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Coronary artery bypass grafting with composite grafts: comparison of blood flow to the left coronary artery with the conventional technique

Revascularização cirúrgica do miocárdio com enxerto composto de artérias torácica interna esquerda e radial: comparação do fluxo sangüíneo para artéria coronária esquerda com a técnica convencional

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Abstract

Background: **Composite grafting techniques for coronary artery bypass grafts (CABG) have been widely used. However, it remains unclear whether this technique provides similar blood flow to the left coronary artery when compared to the conventional alternative. We sought to compare the total blood flow to the left coronary branches that are revascularized with left internal thoracic (LITA) and radial artery (RA) grafts using composite and non-composite techniques.**

Method**: A total of 42 patients were randomly assigned to three groups according to the CABG technique to be used: Group A or composite LITA-RA in a Y format (n=14); Group B or modified composite LITA-RA intercoronary graft with RA and LITA to RA at the left anterior descending artery (LAD-n=14)|; and Group C or pedicled LITA to the LAD and aorto-coronary RA (n=14). The patients were submitted to postoperative blood flow velocity analysis using a 0.014 inch 12 MHz Doppler flowire. Coronary flow reserve (CFR) was calculated by determining the average hyperemic peak velocity (APV) after an injection of adenosine.**

Results**: Proximal LITA baseline APV was 28.4 ± 4.8 cm/s in group A, 34.4 ± 7.9 cm/s in group B (*p*=0.0384 x C) and 25.8 ± 8.6 cm/s in group C. The CFR was 2.1 ± 0.4, 2.0 ± 0.3 and 2.0 ± 0.4 in groups A, B and C respectively (*p*=0.7208 A, B x C). The total Q to LCA branches was 110 ± 30 in group A, 145 ± 59 in B and 133 ± 58 mL/min in C (*p*=0.3232 A, B x C).**

Conclusions: **The LITA-RA composite graft maintains an adequate CFR and conveys similar blood flow to the left coronary artery branches when compared with conventional CABG technique.**

Descriptors**: Mammary arteries. Radial artery. Blood flow velocity. Cardiovascular surgical procedures. Myocardial revascularization, methods.**

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Resumo

Introdução: **Os enxertos compostos têm sido freqüentemente utilizados na cirurgia de revascularização do miocárdio (RM). Entretanto, permanece indefinido se essa técnica é capaz de oferecer o mesmo fluxo sangüíneo (Q) aos ramos da artéria coronária esquerda (CE) que a técnica convencional. O objetivo é comparar o Q total aos ramos revascularizados pelas artérias torácica interna esquerda (ATIE) e radial (AR) nas técnicas compostas e convencional.**

Método: **Estudamos 42 pacientes distribuídos, aleatoriamente, conforme a técnica de RM utilizada. Grupo A ou ATIE e AR composta em Y (n=14). Grupo B ou ATIE e AR composta modificada [enxerto intercoronariano com AR e anastomose da ATIE sobreposta a AR ao nível da artéria interventricular anterior (DA), n=14]. Grupo C ou ATIE pediculada para DA e AR em posição aorto-coronariana (n=14). Trinta e um pacientes foram submetidos a fluxometria (Fx) com cateter-guia doppler de 12-MHz (0,014 polegada, Flowire, Jometrics Inc.), no pós-operatório imediato. A reserva de fluxo coronariano (RFC) foi calculada pela determinação da média da velocidade de pico (APV) em hiperemia após administração de adenosina.**

Resultados: **A APV em repouso no início da ATIE foi, no grupo A, 28,4±4,8 cm/s; no grupo B, 34,4±7,9 cm/s (*p*=0,0384 x C) e, no grupo C, 25,8± 8,6 cm/s. A RFC foi de 2,1 ± 0,4, 2 ± 0,3 e 2±0,4 nos grupos A, B e C, (p=0,7208). O Q total distribuído aos ramos da CE revascularizados foi, no grupo A, 110±30 ml/min, no grupo B, 145±59 ml/min e, no grupo C, 133±58 ml/min (*p*=0,3232 A, B x C).**

Conclusões: **Não houve diferença significativa do Q total oferecido ao território da CE revascularizado pelas técnicas de EC e convencional. A RFC da ATIE nos grupos compostos foi satisfatória.**

Descritores: **Artérias mamárias. Artéria radial. Velocidade do fluxo sangüíneo. Procedimentos cirúrgicos cardiovasculares. Revascularização miocárdica, métodos.**

INTRODUCTION

The good results obtained with the grafting of the left internal thoracic artery (LITA) [1] have widely stimulated the utilization of arterial grafts in surgical myocardial revascularization.

The utilization of two internal thoracic arteries has given benefits [2], but this can be associated with a greater morbidity in obese and diabetic patients [3].

The radial artery (RA), in spite of its easy dissection and handling, initially demonstrated unfavorable results as evidenced by cineangiography. However, with modifications in the surgical dissection technique, in the preparation and handling of the graft, the RA was safely reintroduced for the treatment of coronary artery disease [4]. This graft now gives good results over the long term [5-7].

With experience, it seemed evident that the different sizes between the wall of the RA and the wall of the ascending aorta could compromise the proximal anastomosis of the graft.

Based on works of anastomosis of the right internal thoracic artery (RITA) in the LITA [8-10], some surgeons started to anastomose the RA proximally to the left internal thoracic artery, to revascularize the branches of the left coronary artery (LC) [11] giving the same results in the postoperative period when compared to the RITA under the same conditions [12,13] or the RA anastomosed proximally to the aorta [7].

In composite arterial grafts, all the blood flow (Q) distributed to the revascularized arteries is from the LITA. This can lead to the question about if the blood flow available from the LITA is enough to irrigate the myocardium or, if in the composite arterial grafting technique we offer the same quantity of blood as the conventional technique to the revascularized territory of the left coronary artery.

Thus, it is the aim of this work to compare the total blood flow to the revascularized branches supplied by the left internal thoracic and radial arteries using the composite arterial graft and the conventional techniques. Conventionally, the LITA was anastomosed to the left anterior descending artery and a second graft (in this study the radial artery) in the aorto-coronary artery position, revascularized other branches of the left coronary artery.

METHOD

Clinical-surgical aspects

Forty-two patients (35 male) were enrolled, after written consent was obtained, to participate in the study between January 2003 and March 2004. The inclusion criteria were: clinical diagnosis of stable angina, unstable angina or myocardial infarction and patients who presented lesions of the coronary arteries requiring surgical treatment, age less than or equal to 65 years old; modified Allen test negative; coronary anatomy compatible with the utilization of the arterial grafts; lesions equal to or greater than 60%, a good distal arterial bed and a left ventricle ejection fraction > 40%. We excluded patients who: did not want to participate in the study; presented with a positive modified Allen test; those with suspicion of an obstructive lesion of the left subclavian artery; with inadequate blood flow or calcifications of the LITA or the RA; with mechanical complications of acute myocardial infarction or associated or congenital valvar heart disease; or those who had undergone prior heart surgery.

The work was approved by the Ethics Committee of the institution. Classification of the study was a randomized clinical trial.

The clinical characteristics and the risk factors are shown in Table 1.

Table 1. Clinical and operative variables of patients submitted to coronary artery bypass grafting

	Group A (n=14)	Group B (n=14)	Control Group (n=14)	*p-value*
Age (years)	53±5	50±8	54±6	0.321
Gender (M/F)	13/1	10/4	12/2	0.459
Hypertension (nº)	8 (61.5%)	11 (78.6%)	11 (78.6%)	0.612
Dyslipidemia (nº)	10 (71.4%)	10 (71.4%)	7 (50%)	0.353
Diabetes (nº)	2 (14.3%)	5 (35.7%)	4 (28.6%)	0.558
Smokers (nº)	5 (35%)	4 (28.6%)	7 (50%)	0.525
Stable angina (nº)	9 (64.3%)	9 (64.3%)	9 (64.3%)	1.0
Current and prior MAI (nº)	6 (42.9%)	3 (21.4%)	6 (42.9%)	0.373
CPB time (min)	87±24	93±14	92±15	0.688
anoxia time (min)	58±17	58±9	62±12	0.656
Revasc. Left coronary artery branches (nº)	2.7±0.5	2.7±0.5	2.5±0.6	0.494
Total arteries grafted (nº)	3.7±0.9	3.6±0.6	3.8±0.7	0.746
RITA (nº)	3	3	3	1.0
Saphenous (nº)	8	6	10	0.311

The radial artery was dissected together with tissue and adjacent veins from the non-dominant arm and prepared. The left internal thoracic artery was dissected with pedicle and both grafts were soaked in papaverine (50 mg/20 mL saline solution).

According to the surgical technique employed, the patients were randomly distributed in three groups, Group A or LITA and composite RA in Y, Group B or LITA and modified composite RA and Group C or pedicled LITA to left anterior descending artery and RA in aorto-coronary artery position (conventional or control). The difference in the composite groups consisted in: Group A – after anastomosis with the other branches of the left coronary artery, the RA was anastomosed proximally to the medial portion of the LITA; Modified Group an inter-coronary artery graft of the radial artery was performed and the LITA was anastomosed on the RA at the left anterior descending artery.

All patients were submitted to cardiopulmonary bypass (CPB), with mild systemic hypothermia (32-34 ºC) and intermittent clamping of the aorta. Soon after the CPB was removed venous nitroglycerin was used for 48 hours, which was substituted by an oral calcium channel blocker.

Heart catheterism and flowmetry

Coronary cineangiographic study and flowmetry were performed in the immediate postoperative period (about the seventh day of the postoperative period), via the femoral artery using a 6F sheath.

The mean peak velocity time and the coronary flow reserve were measured in the initial portion of the LITA (3 cm from its source) in all the groups and in the initial portion of the RA, when this graft was used in the aorto-coronary position.

For this, a 175-cm long, 12-MHz Doppler guide wire with 0.014 inch (0.035 cm) of diameter (Flowire, Cardiometrics Inc) was utilized [14]. The measurements were made at rest and in hyperemia induced using 30 µg of adenosine in the graft. The coronary flow reserve consisted of the ratio of the peak velocities in hyperemia and at rest.

The blood volume flow in the proximal portion of the grafts was calculated by the Doucette method utilizing the mean velocity and the cross-sectional area of the graft. This area was obtained after determining the graft diameter by angiography using the QCA analysis program – CMS version 5.1 to analyze the outline of the vessel. The absolute dimensions were calculated using the diameter of the diagnostic catheter as a reference.

Statistical analysis

The data were analysed using the SPSS version 10.0 and GraphPad Prism 4.0 programs. The values are expressed as means ± standard deviation. For qualitative variables the Fisher exact test was used. For quantitative variables with normal distributions, analyses of variance, the Bartlett test (for variance equality) and the Bonferroni test (for multiple comparisons) were employed. For the quantitative variables with non-normal distribution the Kruskal-Wallis non-parametrical test was utilized. A value of $p < 0.05$ was considered statistically significant.

RESULTS

Clinical –surgical results

Each group was formed of 14 patients. There was no hospitable mortality. A mean of 2.7 ± 0.5 left coronary artery branches were revascularized in Group A, 2.7 ± 0.5 branches in Group B and 2.5 ± 0.6 in Group C (p-value = 0.494 A, B x C). The surgical variables are shown in Table 1. Complications in the postoperative period were infection of surgical wound (four cases), perioperative myocardial infarction (two cases), transitory ischemic collapse (one case) – soon after the angiographic study, transitory hypoperfusion of the left forearm (one case), transitory paresthesia of the thumb (one case) and atrial fibrillation (four cases).

Angiographies

Thirty-five patients were submitted to cardiac catheterism in the immediate postoperative period (Figures 1 and 2). At the moment of the examination, there were no significant differences in the arterial blood pressure, heart rate or the hematocrit among the groups. In 31 cases flowmetry was possible.

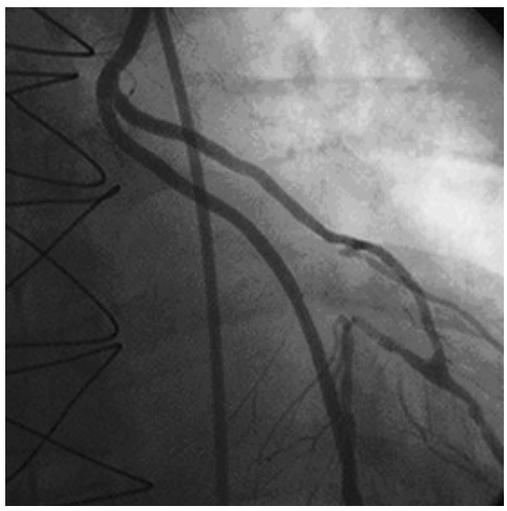

Fig. 1 – Angiographic study in the immediate postoperative period of a composite graft of the left internal thoracic artery (LITA) and the radial artery – Y technique. The radial artery revascularized two branches (one marginal and one diagonal, sequentially), and was proximally anastomosed to the LITA

Fig. 2 – Angiographic study in the immediate postoperative period of a composite graft of the left internal thoracic artery (LITA) and the radial artery – modified technique (anastomosis of the LITA on the radial artery, which had previously been sequentially anastomosed to the anterior descending artery and to 2 marginal branches)

All the LITA and RITA were patent. A radial artery was occluded and another presented with occlusion of its distal portion. Both were in Group A (composite Y). One of the patients of the composite group was submitted to coronary artery endoprosthesis implantation and the others were accompanied clinically.

The mean proximal diameter of the LITA was 3.1 ± 0.3 in Group A (p-value < 0.05 vs. C), 3.2 ± 0.3 in Group B (p-value <0.01 vs. C) and 2.7 ± 0.3 mm in Group C (Figure 3).

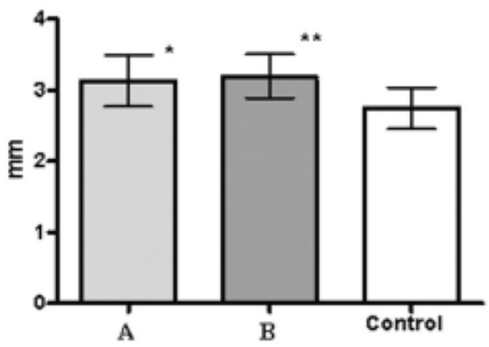

Fig. 3 – Mean proximal diameter of the left internal thoracic artery (LITA) in mm in the groups studied. (*p-value < 0.05 x control; ** p-value < 0.01 x control)

Flowmetry

The mean peak velocity times, in the initial portion of the LITA at rest was 28.4 ± 4.8 cm/s in Group A, 34.4 ± 7.9 cm/s in group B (p-value = 0.0384 vs. C) and 25.8 ± 8.6 cm/s in Group C. The coronary artery flow reserve was 2.1 ± 0.4 in Group C (Control) – Figure 4.

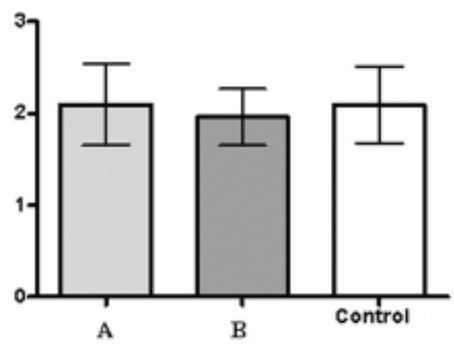

Fig. 4 – Coronary flow reserve in the initial portion of the left internal thoracic artery in the studied groups (p-value = 0.7208 A, B x Control)

The blood flow at rest in the initial portion of the mammary artery was 110 ± 30 mL/min in Group A, 145 ± 59 mL/min in Group B (p-value < 0.01 vs. C) and 78 ± 34 mL/min in Group C.

The proximal flow at rest in the radial artery in the conventional group was 56.1 ± 35.6 mL/min. Thus, the total blood flow distributed to the branches of the left coronary artery in Group C (control) was 133 ± 58 mL/min, without statistically significant difference when compared with the other two groups (p-value = 0.3232) – Figure 5.

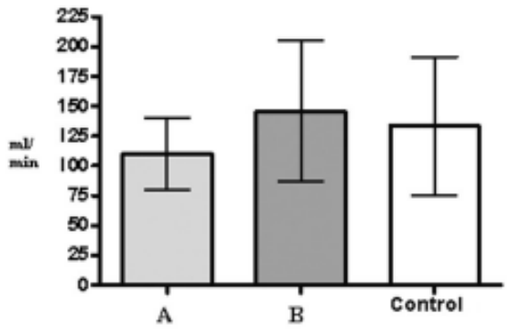

Fig. 5 – Total blood flow (mL/min) distributed to the revascularized branches in each technique. In the Control Group (conventional technique) the total flow consists of the sum of the flows of the left internal thoracic artery and the radial artery (p-value = 0.3232 A, B x Control)

COMMENTS

The use of composite grafts of the left internal thoracic and radial arteries appeared in order to try to utilize arterial grafts more widely in myocardial revascularization [12,15]. Thus, the proximal aortic anastomosis, originally to the radial artery, was changed to the LITA solving the problem of disproportion size between the graft and aortic walls and its possible implications with the reduction of the dP/dT- according to the pressure gradient applied in the radial artery.

However, concern about the technically more difficult anastomosis between the two arterial grafts continued and so, CHACCUR et al. [16] proposed a technical modification. The proximal anastomosis of the radial artery was made to the left anterior descending artery, that is, an inter-coronary artery graft was achieved with the radial artery. Later, near the left anterior descending artery, the LITA was anastomosed to the radial artery. Thus, the LITA prioritizes the left anterior descending artery with its blood flow. Thus, there is no necessity of further handling (for the anastomosis of another graft) of the LITA

One disadvantage of the use of composite arterial grafts is the dependence on the LITA for all the blood supply to the revascularized arteries. Thus, the capacity and reserve of the LITA to supply a quantity of blood sufficient for the revascularized area should be questioned [17].

The functional behavior of the LITA graft to the left anterior descending artery has already been well described [18,19]. However, few authors explored the velocity and the quantity of the blood flow in composite arterial grafts. ROYSE et al. [20] evaluating the flow in Y-shaped arterial grafts formed from the LITA and radial artery, using flowmetry in the intraoperative period, verified that the flow after cardiopulmonary bypass was 82 ± 13 mL/min on average, but the composite arterial graft had a reserve of 2.3 when the free potential maximum outflow of the graft was evaluated. SPEZIALE et al. [21] also evaluated the flow in the intraoperative period and verified an average of 93 ± 9 mL/min in composite arterial grafts using the LITA and another graft that was not the radial artery. In our work, the blood flows at rest, in composite grafts in the immediate postoperative period were on average 110 ± 30 mL/min using the Y technique and 145 ± 59 mL/min using the modified technique. A satisfactory reserve was seen in hyperemia.

The proximal flowmetry of the composite arterial graft in the postoperative period was demonstrated by the same group in two publications. WENDLER et al. [22] showed that, independently of the second graft utilized to form the composite arterial graft (RITA or RA), the coronary flow reserve increased significantly when compared with the immediate postoperative period and at six months after the operation. We did not restudy the patients after six months, but we compared the composite arterial graft with the conventional technique. The flows were greater and the coronary flow reserve was satisfactory. MARKWIRTH et al. [23] verified that the greater the lesion, the greater the flow supplied by the composite arterial graft. One case of this study, in which the radial artery was occluded, was a patient with a lesion to the left coronary artery branch, where the restudy demonstrated a reduction of the original injury. This may have contributed to the occlusion of the radial artery. Other authors identified the degree of injury to the native vessel as a predictor of patency of the radial artery graft [24].

LOBO FILHO et al. [25], evaluating composite arterial grafts of the LITA and saphenous vein (in Y) by Doppler echocardiography demonstrated that the LITA has conditions of increasing the proximal flood flow, when utilized to revascularize more than one branch of the left coronary artery. Our results are in accordance with this author and we demonstrated that there is no significant difference between the total blood flow supplied to the revascularized left coronary artery branches between composite and conventional grafting techniques.

On the other hand, GAUDINO et al. [26] demonstrated suboptimal results with composite arterial grafts using the LITA and saphenous vein. We believe that this occurred due to the difference in calibers between the distal portion of the LITA and the saphenous vein, as this graft has a greater diameter than the radial artery. The blood flow is a variable that, according to the French physicist Poiseuille,

depends of the pressure gradient, on the length and radius of the vessel and of the viscosity of the fluid. In practice, this formula can not be applied to the cardiovascular system, because blood vessels present with dilation and the blood is not exactly a true fluid [27]. Additionally, it has been verified that the flow is directly proportional of the vessel's radius to the power of four. Thus, when the graft is Y-shaped, theoretically the distribution of the blood flow could prioritize the area irrigated by the second graft (if this has the greatest diameter). Distal flowmetry will be able to show the distribution in these cases.

The results presented in this study, with a selected group of patients, permit us to affirm:

- The proximal diameter of the LITA was greater in composite groups;
- The mean peak velocity was greater in the modified group;
- The flow reserve of the LITA was satisfactory in all three groups;
- There was no difference between the total blood flow supplied to the revascularized left coronary artery branches by the two techniques.

Limitations

This study may have limitations attributed to the method of evaluation of the flowmetric variables. The quality of the signal and the value of the mean peak velocity time are dependent on the correct and careful positioning of the Doppler guide wire. The measurements of the mean peak velocity time and of the coronary flow reserve are reproducible as long as there are no significant variations in the heart rate and the hematocrit level in the postoperative period. In calculating the flow rate it is assumed that the peak velocity time has a parabolic distribution, because the velocity is phasic and the value obtained is the mean time. We considered the mean velocity to be half of the peak velocity. Additionally, the variability in the blood flow calculation may be attributed to imprecision of the program to determine the cross-sectional area of the graft.

Finally, the proximal flow of a graft can undergo changes according to variables of the coronary artery bed (types of arteries and ramifications) and of the revascularized myocardium.

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