2001 to February 2002, 186 patients undergoing myocardial revascularization were assessed, excluding those who underwent associated procedures. The patients were divided into 2 groups as follows: group A – comprising 116 patients undergoing MR with ECC; and group B – comprising 69 patients undergoing MR without ECC. Both groups were comparable in regard to pre- and intraoperative characteristics, except for the greater number of distal anastomoses (P=0.0004) in group A, and greater prothrombin activity (P=0.04) and INR (P=0.03) in group B. To avoid discrepancies between the groups, 140 patients with statistically similar characteristics were selected.

Results

Studying the paired groups, both the total bleeding volume in 24 hours (P=0.001) and the bleeding volume indexed for body surface (P=0.004) were greater in group A (609.6 ± 395.8 mL; 331.8 ± 225.8 mL/m^2, respectively) than in group B (437.2 ± 315 mL; 241 ± 173.9 mL/m^2, respectively). Although the need for transfusion was not significantly different between the groups (P=0.1), the amount of erythrocyte concentrate transfused was greater in group A (P=0.01). No statistical difference was observed in regard to transfusion of other hemocomponents and the need for surgical review of hemostasis.

Conclusion

Myocardial revascularization without ECC was more advantageous than MR with ECC in regard to smaller postoperative blood loss and a lesser need for transfusion of erythrocyte concentrate. The repercussions of this finding may be innumerable, particularly in regard to minimization of morbid factors and hospital costs.

Key words

myocardial revascularization, extracorporeal circulation, mediastinal bleeding, blood transfusion.

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Bleeding and the complications related to hemotransfusion continue to be 1 of the major factors of morbidity and mortality in cardiac surgery. Knowledge about the risk factors [1] for this complication is fundamental for the adoption of therapeutic and preventive measures.

However, the multifactorial nature of the problem requires the implementation of universal protocols [2], invariably implying alterations in coagulation caused by extracorporeal circulation. The methods proposed to minimize blood loss in cardiac surgery include the use of cell saver [3], autotransfusion[4], heparin-bonded circuits [5], leukocyte filters [6], and antifibrinolytic drugs [7]. The disadvantages of these methods reside in their elevated costs for routine, wide implementation.

The advent of myocardial revascularization without extracorporeal circulation has renewed interest in this field due to incorporation of new technology and knowledge of its results, confirming its feasibility in a large group of patients [8]. Recent studies [9,10] have suggested that this technique reduces postoperative bleeding, the need for transfusion, and hospital costs. Few studies specifically analyze smaller blood loss as an advantage of myocardial revascularization without extracorporeal circulation, with relevant implications in terms of postoperative morbidity.

This study aimed at comparing myocardial revascularization with and without extracorporeal circulation in regard to postoperative bleeding and the need for blood and hemoderivate transfusion.

Methods

From November 2001 to February 2002, 186 consecutive patients with coronary heart disease indicated for surgical treatment were assessed in a prospective nonrandomized study. Patients undergoing associated surgical procedures were excluded.

The patients were divided into 2 groups according to the type of myocardial revascularization performed, which was decided by the clinicosurgical staff responsible for each case. The authors did not participate in the selection of the type of surgical treatment adopted.

Group A comprised 116 patients undergoing myocardial revascularization with extracorporeal circulation, and group B comprised 69 patients undergoing MR without extracorporeal circulation. The male sex predominated in both groups, 93 (80.2%) male patients in group A and 47 (68.1%) in group B. The ages ranged from 37 to 84 (mean of 62.5 ± 10.4) years in group A, and from 43 to 84 (mean of 64.9 ± 10.8) years in group B. No patient required, due to technical difficulties, the conversion of myocardial revascularization without extracorporeal circulation to MR with extracorporeal circulation.

Group A patients were conventionally anesthetized and prepared. The access route was a median sternotomy, followed by a longitudinal pericardiotomy. Extracorporeal circulation was instituted after administration of 4 mg/kg of heparin to obtain an activated clotting time (ACT) > 480 seconds. In our institution, cannulation of the ascending aorta is performed in sites with no atheromatous processes, and double venous cannulation or a 2-stage cannula is used in the right atrium according to the surgeon's preference. The arterial flow is kept around 2.4 $L/m^2/min^{-1}$, to maintain mean arterial blood pressure between 50 and 70 mm Hg. Most surgeons in our institution adopt mild systemic hypothermia, but some prefer normothermia. The myocardial protection chosen was cold blood or normothermic cardioplegia, or even intermittent aortic clamping, depending on the preference of the surgical team. After leaving extracorporeal circulation and replacing the priming volume, circulating heparin was neutralized by the administration of protamine in the proportion of 1:1 in regard to heparin.

Group B patients were anesthetized and prepared as were group A patients, ensuring that adequate blood volume was maintained (preferential administration of colloid solutions) and that heart rate was controlled with the administration of intravenous metoprolol. All patients underwent conventional median sternotomy, with reduced cutaneous extension for esthetic purposes. After opening the pericardium and dissecting the grafts to be used for myocardial revascularization, heparin was administered at the dosage of 2 mg/kg to maintain the activated clotting time 2 times its baseline value. Tying off of the coronary artery to be revascularized was routinely performed in the proximal portion of the vessel. A 4-0 polypropylene thread or a Silastic thread (Quest Medical, Inc., Dallas, TX) was used anchored in delicate silicone tubes and carefully pulled prior to arteriotomy due to the risk of vascular lesion [11]. Distal anastomoses were performed with the aid of an Octopus III stabilizer (Medtronic, Minneapolis, MN). Intracoronary shunt was used in most cases, especially in large-caliber arteries and those responsible for the blood supply in a significant myocardial area in the absence of collateral circulation. Proximal anastomosis of the venous grafts was performed by use of partial clamping of the aorta, or in Y anastomoses with the internal thoracic artery. After performing the last anastomosis, circulating heparin was neutralized with the administration of protamine in a ratio of 0.5:1 in regard to heparin.

Postoperative bleeding was determined through the addition of the 24-hour output of all thoracic drains from the moment of thoracic closure onwards. Postoperative management was performed by a multidisciplinary team, including a cardiologist, an intensive care professional, a cardiovascular surgeon, and a hematologist. The latter was responsible for indicating transfusion of the hemocomponents. The authors of this study did not interfere with the correction of postoperative coagulation disorders, indication of blood or hemoderivate transfusion, or both, and surgical revision of hemostasis. Each case was individually analyzed in regard to the need for hemotransfusion, considering the hemodynamic conditions, the bleeding volume, the patient's age, and the history of hemorrhagic disorders. The professionals involved in postoperative care knew nothing about this study and its objectives.

Some criteria for the transfusion of hemocomponents were adopted. Any bleeding considered significant (150 mL/h) in the immediate postoperative period was treated according to the result of the coagulogram. Alterations in laboratory tests in the absence of bleeding did not indicate any type of treatment. The use of protamine was indicated in the enlargement of activated partial thromboplastin time (APTT) or activated clotting time, when available, or when recirculation of heparin was suspected. When alterations in prothrombin activity (PA) or in international normalized ratio (INR) occurred, transfusion of fresh frozen plasma was indicated. Platelet count below 100,000 per microliter in the presence of bleeding indicated the need for transfusion of that hemocomponent. Hematocrit below 28% was corrected by transfusion of erythrocyte concentrate. However, in young patients with myocardial reserve, a hematocrit as low as 20% was tolerated without the need for transfusion. The indication of surgical revision of hemostasia took some individual variations into consideration, but was usually established when blood loss was greater than 500 mL in the first hour, greater than 300 mL for 2 consecutive hours, or greater than 1 liter in the first 8 hours.

To determine the homogeneity between the groups, they were compared in regard to several preoperative (tab. I) and intraoperative (tab. II) characteristics. The preoperative characteristics assessed were as follows: age, sex, weight, height, presence of arterial hypertension, ejection fraction below 50% estimated using 2-dimensional echocardiography, Canadian Cardiology Society functional class, dialysis-dependent chronic renal failure, coagulogram with platelet count, and use of aspirin, heparin, thrombolytic agents, and IIb/IIIa protein inhibitors. The intraoperative characteristics analyzed were as follows: emergency surgery, reoperations, use of e-aminocaproic acid, and number of internal thoracic arteries and bypass grafts used for myocardial revascularization.

The statistical analysis was performed using Statview software (Berkeley, CA). The data were expressed as means and standard deviations or as percentages. The statistical significance level adopted was $P < 0.05$. The Fisher exact test and chi-square test were used for the analysis of categorical variables, and the Student *t* test and Wilcoxon test were used for the analysis of continuous variables.

Results

Table I shows the comparison between groups A and B in regard to the pre- and intraoperative characteristics. Both groups were considered comparable in regard to all characteristics, except for the greater number of distal anastomoses (P=0.0004) in group A, and the greater prothrombin activity (P=0.04) and international normalized ratio (P=0.03) in group B, although these values were within the normal range in both groups.

Aiming at ruling out these differences between the groups, both underwent selection using the method of the probabilities, and a subgroup of 140 patients was selected. Group A1 comprised 71 patients and group B1 comprised 69 patients. The pre- and intraoperative characteristics were statistically similar, as shown in tables II and III.

Both the total bleeding volume in 24 hours (P= 0.001) and the bleeding volume indexed for body surface (P= 0.004) were

Table I - Pre- and intraoperative characteristics of the groups of myocardial revascularization with ECC (A) and without ECC (B)

	Group A (n=116)	Group B (n=69)	P
Age (years)	62.5 ± 10.4	64.9 ± 10.8	0.15
Male	93 (80.2%)	47 (68.1%)	0.90
Weight (kg)	74 ± 12.7	72.5 ± 12.8	0.46
Height (cm)	167.1 ± 8.8	165.1 ± 9.3	0.20
SAH	91 (78.4%)	48 (69.6%)	0.22
EF<50%	23 (19.8%)	10 (14.5%)	0.43
FC	2.12	2.23	0.9
ASA	39 (33.6%)	29 (42%)	0.27
Heparin	29 (25%)	16 (23.2%)	0.86
Thrombolytic agents	1 (0.9%)	1 (1.4%)	0.99
CRF	11 (9.5%)	10 (14.5%)	0.34
IIb/IIIa protein inhibitors	13 (11.2%)	8 (11.6%)	0.99
PA (%)	86.2 ± 13.1	90.3 ± 12.2	0.04*
INR	1.13 ± 0.1	1.08 ± 0.1	0.03*
APTT (seconds)	32.5 ± 13.2	31.5 ± 9.2	0.57
TD/TR	1.13 ± 0.4	1.12 ± 0.3	0.68
Platelet count	236.1 ± 39.2 x10^3	238.4 ± 26.7 x10^3	0.8
Previous MR	5 (4.3%)	4 (5.8%)	0.73
Emergency	10 (8.6%)	3 (4.3%)	0.38
EACA	16 (13.8%)	4 (5.8%)	0.14
1 ITA	84 (72.4%)	56 (81.2%)	0.24
2 ITA	16 (13.8%)	7 (10.1%)	0.65
Number of bypass grafts	3.1 ± 0.8	2.5 ± 0.9	0.0004*

* Statistically significant; ECC - extracorporeal circulation; SAH - systemic arterial hypertension; EF - ejection fraction on 2-dimensional echocardiogram; FC - functional class; ASA - use of aspirin up to 5 days prior to surgery; CRF - dialysis-dependent chronic renal failure; PA - prothrombin activity; INR - international normalized ratio; APTT - activated partial thromboplastin time; TD/TR - activated partial thromboplastin times ratio; MR - myocardial revascularization; EACA - epsilon aminocaproic acid; ITA - internal thoracic artery.

Table II - Preoperative characteristics of 140 patients undergoing myocardial revascularization with ECC (A1) and without ECC (B1)

	Group A1 (n=71)	Group B1 (n=69)	P
Age (years)	62.9 ± 9.8	64.9 ± 10.8	0.29
Male	57 (80.2%)	47 (68.1%)	0.74
Weight (kg)	74.2 ± 12.9	72.5 ± 12.8	0.43
Height (cm)	167.9 ± 8.1	165.1 ± 9.3	0.14
SAH	54 (76.1%)	48 (69.6%)	0.39
EF<50%	14 (19.7%)	10 (14.5%)	0.41
FC I	5 (7%)	7 (10.1%)	0.35
II	36 (50.7%)	28 (40.9%)	
III	24 (33.8%)	31 (44.9%)	
IV	6 (8.4%)	3 (4.3%)	
ASA2	4 (33.8%)	29 (42%)	0.31
Heparin	16 (22.5%)	16 (23.2%)	0.93
Thrombolytic agents	0	1 (1.4%)	0.23
CRF	5 (7%)	10 (14.5%)	0.15
IIb/IIIa protein inhibitors	7 (9.9%)	8 (11.6%)	0.74
PA (%)	87.3 ± 14.6	90.3 ± 12.2	0.2
INR	1.12 ± 0.2	1.08 ± 0.1	0.08
APTT (seconds)	31.2 ± 6.1	31.5 ± 9.2	0.78
TD/TR	1.08 ± 0.2	1.12 ± 0.3	0.42
Platelet count	240 ± 69.9 x10^3	238.4 ± 26.7 x10^3	0.58

ECC - extracorporeal circulation; SAH - systemic arterial hypertension; EF - ejection fraction on 2-dimensional echocardiogram; FC - functional class; ASA - use of aspirin up to 5 days prior to surgery; CRF - dialysis-dependent chronic renal failure; PA - prothrombin activity; INR - international normalized ratio; APTT - activated partial thromboplastin time; TD/TR - activated partial thromboplastin times ratio.

greater in group A1 (609.6 ± 395.8 mL; 331.8 ± 225.8 mL/m^2, respectively) as compared with those in group B1 (437.2 ± 315 mL; 241 ± 173.9 mL/m^2, respectively). Although the need for transfusion did not significantly differ between the groups (P= 0.1), the volume of erythrocyte concentrate transfused was greater in group A1 (P= 0.01). No statistically significant difference was observed in regard to the volumes of fresh frozen plasma, cryoprecipitate, and platelet concentrates transfused, and the need for surgical revision of hemostasia (tab. IV).

Figure 1 shows the greater need for transfusion of erythrocyte concentrate in group A1 as compared with that in group B1. This difference was more pronounced when 3 or more units of erythrocyte concentrate were used per patient.

Discussion

Bleeding in the postoperative period of cardiac surgery continues to be a problem, particularly with the appearance of more complex procedures with prolonged extracorporeal circulation and interventions in acutely decompensated patients. Bleeding and the consequent surgical reexploration, with frequently associated polytransfusion, account for an elevation in the morbidity and mortality indices in cardiac surgery [12,13].

Despite improvement in the methods of selection of donors, a risk related to transfusion of blood and its components, such as viral infections, induction of transfusional reactions of immunological origin, and suppression of the immune system, exists [14].

Perioperative bleeding is related to the surgical damage of blood vessels and defects in the hemostatic mechanisms. Most of the latter relate to exposure of the nonsuspended, formed elements of the blood to the extracorporeal circuit. Extracorporeal circulation has been proven to cause alterations in hemostasia, such as a reduction in the level of clotting factors, stimulation of fibrinolysis, induction of a reduction in the number of platelets, disseminated intravascular coagulation, and platelet dysfunction, in addition to effects on circulating heparin and protamine [15].

Table III - Intraoperative characteristics of 140 patients undergoing myocardial revascularization with ECC (A1) and without ECC (B1)

	Group A1 (n=71)	Group B1 (n=69)	P
Previous MR	5 (7%)	4(5.8%)	0.76
Emergency	6(8.5%)	3(4.3%)	0.31
EACA	10(14.1%)	4(5.8%)	0.1
1 ITA	52(73.2%)	56(81.2%)	0.26
2 ITA	8(11.3%)	7(10.1%)	0.83
Number of bypass grafts	2.6 ± 0.5	2.5 ± 0.9	0.13

MR - myocardial revascularization; EACA - epsilon aminocaproic acid; ITA- internal thoracic artery.

Table IV - Bleeding volume, transfusional need, and surgical revision of the hemostasia in the subgroups of myocardial revascularization with ECC (A1) and without ECC (B1)

	Group A1 (n=71)	Group B1 (n=69)	P
Bleeding** (mL)	609.6 ± 395.8	437.2 ± 315	0.001*
Indexed bleeding† (mL/m²)	331.8 ± 225.8	241 ± 173.9	0.004*
Transfusion	30 (42.3%)	21 (30.4%)	0.1
EC (units)	0.99 ± 1.54	0.54 ± 0.99	0.01*
FFP (units)	0.53 ± 0.99	0.39 ± 1.01	0.1
Cryoprecipitate (units)	0.15 ± 0.92	0.09 ± 0.72	0.58
Platelet concentrate (units)	0.08 ± 0.71	0	0.32
Revision of hemostasia	0	0	-

* Statistically significant; ** Total bleeding volume through the thoracic drains during 24 hours (milliliters); † Total bleeding volume in milliliters divided by body surface in m²; EC - erythrocyte concentrate; FFP - fresh frozen plasma.

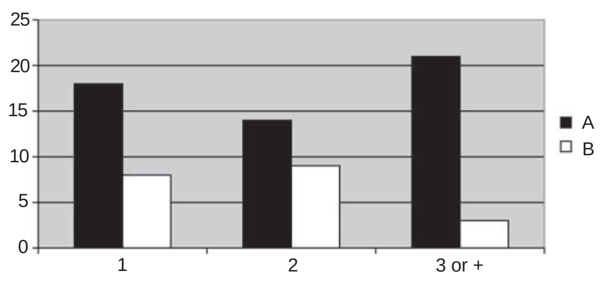

Fig. 1 - Number of patients receiving transfusion of erythrocyte concentrate (units) in both groups.

Thus, avoiding the use of extracorporeal circulation would theoretically be advantageous in regard to postoperative bleeding. Recent studies [9,10] have confirmed this hypothesis.

Myocardial revascularization surgery without extracorporeal circulation has progressively stood out in the treatment of coronary artery disease with excellent results [8,16,17]. In the mid 1990s, boosted by the advantages of minimally invasive surgery [18], with more rapid recovery and esthetic superiority, the applicability of myocardial revascularization surgery without extracorporeal circulation was restricted to the treatment of single-vessel lesions limited to the anterior interventricular branch of the left coronary artery. Technological development, especially the use of stabilizers [19], in addition to surgical experience [20], allowed the safe treatment of the posterior arteries of the heart [21], spreading the acceptance of the technique among surgeons and cardiologists. Recently, due to the suggestion that myocardial revascularization without extracorporeal circulation reduces morbidity in the surgical treatment of coronary artery disease, its indications expanded to the following patients: those with multivessel disease [22], high-risk patients [23], patients with chronic renal diseases [24], the elderly [25], and those with ventricular dysfunction [26].

Although most authors support the hypothesis that myocardial revascularization without extracorporeal circulation is associated with lower morbidity, this is still controversial [27,28]. The impact in regard to hospital costs is evident, stimulating even more the comparative studies between the techniques. In recent years, the literature has been enriched with several case series of different national and international centers, analyzing the issue. However, the methodological limitations of these studies hinder definitive conclusions, and prospective, randomized studies with careful methodology are required. Such studies should include patients with similar clinical characteristics, who could be treated according to both techniques. Because the indications of myocardial revascularization without extracorporeal circulation have been expanded, inclusion criteria have been difficult to establish. On the other hand, if the exclusion criteria were very broad, because of the low incidence of postoperative complications, thousands of patients would be required in each group to obtain statistical significance.

The expansion in the indications of myocardial revascularization without extracorporeal circulation has been reflected in the treatment. Comparative studies at the end of the 1990s [23] showed that patients referred for myocardial revascularization with extracorporeal circulation were traditionally more severely ill in regard to the number of risk factors and extension of coronary and systemic atherosclerosis, were older, more symptomatic, and more prone to urgent operations. The current scenario has changed drastically, and our case series reflects this tendency very well. Both groups were considered comparable, except for the greater number of bypass grafts in the group with extracorporeal circulation, which may indirectly indicate a greater extension of coronary artery disease, because we have adopted the concept of complete myocardial revascularization. No differences were observed in regard to the presence of ventricular dysfunction, coronary artery reoperations, emergency surgeries, and the use of the internal thoracic artery, reflecting the reproducibility of myocardial revascularization without extracorporeal circulation in several clinical situations.

The differences initially found between the groups could be eliminated by the selection of a subgroup with similar pre- and intraoperative characteristics, which enriched the results of this case series. Thus, a greater incidence of bleeding and transfusion of erythrocyte concentrate occurred in the group with extracorporeal circulation. The repercussions of these findings in regard to morbidity and mortality were not assessed. Nader et al [9], retrospectively studying 2 similar groups of patients, found a lower incidence of bleeding and transfusions in the group of myocardial revascularization without extracorporeal circulation. Those authors attribute that finding to the partial heparinization of that group. In our opinion, the determining factor for this difference may be the clotting alterations triggered by extracorporeal circulation. Although we did not assess the activated clotting time in the postoperative period, the comparison between both groups showed that the group without extracorporeal circulation received partial neutralization of heparin, having, therefore, a greater tendency to bleed, if only this factor was considered.

Ascione et al [10], in a prospective randomized study in groups with low preoperative risk, found a 1.6 times greater incidence of bleeding in the group with extracorporeal circulation than in that without extracorporeal circulation. Less than 20% of the patients in the latter group required a blood transfusion as compared with more than half in the former group. The repercussions of these findings in regard to hospital costs were significant, in agreement with that in other studies [16]. Although, Sabik et al [28] reported a lower incidence of transfusions in the group without extracorporeal circulation, they also reported 13% greater direct costs in that group, attributed to expenses for equipment and a longer duration of surgery.

The limitations of our study include the lack of randomization in the groups, with defined criteria of patient selection. Variation in the surgical teams also occurred, reflected in the perfusion surgical technique, and mainly in the experience of the health aides, with a direct effect on the revision of hemostasia prior to thoracic closure. In addition, the dosages of heparin and protamine were not uniform in both groups, which may have directly influenced the results.

In conclusion, myocardial revascularization without extracorporeal circulation has advantages as compared with myocardial revascularization with extracorporeal circulation, in regard to the lower incidence of bleeding in the postoperative period and lesser need for transfusion of erythrocyte concentrate. The repercussions of this finding may be innumerable, mainly in regard to minimizing morbid factors and hospital costs. Other factors of morbidity should be analyzed in prospective, randomized studies, aiming at defining the actual role played by myocardial revascularization without extracorporeal circulation in the surgical treatment of coronary artery disease.

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