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Myocardial revascularization surgery using composite Y-graft of the left internal thoracic artery: blood flow analysis

Revascularização miocárdica com enxerto composto de artéria torácica interna esquerda em Y: análise de fluxo sangüíneo

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Abstract

Objective: **To assess the left internal thoracic artery (LITA) flow pattern, when it was used to supply the left anterior descending artery (LADA) and another branch from the left coronary artery system (LCAS).**

Methods: **In the following study, the left internal thoracic artery flow was investigated by echocardiography Doppler, at rest and under dobutamine stress, in two twenty-patient groups. Group A consisted of patients who received only a pedicled LITA graft to the LADA. Group B consisted of patients who received a pedicled LITA graft associated with a vein graft to supply the LADA and another artery from the LCAS. The angiographic study showed graft patency in all patients from both groups. The following parameters were used: systolic flow (SF), diastolic flow, total flow, total flow in stress/total flow at rest ratio (TFS/TFR), systolic peak velocities (SPV), diastolic peak velocities and systolic peak velocity/diastolic peak velocity ratio.**

Results: **All analyzed parameters were considered statistically significant, except SF, TFS/TFR and SPV.**

Conclusions: **We concluded that in the same conditions and methodology, the LITA flow in the composite graft (group B) is higher than in the free graft (group A), which shows the great flow adaptability of the LITA to respond to flow demand.**

Descriptors: **Myocardial revascularization. Internal mammary-coronary artery anastomosis. Echocardiography, Doppler. Echocardiography, stress. Blood flow velocity.**

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Resumo

Objetivo: **Verificar o comportamento do fluxo sangüíneo na artéria torácica interna esquerda (ATIE), quando utilizada para revascularizar a artéria interventricular anterior (AIA) e mais um ramo do sistema coronariano esquerdo (SCE).**

Método: **No presente estudo, compara-se o fluxo obtido pela ecocardiografia Doppler na ATIE, em repouso e sob estresse com dobutamina, em dois grupos de 20 pacientes cada. No grupo A, foi utilizado enxerto pediculado de ATIE anastomosada unicamente à AIA. No grupo B, a ATIE revasculariza a AIA, e um enxerto de veia safena magna, anastomosado em "Y" à ATIE, revasculariza outro ramo do SCE. O estudo angiográfico demonstrou patência de todos os enxertos em ambos os grupos. Na avaliação pela ecocardiografia Doppler foram realizadas as seguintes medidas: débitos sistólico (DS), diastólico e total, razão entre o débito total em estresse pelo débito total em repouso (DTE/DTR), velocidades de pico sistólico (VPS) e diastólico e razão entre essas velocidades.**

Resultados: **Todos os parâmetros analisados apresentaram diferença estatisticamente significativa, com exceção do DS, DTE/DTR e VPS.**

Conclusão: **Nas condições e métodos usados neste estudo, pode-se inferir que o fluxo sangüíneo na ATIE no enxerto composto (Grupo B) é maior que no enxerto simples (Grupo A), o que demonstra a grande capacidade da ATIE em adaptar-se à demanda de fluxo.**

Descritores: **Revascularização miocárdica. Anastomose mamário-coronária. Ecocardiografia Doppler. Ecocardiografia sob estresse. Velocidade do fluxo sangüíneo.**

INTRODUCTION

Current literature is looking for techniques to minimize complications of coronary artery bypass grafting (CABG), in particular strokes. Among these techniques are CABG without the use of cardiopulmonary bypass [1,2] and CABG without manipulation of the aorta [3-6].

In 1982, aiming at reducing the high risk caused by manipulation of atherosclerotic ascending arteries during CABG, a technique based on the proximal end-to-side anastomosis of a magna saphenous vein (GSV) graft to the left internal thoracic artery (LITA) previously anastomosed to the anterior interventricular artery (AIA) was described. Subsequently, several authors published studies reporting results with the utilization of compound grafts [7,8].

From the more effective use of this technique in which the blood supply originates only from the LITA, it is possible to investigate if this vessel if capable of responding to the flow demand of two or more coronary arteries [9,10].

We did not find reports of studies using Doppler echocardiography of the LITA flow comparing the LITA graft anastomosed to the AIA to a homogenous compound Y-shaped graft using the LITA and GSV grafted to the AIA and another branch of the left coronary system (LCS), respectively.

This study aims at investigating the behavior of the blood flow in the LITA, when utilized for CABG of the AIA and another branch of the LCS.

METHOD

This study was performed in the period from May 2000 and October 2002.

All the patients were indicated for surgery after angiographic studies, which demonstrated significant obstruction of the AIA and another artery of the LCS. Patients who had previously suffered from extensive anterior infarction identified by angiographic, electrocardiographic and echocardiographic studies were excluded from this study. The essential condition for the participation of the patients was the patency of the grafts demonstrated by angiography.

All the patients underwent angiographic studies two months after the surgical procedure and presented with patency of the grafts. In the same period, the grafts were studied using Doppler echocardiography to measure the flow of the LITA at rest and under stress.

A formal written consent was obtained from all of the patients.

Sample

This study was performed in 40 patients divided in two groups of 20 patients each. In the Group A (control group) there were more men (60%) than women and the age ranged from 38 to 75 years with a mean of 58.3 ± 8.6 years. All the patients of this group were submitted to CABG with pedicled LITA grafts replacing only the AIA. We denominated this procedure as the simple graft.

In Group B (the study group) again there were more men (60%) than women and the ages varied from 49 to 83 years with a mean of 65.0 ± 10.2 years. The patients were submitted to grafting of two vessels of the LCS, with blood supply originating from only the LITA. The pedicled LITA was anastomosed to the AIA and for the second graft, the GSV was always anastomised in Y-shape to the LITA and then grafted to another branch of the LCS. We denominated this procedure as the compound graft (Figures 1 and 2).

Fig. 1 - Illustration of the compound graft of the left internal thoracic artery with the great saphenous vein used to graft the anterior interventricular artery and a circumflex marginal artery, respectively

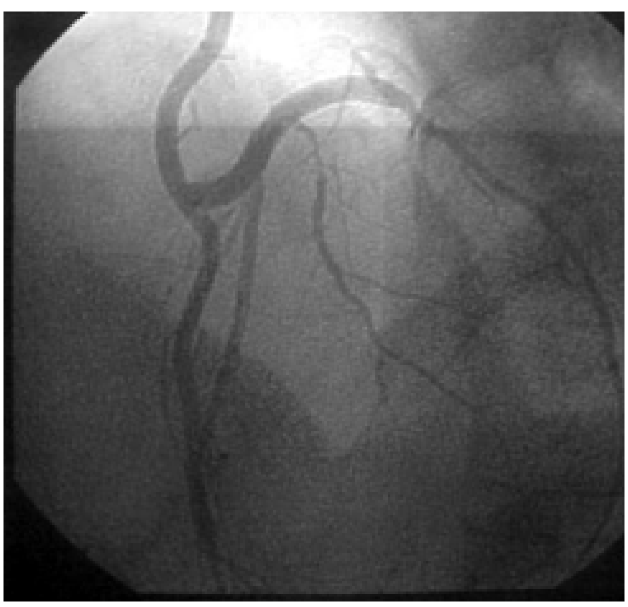

Fig. 2 - Angiographic study of the compound graft with the left internal thoracic artery grafted to the anterior interventricular artery and a segment of the great saphenous vein grafted to a circumflex marginal artery

Surgical technique

The LITA was dissected with its pedicle from its root to its bifurcation at the 6th intercostal space. The GSV was dissected and removed in preference from the right thigh. Heparin sodium at 1.5 mg/kg of body mass was utilized as anticoagulant. The GSV graft was chosen without deformities or valves, measuring from three to eight centimeters in length. To prepare the compound graft, first the anastomosis of the GSV to a diagonal, diagonalis or marginal branch of the LCS was performed. Consequently, the end portion of the pedicled LITA was anastomosed to the AIA. Finally, the Y-shaped anastomosis between the proximal portion of the GSV graft and the side face of the LITA was achieved (Figures 1 and 2). These anastomoses were performed with running stitches utilizing polypropylene 7-0 or 8-0 thread. A dose of 1.0 mg of protamine chloride was administered for each 1.0 mg of heparin to interrupt the anticoagulation. With the simple graft, the same procedure was followed, however only anastomosis of the LITA to the AIA was performed.

In the two groups, the surgeries were performed without the use of cardiopulmonary bypass. Coronary stabilizers or intracoronary perfusates were not systematically used. For a better access of the marginal branches of the circumflex artery, the Lima point was routinely used [11].

Protocol of the Doppler echocardiography at rest and under stress with dobutamine

Doppler echocardiography of the LITA was performed by the same team of professionals. With the patient in the dorsal decubitus position the LITA was viewed at the left supraclavicular fossa. ATL® or Vingmed System Five® echocardiographs with 7.5 or 5 MHz linear transducers were utilized.

The flow parameters studied to evaluate the adaptability of the LITA were:

- The systolic outflow (SO) expressed in mL/minute: Obtained from the product of the integral of the velocity by the time during systole multiplied by the cross-sectional area of the vessel multiplied by the heart rate (HR);
- The diastolic outflow (DO) expressed in mL/minute: Obtained from the product of the integral of the velocity by the time during diastole times multiplied by cross-sectional area of the vessel multiplied by the heart rate;
- Total outflow (TO) expressed in mL/min. Calculated by summing the SO and the DO;
- The ratio between the total outflow under stress (TOS) and the total outflow at rest (TOR);
- The peak systolic velocity (PSV), which represents the maximum blood flow velocity during systole;
- The peak diastole velocity (PDV), which represents the maximum blood flow velocity during diastole;
- The ratio between peak systole velocity and peak diastole velocity (PSV/PDV).

After the evaluation of the flow parameters at rest, the two groups of patients were submitted to the same protocol of dobutamine infusion to induce stress [12] (Figure 3).

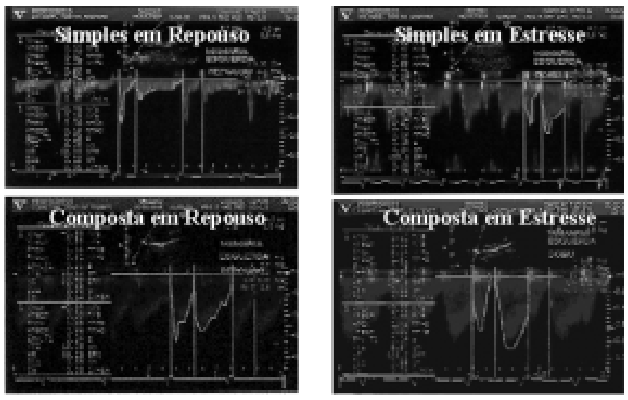

Fig. 3 - Flow velocity curve obtained by a Doppler echocardiographic study of the left internal thoracic artery, in both groups at rest and under stress

Progressively higher doses of 10, 20, 30 and 40 µg per kg of body mass per minute, were utilized with increments at every three minutes. The examination was concluded when the HR reached a value greater than or equal to 85% of the maximum HR.

Statistical analysis

Statistical analysis of the flow parameters obtained at rest and under stress within the same group was achieved utilizing the Student t-test for matched values. For the statistical analysis of the flow parameters obtained at rest and under stress in the different groups the Student t-test for non-matched parameters was used. Welch correction for non-matched values was employed when the variances between the groups was different. A statistical difference with a p-value < 0.05 was considered significant. To analyze the data, the Microsoft Excel 1997 and GraphPad Prism 2.0 1995 computer programs were used.

RESULTS

1. Systolic Outflow (SO)

The SO at rest in group A varied from 10 to 40 mL/min, with a mean of 19 ± 10.2 mL/min. Under stress, the SO ranged from 0 to 50 mL/min, with an average of 19.5 ± 18.8 mL/min. In group B, the SO at rest varied from 15 to 85 mL/min, with a mean of 36.7 ± 20.5 mL/min. In this group the SO under stress varied from 0 to 92 mL/min with a mean of 41.4 ± 31.1 mL/min. On analyzing the results of each group, at rest and under stress, no significant differences were evidenced.

When comparing the means obtained at rest, between groups A and B, the results demonstrated a flow difference of 19.0 ± 10.2 and 36.7 ± 20.5 mL/min, respectively. There was an increase of 17.7 mL/min, or 93.2%. Under stress the comparison of the means of SO between groups A and B, they presented with a difference of 19.5 ± 18.8 to 41.4 ± 31.1 mL/min respectively, that is 112.3%. These results were statistically significant with p-values of 0.01 and 0.05 respectively (Tables 1 and 2).

Tabela 1 – Analysis of the flow parameters in the left internal thoracic artery obtained by Doppler echocardiography both at rest and under stress, of the two groups, group A (control group) and group B (study group).

	Group A n = 20		Group B n =20	
Parameter	**Rest**	**Stress**	**Rest**	**Stress**
SO (mL/min)	19.0±10.2	19.5±18,8	36.7±20.5	41.4±31.1
DO (mL/min)	26.4±13.6	49.3±19.9 [d]	61.6±31.5	134.3±58.6 [d]
TO (mL/min)	45.5±21.6	68.3±32.9 [c]	98.2±50.4	175.7±79.2 [d]
SPV (cm/s)	34.9±9.9	37.4±26.1	37.7±11.4	34.6±18.5
DPV (cm/s)	20.9±7,0	39.3±12.0 [d]	33.9±10.5	61.3±17.7 [d]
SPV/DPV	1.8±0.6	1.0±0.7 [c]	1.2±0.3	0.6±0.3 [d]

SO = systolic outflow; DO = diastolic outflow; TO = total outflow; SPV = systolic peak velocity; DPV = diastolic peak velocity; SPV/DPV = ratio systolic peak velocity/ diastolic peak velocity

Tabela 2 – Analysis of the flow parameters in the left internal thoracic artery obtained by Doppler echocardiography both at rest and under stress, of the two groups, group A (control group) and group B (study group). A p-value < 0.05 was considered as statistically significant.

	Rest		Stress	
Parameter	**Group A**	**Group B**	**Group A**	**Group B**
SO (mL/min)	19.0±10.2	36.7±20.5[b]	19.5±18.8	41.4±31.1[a]
DO (mL/min)	26.4±13.6	61.6±31.5[d]	49.3±19.9	134.3±58.6[d]
TO (mL/min)	45.5±21.6	98.2±50.4[c]	68.3±32.9	175.7±79.2[d]
SPV (cm/s)	34.9±9.9	37.7±11.4	37.4±26.1	34.6±18.5
DPV (cm/s)	20.9±7.0	33.9±10.5[d]	39.3±12.0	61.3±17.7[d]
SPV/DPV	1.8±0.6	1.2±0.3[c]	1.0±0.7	0.6±03[a]

[a] p-value <0.05 [b] p-value <0.01 [c] p-value <0.001
[d] p-value <0.0001

SO = systolic outflow; DO = diastolic outflow; TO = total outflow; SPV = systolic peak velocity; DPV = diastolic peak velocity; SPV/DPV = ratio systolic peak velocity/ diastolic peak velocity

2. Diastolic Outflow (DO)

In group A (control group), the DO at rest varied from 7 to 50 mL/min, with a mean of 26.4 ± 13.6 mL/min. Under stress, the DO ranged from 15 to 90 mL/min, with an average of 49.3 ± 19.9 mL/min. The increase of the diastolic blood flow in the group submitted to stress was 22.9 mL/min or 86.7% (p-value < 0.0001).

In group B, the DO at rest varied from 23 to 137 mL/min, with a mean of 61.6 ± 31.5 mL/min. Under stress the DO varied from 37 to 256 mL/min, with a mean of 134.3 ± 58.6 mL/min. Again, the stress caused a significant increase in the diastolic blood flow in the order of 72.7 mL/min or 118.0% (p-value < 0.0001).

When comparing the diastolic outflow of groups A and B at rest, the means of the blood flow were 26.4 ± 13.6 and 61.6 ± 31.5 mL/min respectively, that is a difference of 35.2 mL/min or 133.3% (p-value < 0.0001). Under stress the means for the DO of groups A and B were 49.3 ± 19.9 mL/min and 134.3 ± 58.6 mL/min respectively that is an increase of 85 mL/min, or 172.4% (p-value < 0.0001) – Tables 1 and 2; Figure 4).

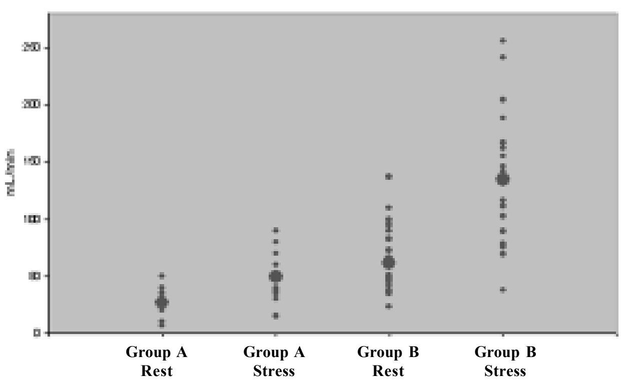

Fig. 4 - Spread on diastolic outflow (DO) values in mL/min in groups A and B at rest and under stress. The mean values of the diastolic outflow are highlighted and linked with a line. Group A = control; group B = Study

3. Total Outflow (TO)

In group A, the TO at rest varied from 17 to 90 mL/min with a mean of 45.5 ± 21.6 mL/min. Under stress, the TO varied from 25 to 140 mL/min, with a mean of 68.3 ± 32.9 mL/min. These results demonstrated an increase between the means of 22.8 mL/min or 50.1% (p-value < 0.001).

The TO at rest in group B varied from 38 to 222 mL/min, with a mean of 98.2 ± 50.4 mL/min. Under stress, the results of the TO varied from 63 to 334 mL/min, with a mean of 175.7 ± 79.2 mL/min. The difference between the mean results was 77.5 mL/min or 78.9% (p-value 0.0001).

A comparison of the total outflow, at rest between groups A and B gave means of 45.5 ± 21.6 mL/min and 98.2 ± 50.4 mL/min respectively, that is an increase of 52.7 mL/min or 115.8% (p-value < 0.001). Under stress, the means of the TO for groups A and B were 68.3 ± 32.9 mL/min and 175.7 ± 79.2 mL/min, respectively, that is an increase of 107.4 mL/min or 157.2% (-p-value < 0.0001) – (Tables 1 and 2; Figure 5).

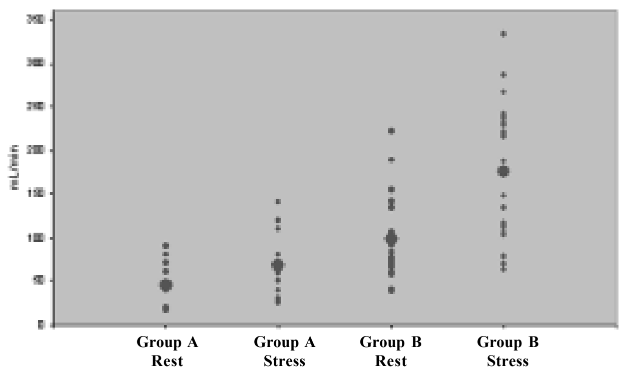

Fig. 5 - Spread on total outflow (TO) values in mL/min in groups A and B at rest and under stress. The mean values of the total outflow are highlighted and linked with a line. Group A = control; group B = Study

4. Ratio between total outflow under stress and total outflow at rest (TOS/TOR)

The TOS/TOR ratio in group A ranged from 0.83 to 3.0 with a mean of 1.6 ± 0.57. The TOS/TOR for group B ranged from 1.10 to 3.87 with a mean of 1.89 ± 0.67. The difference between the two means was considered statistically significant (p-value = 0.1463).

5. Systolic peak velocity (SPV)

There was no significant difference in the means of the SPV at rest and under stress of the two groups. In the analysis, both at rest and under stress, there was no significant difference of this index between the two groups (Tables 1 and 2; Figure 6).

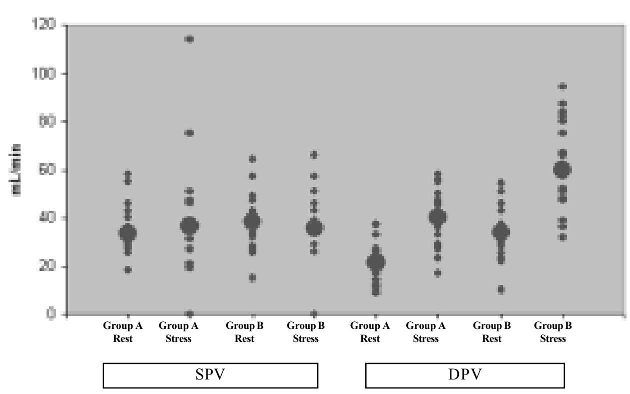

Fig. 6 - Spread of systolic peak velocity values (SPV) and diastolic peak velocity values (DPV) in cm/s in groups A and B at rest and under stress. The mean values of the SPV and DPV are highlighted and linked with lines. Group A = control; group B = Study

6. Diastolic peak velocity (DPV)

Both in group A and group B there was a significant increase after the induction of stress (p-value < 0.0001). The comparison of the mean DPV, at rest and under stress, between the groups demonstrated a statistically significant increase (p-value < 0.0001) – (Tables 1 and 2; Figure 6).

7. Ratio between the systolic peak velocity and the diastolic peak velocity (SPV/DPV)

Analysis of this ratio both in group A and in group B, at rest to under stress, demonstrated a significant reduction. There was also a significantly lower value of the SPV/DPV ratio in group A compared to group B, both at rest (p-value < 0.001) and under stress (p-value < 0.05) – (Tables 1 and 2).

COMMENTS

When the results found in the SO are analyzed, we see that, both at rest and under stress, the SO of group B is around 100% greater than in group A. This demonstrates that probably the LITA presents a capacity to adapt to flow, when it is utilized as the only blood supply for the grafting of two coronary arteries.

Additionally, on analyzing the DO in the LITA with simple or compound grafts, the results demonstrate a significant increase from rest to stress. Group B showed elevations of 133.3% and 172.4% in the values at rest and under stress respectively in relation to group A. These findings confirm that irrigation of the myocardium is prominently during diastole. Thus, the LITA presents a capacity of flow adaptation from rest to stress in both groups. This condition clearly indicates that this is related to metabolic demand.

In relation to the TO, the results of this study demonstrate that there is no increase in the SO from rest to stress within the same group. As was observed, the increase of the TO from rest to stress is basically owing to an increase in the DO. However, comparing groups A and B, it was observed that in group B, both at rest and under stress, the TO increased by more than two-fold. This infers that the LITA increases its flow to the two coronary arteries extraordinarily, which supports the hypothesis of adaptation of the graft to the required sanguineous flow [9].

The STO/RTO ratio, that is the coronary flow reserve, has been considered by several authors as the best manner to evaluate if the graft is capable of offering an adequate blood flow in situations of increased demand [8,13,14]. In this study, the STO/RTO ratio in the anastomosed LITA graft was 1.60 in group A, while in group B it was 1.89. Thus a non-significant difference of 18.1% (p-value > 0.05) was observed. We expect that this ratio did not alter between the two groups, as if there is an increase of flow in the control group to the study group, this would be seen both at rest and under stress in a proportional manner. Thus when the ratio is calculated no significant variation between the two groups would be attributed.

These parameters were recently studied by SAKAGUCHI et al. [15]. The results of these authors, contrary to this work, demonstrated that the compound Y-shaped arterial grafts presented with a reserve of coronary flow lower than the simple grafts. The differences observed in the comparison of the two works might be related to the different procedures utilized. The control group was composed of patients submitted to LITA grafts to the AIA in association with another simple graft to a second branch of the LCS. Additionally, SAKAGUCHI et al. [15] did not measure the flow but only measured the perfusion to an area, a rate that is influenced by the flow of other nearby vessels. This measurement was achieved by a tomographic technique using emission of positrons. Furthermore, the stress was induced by dipiridamol and the flow measurement was performed in different regions of the myocardium. We believe that the reason for the lesser blood flow adaptation of the Y-shaped compound grafts is due to precocity with which the study was performed, that is, two weeks after surgery, an insufficient time according to the findings of MARKWIRTH et al. [14].

OCHI et al. [16], in 2001, performed a study in 40 patients with the aim of evaluating the capacity of the LITA to provide adequate flow to two or more arteries of the LCS. In all the studied patients, the LITA presented an increase of the diameter of its lumen and in the echocardiographic examination under stress, ventricular contraction abnormalities in the revascularized regions were not observed. However, in this study, the blood flow was not measured and the sample patients deviated in relation to the number of grafts.

In respect to the SPV in our study, both the groups did not demonstrate a significant increase from rest to stress situations. There was also no significant increase in the SPV when comparing group A with group B, both at rest and under stress. Thus, the increase in the SO, both at rest and under stress, of group A to group B probably occurred due to the change in the curve pattern of the systolic velocity, which maintained its peak, but that presented with greater velocities during the curve. Additionally, although the mean results of the SPV for the two groups were observed to be similar, group B, in which the LITA provided blood for two coronary arteries, presented results where the systolic velocity curve could provide flow two times greater than that in group A.

The results demonstrated that the DPV at rest or under stress significantly increased from group A to group B. In these two groups, the DPV presented with a significant increase from rest to stress. These findings agree with the increase in the DO, as was previously described.

Several published works demonstrated that the SPV/DPV ratio, when calculated for a LITA grafted to the AIA, is lower than that observed for the LITA in its original position. This technical observation suggests a change in the curve pattern of the flow velocity, which starts to present with an increase in velocity during diastole, resembling the coronary flow pattern [17,18].

From the results of this study, it can be observed that the LITA when used to revascularize the AIA and another artery of the LCS, presents a SPV/DPV ratio significantly lower, both at rest and under stress, when compared to the LITA only grafted to the AIA. These findings can be explained by the increase of the diastolic component of the blood flow within the LITA, mainly when it is utilized as a compound graft. Thus, the LITA increases its diastolic component in a preponderant manner in relation to the systolic component, adopting a coronary flow pattern and favoring the sanguineous irrigation adequate both for basal levels and in situations of greater demand of blood flow.

Several scientific studies have established a parameter of patency of the LITA graft that only revascularizes the AIA, in which the SPV/DPV ratio is used [19,20]. We believe that subsequent studies in this direction might demonstrate the possibility of patency criteria in relation to compound grafts.

As was cited in this study, we opted to utilize GSV as a secondary graft to prepare the compound graft with the LITA. Apart from being two grafts proven over time, we believe that the GSV, in the manner in which it was used, can have a better behavior than those currently described, owing to the following reasons:

- The GSV segments that were used were small and without valves, reducing the resistance to blood flow and eliminating sites favoring the development of stenosis [21];
- Lower stress due to the pressure and circulation exerted on the GVS segments originating from the LITA, in relation to those originating from the aorta, might bear less damage to the intima layer, less development of intimal hyperplasia and atherosclerosis [22,23].
- As the endothelium of the internal thoracic artery produces much nitric oxide [23], this condition leads us to believe that the GSV, originating from this artery, may receive part of this substance, thus reducing the incidence of atherosclerotic disease both in the venous graft and the grafted coronary arteries [24].

Based on the results described in this study, we can deduce that the behavior of the blood flow in the LITA, when used for the revascularization of two branches of the LCS, presents with a significant ability to adapt, providing an adequate blood supply both at rest and under stress.

Thus, from these results, we believe a new concept of CABG might be emerging, that is, surgical revascularization of the LCS without cardiopulmonary bypass and without manipulation of the aorta, utilizing the LITA as the only blood supply.

CONCLUSION

Under the conditions and methods used in this study, it is possible to infer that the blood supply of the LITA in the compound graft (group B) is greater than in the simple graft (group A). This can be explained by the great capacity of the LITA to adapt to the demand of blood flow.

BIBLIOGRAPHIC REFERENCES

1. Buffolo E, Andrade JC, Succi J, Leão LE, Gallucci C. Direct myocardial revascularization without cardiopulmonary bypass. Thorac Cardiovasc Surg 1985; 33:26-9.

2. Patel NC, Deodhar AP, Grayson AD, Pullan DM, Keenan DJ, Hasan R et al. Neurological outcomes in coronary surgery: independent effect of avoiding cardiopulmonary bypass. Ann Thorac Surg 2002; 74:400-6.

3. Mills NL. Physiologic and technical aspects of internal mammary artery bypass graft. In: Cohn LH, editor. Cardiac/thoracic surgery. New York: Futura; 1982. p.1-19.

4. Mills NL, Everson CT. Atherosclerosis of the ascending aorta and coronary artery bypass: pathology, clinical correlates and operative management. J Thorac Cardiovasc Surg 1991; 102:546-53.

5. Lobo Filho JG, Dantas MCBR, Rolim JGV, Rocha JA, Oliveira FM, Ciarline C et al. Cirurgia de revascularização completa do miocárdio sem circulação extracorpórea: uma realidade. Rev Bras Cir Cardiovasc 1997; 12:115-21.

6. Lobo Filho JG, Leitão MCA, Lobo Filho HG, Soares JPH, Magalhães GA, Leão Filho CSC et al. Cirurgia de revascularização coronariana esquerda sem CEC e sem manuseio da aorta em pacientes acima de 75 anos: análise das mortalidades imediata e a médio prazo e das complicações neurológicas no pós-operatório imediato. Rev Bras Cir Cardiovasc 2002; 17:208-14.

7. Tector AJ, Amundsen S, Schmahl TM, Kress DC, Peter M. Total revascularization with T grafts. Ann Thorac Surg 1994; 57:33-9.

8. Wendler O, Hennen B, Markwirth T, Konig J, Tscholl D, Huang Q et al. T grafts with the right internal thoracic artery to left internal thoracic artery versus the left internal thoracic artery and radial artery: flow dynamics in the internal thoracic artery main stem. J Thorac Cardiovasc Surg 1999; 118:841-8.

9. Jones EL, Lattouf OM, Weintraub WS. Catastrophic consequences of internal mammary artery hypoperfusion. J Thorac Cardiovasc Surg 1989; 98(5 Pt 2):902-7.

10. Vajtai P, Ravichandran PS, Fessler CL, Floten HS, Ahmad A, Gately HL et al. Inadequate internal mammary artery graft as a cause of postoperative ischemia: incidence, diagnosis and management. Eur J Cardiothorac Surg 1992; 6:603-8.

11. Lima RC. Padronização técnica de revascularização miocárdica da artéria circunflexa e seus ramos sem circulação extracorpórea [Tese de doutorado]. São Paulo: Universidade Federal de São Paulo, Escola Paulista de Medicina, 1999. 79p.

12. Arruda AM, Pellikka PA, Mahoney DW, Joseph Jr. A, Mathias Jr. W, Seward JB. Transthoracic Doppler echocardiographic comparison of left internal mammary grafts to left anterior descending coronary artery with ungrafted right internal mammary arteries in patients with and without myocardial ischemia by dobutamine stress echocardiography. Am J Cardiol 2000; 86:919-22.

13. Bonacchi M, Prifti E, Giunti G, Salica A. Right Y-graft, a new surgical technique using mammary arteries for total myocardial revascularization. Ann Thorac Surg 2000; 70:820-3.

14. Markwirth T, Hennen B, Scheller B, Schafers HJ, Wendler O. Flow wire measurements after complete arterial coronary revascularization with T-grafts. Ann Thorac Surg 2001; 71:788-93.

15. Sakaguchi G, Tadamura E, Ohnaka M, Tambara K, Nishimura K, Komeda M. Composite arterial "Y" graft has less coronary flow reserve than independent grafts. Ann Thorac Surg 2002; 74:493-6.

16. Ochi M, Hatori N, Bessho R, Fujii M, Saji Y, Tanaka S et al. Adequacy of flow capacity of bilateral internal thoracic artery T graft. Ann Thorac Surg 2001; 72:2008-12.

17. Crowley JJ, Shapiro LM. Noninvasive assessment of left internal mammary artery graft patency using transthoracic echocardiography. Circulation 1995; 92(9 suppl.):II25-30.

18. de Bono DP, Samani NJ, Spyt TJ, Hartshorne T, Thrush AJ, Evans DH. Transcutaneous ultrasound measurement of blood-flow in internal mammary artery to coronary artery grafts. Lancet 1992; 339:379-81.

19. Chirillo F, Bruni A, Balestra G, Cavallini C, Olivari Z, Thomas JD et al. Assessment of internal mammary artery and saphenous vein graft patency and flow reserve using transthoracic Doppler echocardiography. Heart 2001; 86:424-31.

20. Katz WE, Zenati M, Mandarino WA, Cohen HA, Gorcsan 3rd J. Assessment of left internal mammary artery graft patency and flow reserve after minimally invasive direct coronary artery bypass. Am J Cardiol 1999; 84:795-801.

21. Cox JL, Chiasson DA, Gotlieb AI. Stranger in a strange land: the pathogenesis of saphenous vein graft stenosis with emphasis on structural and functional differences between veins and arteries. Prog Cardiovasc Dis 1991; 34:45-68.

22. Motwani JG, Topol EJ. Aortocoronary saphenous vein graft disease: pathogenesis, predisposition and prevention. Circulation 1998; 97:916-31.

23. Nwasokwa ON. Coronary artery bypass graft disease. Ann Intern Med 1995; 123:528-45.

24. Tarr F, Dudas G, Tarr M, Racz R, Sasvari M, Tomcsanyi I. Analysis of the stable metabolite of endothelium-derived nitric oxide of internal mammary artery bypass grafts at the venous drainage system of the recipient coronary artery: morphologic implications and consequences. Orv Hetil 2002;143:2549-52.