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Comparative randomized study of the immediate outcomes of patients with radial arteries proximally anastomosed to the aorta or as a composite graft

Estudo comparativo randomizado da evolução imediata dos pacientes com artéria radial anastomosada proximalmente na aorta ou como enxerto composto

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Abstract

Objective: **The clinical results of the radial artery when proximally anastomosed to the aorta or to the left internal thoracic artery (LITA) as a composite Y-graft were comparatively evaluated.**

Methods: **From November 1999 to March 2001, 100 patients who underwent coronary artery bypass grafting using the RA, the LITA and, when required, the saphenous vein, were divided into two groups of 50 patients each in a prospective randomized study. Group I (GI) with radial artery proximally anastomosed to the aorta and Group II (GII) as a composite graft (Y-graft) with the LITA.**

Results: **Early mortality was 1.0% (GI 2.0% and GII 0.0%) (p=1.00). A mean of 3.0 ± 0.12 (GI) versus 2.82 ± 0.12 (GII) (p=0.29) coronary vessels were grafted per patient. Patients in composite Y-graft group had shorter bypass times (p=0.0001). There were no significant differences in terms of perioperative outcomes.**

Conclusions: **The RA provides similar clinical results as aorto-coronary grafts and as composite Y-grafts with the LITA, except in respect to the bypass time.**

Descriptors: **Myocardial revascularization. Radial artery. Anastomosis, surgical, methods.**

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Resumo

Objetivo: **A artéria radial (AR) tem sido largamente empregada na revascularização do miocárdio (RM), porém a diferença da anastomose proximal na aorta ou em enxerto composto com a artéria torácica interna esquerda (ATIE) ainda é controversa. Avaliamos os resultados clínicos imediatos do uso da artéria radial (AR) anastomosada proximalmente na aorta ou como enxerto composto em "Y" com a ATIE.**

Método: **Cem pacientes foram randomizados e submetidos à RM no Hospital Beneficência Portuguesa de São Paulo, no período de novembro de 1999 a março de 2001. Nos pacientes do Grupo I (GI), a AR foi anastomosada proximalmente na aorta e, nos pacientes do Grupo II (GII), a AR foi anastomosada na ATIE. A veia safena (VS) autógena foi usada quando necessário.**

Resultados: **Os grupos I e II mostraram-se homogêneos quanto às características pré-operatórias. A mortalidade imediata total foi de 1,0% (GI 2,0% e GII 0,0%) - p =1,00. O número de artérias coronárias anastomosadas por paciente foi de 3,0+0,12, no GI e de 2,82+0,12, no GII (p=0,29). Os pacientes do GII apresentaram tempo de circulação extracorpórea (CEC) menor do que do GI (p=0,0001). Não houve diferença significativa entre as outras variáveis peri-operatórias estudadas.**

Conclusão: **Os pacientes apresentaram resultados clínicos semelhantes quando a AR foi anastomosada proximalmente na aorta ou como enxerto composto em "Y" na ATIE, e a anastomose proximal na ATIE não aumenta os riscos de complicações imediatas.**

Descritores: **Revascularização miocárdica. Artéria radial. Anastomose cirúrgica, métodos.**

INTRODUCTION

The superiority of the left internal thoracic artery (LITA) over the saphenous vein (SV) led to the search for other arterial grafts that could substitute the SV aiming at improving the late results. Among possible arterial grafts, the radial artery (RA) has frequently been used, mainly after the reports of Acar et al. [1] and others [2] who showed good mid-term results. Several inconveniences were reported for the proximal anastomosis of the AR on the ascending aorta and in an attempt to get around these problems, Calafiore et al. [3] proposed the utilization of an alternative arterial graft proximally anastomosed as a Y-type compound graft on the LITA according to the concept introduced by Mills [4] and employed by Sauvage et al. [5] with the right internal thoracic artery (RITA), in 1986. The published results are from independent series without a comparison of the two cited methods.

The objective of this study was to compare in a prospective randomized study the immediate postoperative clinical results between the two groups of patients who were submitted to coronary artery bypass grafting (CABG) using the left radial artery (LRA) proximally anastomosed to the aorta in a compound graft with the LITA.

METHOD

In the period from November 1999 to March 2001, 100 patients were randomized into two groups of 50 patients each and operated on in the Hospital São Joaquim da Real and Benemérita Associação Portuguesa de Beneficência of São Paulo. The patients of Group I (GI) were submitted to CABG using the LRA anastomosed proximally to the aorta and with the patients in Group II (GII) the LRA was used in a Y-type compound graft with the proximal anastomosis to the anterior face of the LITA. All the patients were treated according to the uniform surgical protocol and operated on by the same surgeon. The study was projected to identify the differences in the clinical evolution of the patients with a degree of significance established at 5% (p-value = 0.05). The research was approved by the Ethics Research Committee of the institutions.

Patient Selection

All the patients had obstructive lesions of the anterior interventricular artery (AIA) of greater than 75% and in at least one artery in the lateral region of the left ventricle as seen on preoperative coronary cineangiography.

Before the randomization, The following exclusion criteria were used: age over 70 years old, a positive Allen test; reoperation, the necessity of associated surgical procedures, contraindications for the use of calcium channel blockers, hemodynamic instability in the preoperative period and cases of palpable or visible arteriosclerosis of the LRA or LITA. The incidence of prior myocardial infarction, number of obstructed arteries, age, gender, hypertension, diabetes mellitus and other preoperative characteristics were similar in both groups (Tables 1 and 2). The patients presented in anginal functional class I to IV according to the Canadian Cardiovascular Society (CCS) or were asymptomatic with

significant coronary lesions and prior acute myocardial infarction (AMI). All the patients were operated on under elective conditions.

Table 1. Preoperative characteristics

Characteristics	GI	GII	p-value
Age (years)			0.85 (ns)*
Min-Max	38 - 67	34 - 70	
Mean ± SD	56.30 ± 1.09	56.60 ± 1.16	
Male	35 (70.0%)	40 (80.0%)	0.25 (ns) **
Diabetes	20 (40.0%)	18 (36.0%)	0.68 (ns) **
Hypertension	37 (74.0%)	30 (60.0%)	0.14 (ns)**
Dyslipidemia	19 (38.0%)	23 (46.0%)	0.42 (ns)**
Smokers	32 (64.0%)	35 (70.0 %)	0.52 (ns)**
Myocardial infarct	20 (40.0%)	20 (40.0%)	1.00 (ns)**
Alcoholism	14 (28.0%)	23 (46.0%)	0.062(ns)**
Stroke	1 (2.0%)	1 (2.0%)	1.00 (ns)***

** level of probability by the Student-t test: ** level of probability by the chi-squared test: *** level of probability by the Fisher Exact test: ns – non-significant: SD – standard deviation*

Table 2. Pre-operative characteristics

Characteristics	GI	GII	p-value
Asymptomatic	16(32%)	11(22%)	0.72(ns)**
Functional Class (CCS)			
I	2(4%)	4(8%)	
II	19(38%)	23(46%)	
III	8(16%)	8(16%)	
IV	5(10%)	4(8%)	
Obstructed coronary arteries >50%	2.60±0.09	2.44±0.09	0.21 (ns)*
Ejection fraction of LV>50%	29(58.0%)	30(60.0%)	0.67(ns)**
40-49%	18(36.0%)	15(30.0%)	
30-39%	3(6.0%)	5(10%)	

CCS - Canadian Cardiovascular Society. LV – left ventricle
** level of probability by the Student-t test: ** level of probability by the chi-squared test: ns – non-significant*

Operative technique and pharmaceutical protocol

The LITA was dissected without skeletonization. After dissection, the LITA was immersed in a topical papaverine solution and kept wrapped in gauze dampened in the same solution; its flow was examined before anastomosis. The LRA was dissected according to the normal previously described technique [6] and the proximal portion of the LRA was chosen where the caliber is greater and there is a lower incidence of arteriosclerotic process. After dissection, the graft was irrigated with a solution containing verapamil and isossorbide hydrochloride and kept under these conditions up to anastomosis. The SV, when necessary, was dissected at the same time as the LITA and the LRA, normally from the left leg.

In GII before establishing cardiopulmonary bypass (CPB), the Y-type compound graft was prepared between the LRA and the LITA with the proximal anastomosis on the anterior face of the LITA in its medial portion, after its entry into the pericardial sac. The anastomosis was end-to-side using the proximal limb of the graft and performing running sutures of 8-0 polypropylene thread. After completing the proximal anastomosis, the blood flow through the LITA and by the arterial graft was checked. All the patients were operated on using CPB, moderate hypothermia at 28 ºC and iced sanguineous cardioplegia with warm reperfusion. The LITA was anastomosed in the AIA and the LRA was anastomosed on the arteries of the lateral face of the heart, left diagonal or marginal arteries. Aiming at uniformity of the procedures, the right coronary artery (RC) or its branches also received venous grafts when necessary.

The patients received an intravenously infused solution of isossorbide hydrochloride (8 mg/kg/min) and diltiazem (2 ug/kg/min) from the start of the operation up to 24 hours after finishing. These drugs were orally administered as soon as possible and maintained for a period of at least six months.

The groups were analyzed in respect to the operative data and the immediate postoperative evolution.

The data are expressed as minimum and maximum values, means and standard deviations or as percentages. The following statistics tests were employed: the non-paired Student t-test for quantitative variables and the chi-squared test or Fisher exact test, whichever was appropriate, for the qualitative variables.

RESULTS

A total of 291 distal anastomoses were performed in the two groups; 150 (51.5%) in GI and 141 (48.5%) in GII. One hundred and three distal anastomoses were performed with LITA, 52 in GI and 51 in GII. A total of 113 distal anastomoses were performed with LRA; 56 in GI and 57 in GII. Seventy-four distal anastomoses were made with SV grafts; 41 in GI and 33 in GII. A RITA was utilized in one patient in GII. The operative data are shown in Tables 3 to 5. There were no significant differences between the operative data analyzed except for the time of CPB (p-value = 0.0001).

Table 3. Distal Anastomoses per patient

Distal Anastomoses	**GI**	GII	p-value
2	15	21	
3	22	18	
4	12	10	
5	0	1	
6	1	0	
Total	150(51.5%)	141(48.5%)	0.29 (ns)
Mean - SD	3.00±0.12	2.820±0.12	

** level of probability by the Student-t test: s-significant: ns – non-significant: SD – standard deviation*

Table 4. Revascularized arteries

Revascularized artery	GI	GII	p-value
Interventricular Anterior	51	51	
Diagonal	26	22	
Diagonalis	7	8	
Circumflex (branches)	35	34	
Right Coronary	20	18	
Posterior Interventricular	7	7	
Right Posterior Ventricular	4	1	
Total	150	141	0.29 (ns)
Sequential Anastomosis	9	7	

ns – non-significante

Table 5. Operative times

Variable (min)	Group	Minimum	Maximum	Mean	SD	p-value
Time of operation	GI	180	490	250.7	6.66	0.96(ns)*
	GII	180	360	250.3	6.09	
CPB time	GI	53	152	89.62	3.05	0.0001(s)*
	GII	32	128	70.52	3.26	
Time of Anoxia	GI	30	88	47.60	1.68	0.22 (ns)*
	GII	22	85	44.42	1.93	

** level of probability by the Student-t test*
s-significant: ns – non-significant: CPB – cardiopulmonary bypass: SD – standard deviation

There was only one (1%) death in all the study. The patient belonged to GI and there was no significant differences in the immediate mortality between the groups (p-value = 1.00). This patient presented with spasms of the arterial grafts immediately after removing the CPB, received vasoactive agents with a good result in the intra-operative period. However the patient evolved with low output syndrome in the ICU and high doses of vasoactive drugs and the use of an intra-aorta balloon (IAB) were necessary. The patient evolved to acute renal failure and death on the 4th postoperative day. The mean peak levels of CKMB in the postoperative period were 75.02 ± 22.48 in GI and 53.52 ± 5.77 in GII (p- value = 0.36).

In respect to the immediate evolution, six patients presented with low output syndrome in the peri-operative period and required vasoactive agents; three (6.0%) in GI and three (6.0%) in GII (p-value = 1.0). Of these one (2.0%) patient required IAB in GI and eventually died. There were two (4.0%) patients with electrocardiographic evidence and elevated enzymatic (CKMB) levels suggestive of AMI, one in GI and one in GII. The patient in GI presented AMI in the anterior wall and the one in GII in the posterior wall. The incidence of arrhythmias was: transitory total atrioventricular block in three (6.0%) patients of GI and three (6.0%) in GII and atrial fibrillation in one (2%) patient in GII without significant differences between the groups. Other temporary neurological and pulmonary changes were observed and are shown in Table 6. The mean blood loss in the first 36 hours was 881.3 ± 56.16 in GI and 858.9 ± 46.67 in GII (p-value = 0.76). The mean ICU stay is shown in Table 7 but there were no significant differences between the groups. One (2%) patient of GI required a reoperation for bleeding (p-value = 1.0) and no patient suffered dehiscence of the sternum. There was no evidence of ischemia of the hand or complications related to the removal of the LRA.

Table 6. Immediate evolution

Events	GI	GII	p-value
Low output	3 (6.0%)	3 (6.0%)	1.00 (ns)*
(Intra-Aortic balloon)	1	0	1.00 (ns)*
AMI ECG + Enzymes	1	1	1.00 (ns)*
Arrhythmias:			
TAVB (temporary)	3	3	1.00 (ns)*
Atrial fibrillation	0	1	1.00 (ns)*
Neurological (temporary)	1	1	1.00 (ns)*
Pulmonary (Bronchospasm)	1	0	1.00 (ns)*

**level of probability by the Fisher exact test: ns – non-significant*

Table 7. Intensive care unit stay in days

Groups	Days	N
GI	1 to 2	10
	2 to 3	30
	3 to 4	6
	5	1
	6	1
	7	1
	8	1
GII	1 to 2	10
	2 to 3	34
	3 to 4	3
	5	1
	6	1
	12	1

DISCUSSION

The success of the LITA led to a search for other arterial grafts to substitute the SV. The use of the bilateral ITAs was also proposed and a better clinical evolution was confirmed by some authors [7-9] and contested by others [10,11]. It is frequently not used due to the increase in morbidities and the complexity of the technique [7,12].

Among the alternative arterial grafts used to substitute the RITA or concomitantly with the ITAs, the RA has become very popular and is considered by many as the second option as an arterial graft after the LITA [7,13].

The RA is easy to dissect, has a good caliber and is long enough to reach the arteries of the posterior face of the heart, and can be used in sequential anastomoses [7,13]. Its negative points are: the presence of atheroma plaque in elderly patients and a greater tendency for vasospasms due to its histological characteristics, even with the use of pharmacological protocols to prevent spasms [13-15]. From a technical point of view, the RA can be used as an aorto-coronary graft or as the proximal anastomosis in Y or T grafts with the LITA thereby forming a compound graft.

The use of compound grafts attempt to prevent proximal anastomosis of the ascending aorta, an aggravating factor in the results of the LITA when it is used as a free graft [16]. The disadvantages cited are: eventual calcification and thickening of the aortic wall, discrepancy in the thickness of the vessels, pressure regime and elevated pulse pressure leading to greater reactivity of the graft, as well as early an atherosclerotic process with vasospasms and occlusion of the graft [3,17-19]. The use of a compound graft also favors the use of sequential anastomoses, increasing the utilization of arterial grafts [7,19-21]. The main disadvantage in their use is the great area of myocardium that will be dependent on the flow through the LITA which, when insufficient due to spasms or occlusion, leads to a large infarcted area. However there are well designed works in the literature that demonstrate that the LITA has a good adaptation to the flow when necessary [18,22].

In respect to the technique, the anastomosis of the LITA demands greater ability and experience by the surgeon, to choose the best location of the anastomosis, taking care not to cause injury to the LITA and establish the exact length of graft avoiding bending. There are several published reports in respect to the results of both the techniques however, there are few comparative studies. In the present study, we analyzed the applicability of the technique comparing the immediate evolution of patients in similar groups.

The proximal anastomosis in the LITA was achieved before establishing the CPB in patients in GII thereby significantly reducing the total CPB time providing benefits to patients, but not contributing to a reduction in the ischemia time as the proximal anastomoses in GI were performed with partial clamping of the aorta. In this study, there was not a greater number of anastomoses with the LRA due to sequential anastomoses in GII; it was impossible to prove this benefit to this group of patients. This data shows that sequential anastomoses are also possible in patients undergoing proximal anastomoses to the aorta.

The incidence of severe immediate cardiac complications, such as low output syndrome, was similar in both groups, however only one patient of GI died, whilst all the rest had good recoveries. The incidence of this complication in the literature varies from 2.8 to 4.3 for series similar to the patients in GI and 0.8 to 4.0 for GII [15,19,23]. The occurrence of perioperative AMI was also similar however, the patient of GI had AMI of the anterior wall, whilst the patient from GII had AMI of the posterior wall,

where an arterial graft had not been employed. In the literature, this occurrence varied from 0 to 3.3% of the cases in GI-type series and from 0 to 3.6% in GII [7,15,19,23].

In relation to cardiac complications, low output syndrome and acute myocardial infarction in the peri-operative period may be related to the technique and to the type of graft used, as well as the previous function of the myocardium, the old areas of infarct and fibrosis and the presence of fine coronary branches with diffuse lesions that make adequate revascularization difficult.

These data show that the use of compound grafts does not increase the incidence of significant immediate cardiac complications in relation to the conventional anastomoses of the aorta. These complications are often related to insufficient flow through the grafts when vasospasms occur. In normal conditions, the LITA possesses a good reserve flow and can adequately supply the territory of the AVI and the region irrigated by the LRA, even when sequential anastomoses are employed, increasing this flow when necessary [18,22,24].

The occurrence of spasms with the LITA is rare; however, it must be replaced immediately when they are observed due to the high morbidity and mortality this causes. Vasospasms are an important complication of the RA and are described by some authors [13,15,25] and are highlighted as the main cause of graft failure [23]. Coronary lesions of less than 75% were related to the presence of competition of flow in the RA, leading to spasms and occlusion of the graft [7,13,19]. In this study, the drugs used to prevent spasms were topically used papaverine, verapamil and isossorbide nitrate, as well as intravenous nitroglycerine and diltiazem. Several protocols have been proposed, however there is no consensus on their effectiveness [13]. Spasms of arterial grafts were responsible for the only death in this series of patients.

Other non-cardiac complications, pulmonary and neurological, also had similar incidences. The use of compound grafts avoids the manipulation of the ascending aorta and might prevent temporary neurological complications in both groups, however without giving statistical significance and no patients presented with strokes or postoperative sequels.

In our study, we avoided the use of the RA in over 70-year-old patients, nevertheless recent studies showed better results of the RA compared to the SV in this group of patients, with a lower incidence of neurologic complications and similar mortality rates [25].

The immediate patency of the RA grafts when anastomosed in the aorta varies from 91.5 to 98.9% and from 76.7 to 93.8% over 12 to 60 months [15,19,23]. The compound RA graft showed early patency of 89.65 to 100% and late patency of 88.5 to 100% [7,15,23]. Iacó et al. [15] reported late patency of 93.8% for the compound graft and 100% for the proximal graft in the aorta after a mean follow-up of 48 months. A recent study comparing both techniques showed an early patency of 100% for the LITA and RA in both groups and only symptomatic patients were submitted to angiography in the late evolution showing a patency of 53.5% for the GI group and 60% for GII without significant differences [7].

CONCLUSION

The RA is a safe graft which does not increase operative morbidity; it is easy to use, it has a good caliber and length and presents with initial clinical results similar when anastomosed proximally in the aorta or in the LITA in Y-type compound grafts. A long-term study of the patency is necessary to define the superiority of one of the techniques.

REFERENCES

1. Acar C, Jebara VA, Portoghese M, Beyssen B, Pagny JY, Glare P et al. Revival of the radial artery for coronary bypass grafting. Ann Thorac Surg. 1992;54(4):652-60.

2. Bhan A, Gupta V, Choudhary SK, Sharma R, Singh B, Aggarwal R et al. Radial artery in CABG: could the early results be comparable to internal mammary artery graft. Ann Thorac Surg. 1999;67(6):1631-6.

3. Calafiore AM, Di Giammarco G, Luciani N, Maddestra N, Di Nardo E, Angelini R. Composite arterial conduits for a wider arterial myocardial revascularization. Ann Thorac Surg. 1994;58(1):185-90.

4. Mills NL. Physiologic and technical aspects of internal mammary artery coronary artery bypass grafts. In: Cohn LH, ed. Modern techniques in surgery. Cardio-thoracic Surgery. Mt. Kisco NY: Futura;1982. p.1-19.

5. Sauvage LR, Wu HD, Kowalsky TE, Davis CC, Smith JC, Rittenhouse EA et al. Healing basis and surgical techniques for complete revascularization of the left ventricle using only the internal mammary arteries. Ann Thorac Surg. 1986;42(4):449-65.

6. Reyes AT, Frame R, Brodman RF. Technique for harvesting the radial artery as a coronary artery bypass graft. Ann Thorac Surg. 1995;59(1):118-26.

7. Lemma M, Mangini A, Gelpi G, Innorta A, Spina A, Antona C. Is it better to use the radial artery as a composite graft? Clinical and angiographic results of aorto-coronary versus Y-graft. Eur J Cardiothorac Surg. 2004;26(1):110-7.

8. Lytle BW, Blackstone EH, Loop FD, Houghtaling MS, Arnold JH, Akhrass R et al. Two internal thoracic artery grafts are better than one. J Thorac Cardiovasc Surg. 1999;117(5):855-72.

9. Pick AW, Orszulak TA, Anderson BJ, Schaff HV. Single versus bilateral internal mammary artery grafts: 10-year outcome analysis. Ann Thorac Surg. 1997;64(3):599-605.

10. Sergeant PT, Blackstone EH, Meyens BP. Does arterial revascularization decrease the risk of infarction after coronary artery bypass grafting? Ann Thorac Surg. 1998;66(1):1-11.

11. Morris JJ, Smith LR, Glower DD, Muhlbaier LH, Reves JG, Wechsler AS et al. Clinical evaluation of single versus multiple mammary artery bypass. Circulation. 1990;82(5 suppl.):IV214-23.

12. Loop FD, Lytle BW, Cosgrove DM, Stewart RW, Goormastic M, Williams GW et al. Influence of the internal-mammary-artery graft on 10-year survival and other cardiac events. N Engl J Med. 1986;314(1):1-6.

13. Possati G, Gaudino M, Prati F, Alessandrini F, Trani C, Glieca F et al. Long-term results of the radial artery used for myocardial revascularization. Circulation. 2003;108(11):1350-4.

14. He GW, Yang CQ. Comparison among arterial grafts and coronary artery: an attempt at functional classification. J Thorac Cardiovasc Surg. 1995;109(4):707-15.

15. Iacó AL, Teodori G, Di Giammarco G, Di Mauro M, Storto L, Mazzei V et al. Radial artery for myocardial revascularization: long-term clinical and angiographic results. Ann Thorac Surg. 2001;72(2):464-9.

16. Loop FD, Lytle BW, Cosgrove DM, Golding LA, Taylor PC, Stewart RW. Free (aorto-coronary) internal mammary artery graft: late results. J Thorac Cardiovasc Surg. 1986;92(5):827-31.

17. Curtis JJ, Stoney WS, Alford Jr. WC, Burrus GR, Thomas Jr. CS. Intimal hyperplasia: a cause of radial artery aortocoronary bypass graft failure. Ann Thorac Surg. 1975;20(6):628-35.

18. 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(5):841-8.

19. Maniar HS, Barner HB, Bailey MS, Prasad SM, Moon MR, Pasque MK et al. Radial artery patency: are aortocoronary conduits superior to composite grafting? Ann Thorac Surg. 2003;76(5):1498-504.

20. Gatti G, Dondi M, Ferrari F, Trane R, Bentini C, Pugliese P. Non-invasive assessment of the composite radial artery and in situ left internal thoracic artery Y-graft for myocardial revascularization. Ital Heart J. 2003;4(11):776-81.

21. Royse AG, Royse CF, Raman JS. Exclusive Y graft operation for multivessel coronary revascularization. Ann Thorac Surg. 1999;68(5):1612-8.

22. Lemma M, Mangini A, Gelpi G, Innorta A, Spina A, Antona C. Analysis of Y-graft blood flow and flow reserve in conditions of increased myocardial oxygen consumption. Ital Heart J. 2004;5(4):290-4.

23. Santos GG, Stolf NA, Moreira LF, Haddad VL, Simões RM, Carvalho SR et al. Randomized comparative study of radial artery and right gastroepiploic artery in composite arterial graft for CABG. Eur J Cardiothorac Surg. 2002;21(6):1009-14.

24. Hata M, Shiono M, Inoue T, Sezai A, Negishi N, Sezai Y. Midterm results of coronary artery bypass graft surgery with internal thoracic artery under low free-flow conditions. Ann Thorac Surg. 2004;78(2):477-80.

25. Muneretto C, Bisleri G, Negri A, Manfredi J, Carone E, Morgan JA et al. Left internal thoracic artery-radial artery composite grafts as the technique of choice for myocardial revascularization in elderly patients: a prospective randomized evaluation. J Thorac Cardiovasc Surg. 2004;127(1):179-84.