ORIGINAL ARTICLE

Braz J Cardiovasc Surg 2006; 21(2): 165-172

Incidence of atherosclerosis in radial arteries of cadavers

Incidência de aterosclerose em artérias radiais de cadáveres

João Augusto Ferraz de SAMPAIO[1], Domingo Marcolino BRAILE[2], Maria Cecília FERRO[3], Luis Alberto MAGNA[4], Décio Cardoso da SILVA JUNIOR[5], André Portella ALCOLÉA[6]

RBCCV 44205-812

Abstract

Objective: **To verify the incidence of atherosclerotic obstructions and microscopic atherosclerotic lesions in radial arteries dissected from cadavers of over 34-year-olds.**

Methods: **Twenty-nine cadavers had both radial arteries dissected as if they were going to be utilized as coronary artery bypass grafts. An angiogram was performed to determine atherosclerotic obstructions of the radial arteries. Subsequently, 3 fragments of each artery (proximal, medial, distal) were prepared on microscope slides using hematoxylin-eosin in order to identify microscopic atherosclerotic lesions. Results were compared with risk factors found in the patient's records: age, gender, hypertension, diabetes, history of smoking, myocardial infarction, stroke, peripheral vascular disease, obesity, family history.**

Results: **No obstructive lesions were found in the angiograms. Four cadavers presented with microscopic atherosclerotic and pre-atherosclerotic lesions. Among the risk factors considered, only age was correlated with microscopic lesions. The arteries measured, on average, 19.22 cm in males and 17.45 cm in females. Their diameters were 1.87 mm for men and 1.72 mm for women.**

Conclusions: **No atherosclerotic obstructions were found in the radial arteries of these cadavers. Age is a risk factor for microscopic atherosclerotic lesions.**

Descriptors: **Radial artery. Arteriosclerosis. Cardiac surgical procedures.**

1. Specialist in Cardiovascular Surgery
2. Ph.D. Professor of Cardiovascular Surgery - UNICAMP.
3. Ph.D. Professor of Pathology - CCMB-PUC-SP.
4. Ph.D. Professor of Biostatistics and medical genetics - UNICAMP.
5. Cardiovascular surgeon - Hospital Unimed Sorocaba.
6. General surgery resident - Conjunto Hospitalar de Sorocaba.

Work carried out in the Centro de Ciências Médicas e Biológicas da Pontifícia Universidade Católica in São Paulo (CCMB-PUC-SP), as the dissertation of Masters Degree in Cardiovascular Surgery in the State University in Campinas (UNICAMP).

Correspondence address:
João Augusto Ferraz de Sampaio.Rua Luiz da Silva Rodrigues, 354. Vila Independência. Sorocaba, SP CEP 18040-336.
E-mail: jafsampaio@uol.com.br

Article received in April, 2006
Article accepted in May, 2006

Resumo

Objetivo: **Determinar a incidência de lesões ateroscleróticas obstrutivas e também lesões ateroscleróticas microscópicas em cadáveres acima de 35 anos, pesquisando toda a extensão da artéria radial.**

Método: **Foram dissecadas ambas as artérias radiais de 29 cadáveres, em toda sua extensão, como se fossem ser utilizadas para cirurgia de revascularização do miocárdio. Foi realizada uma angiografia com contraste nessas artérias, a fim de detectar lesões ateroscleróticas obstrutivas. Após isso, cada artéria teve três fragmentos preparados em parafina, para se detectar histologicamente lesões ateroscleróticas e pré-ateroscleróticas. Os resultados foram confrontados com os fatores de risco para aterosclerose encontrados nesses cadáveres.**

Resultados: **Não foram encontradas lesões obstrutivas à angiografia. Quatro cadáveres apresentaram lesões ateroscleróticas à microscopia. Dos fatores de risco estudados, a idade mostrou associação significante para o aparecimento de lesões ateroscleróticas microscópicas. As artérias mediram, em média, 19,22 cm, nos homens, 17,45 cm, nas mulheres. Seu diâmetro médio foi 1,87 mm, nos homens e 1,72 mm, nas mulheres.**

Conclusão: **Não foram encontradas lesões obstrutivas nas artérias radiais dos cadáveres estudados. A idade é fator que aumenta a incidência de lesão ateromatosa microscópica.**

Descritores: **Artéria radial. Arteriosclerose. Procedimentos cirúrgicos cardíacos.**

INTRODUCTION

The radial artery was first utilized in coronary artery bypass grafting (CABG) over 30 years ago by Carpentier et al. [1]. It was the third type of graft to be described after the internal thoracic artery and the great saphenous vein.

However, after some years, scientific works showed high rates of occlusion of the radial graft over short and medium terms [2,3], in contrast to the good results obtained using saphenous veins and internal thoracic arteries; hence the use of radial arteries for CABG was abandoned.

In 1992, Acar et al. [4] presented their excellent results utilizing the radial artery as a coronary artery graft evaluated over short and medium terms (analyzed by means of hemodynamic studies performed between two weeks and nine months after the surgery). One of the motives attributed to the difference in these results compared to other published studies was the surgical technique employed: removal of the satellite veins from the artery, minimum handling of the artery as electric scalpels were not employed nor was instrumentation inside the lumen to increase vasodilation, as well as the association of diltiazem administered both intravenously and after release from hospital, orally.

These results were reproduced by other authors [5-7]. Calafiore et al. [8] and Buxton et al. [9] commended the exclusive use of arterial grafts whenever possible. These works affirmed that, at least theoretically, arterial grafts were better than saphenous vein grafts as they presented lower occlusion rates over the long term. This has not been proven yet due to the short time that radial arteries and other arterial grafts have been employed [10,11].

The radial artery has anatomic and histologic structures different to the internal thoracic artery, which is currently considered to be the ideal artery for CABG giving the best results. The internal thoracic artery is an artery rich in elastic fibers and its media layer is not very muscular. Additionally it has a continuous internal elastic layer. The radial artery, on the other hand, has a more muscular media layer, less elastic fibers and a greater number of fenestrations in the internal elastic layer, which makes it more susceptible to the formation of atheroma plaques than the internal thoracic artery [12].

For these peculiarities, several comparative studies have been presented in the international literature identifying the radial artery as an anatomic site susceptible to atherosclerotic and pre-atherosclerotic lesions [13-16], especially in the elderly [17].

However, all studies used only segments of the radial artery, fragments of grafts that remained after CABG or segments in the region near the wrist removed from cadavers. Other studies investigated the existence of lesions (plaques or calcification) by means of ultrasound of the arteries, without, however, managing to determine if these plaques were obstructive or not [18,19] due to the limitations of the evaluation method employed which does not distinguish between calcification of the intima layer (related to atherosclerosis) and calcification of the media layer (sclerosis of Mönckberg) in which the patency of the vessel is not compromised.

There have already been reports of intensively calcified and even obstructed radial arteries that could not be utilized as coronary grafts [20].

On reviewing the literature (MEDLINE), we did not find publications about the radial arteries in relation to their use for CABG in our population in the age range in which CABG surgery is most commonly used.

The objective of this work was to investigate the morphological conditions of radial arteries, as well as the incidence of atherosclerotic obstruction of this artery in the adult population (older than 35 years old).

METHOD

This series was made up of patients submitted to autopsies in the Coroner's office in Sorocaba, Service of Pathological Anatomy in the Medicine School of Sorocaba (PUCSP), Brazil.

Inclusion criteria in the current study were:
a) Age greater than or equal to 35 years old;
b) Integrity of the upper limbs.
The following were considered exclusion criteria:
a) Injury to the forearm;
b) Previous surgery or injury to the forearm
c) Prior catheterization of the radial artery;
d) Injectable drug users.

The data on the corpses were obtained by interviewing family members or by investigating the patients' records. In all cases, written consent to remove the radial artery was received from the families.

The data related to the personal history of the cadaver considered relevant as cardiovascular risk factors were:
Gender;
Age;
Arterial hypertension;
Diabetes mellitus;
Smoking;
Prior myocardial infarction;
Acute myocardial infarction;
History of peripheral vascular insufficiency;
History of strokes;
History of related personal or familial diseases;
Body mass index (BMI);
Presence of coronary atheromatosis;
Presence of thoracic artery atheromatosis.

This work was approved by the Ethics Committee of the Medical and Biological Sciences Center of the Pontifícia Universidade Católica of São Paulo.

Method

The radial arteries were removed during autopsy, utilizing the technique described by Reyes et al. [21], from the initial segment at the junction with the brachial artery to the bifurcation forming the superficial and deep palmar arches at the wrist (Figure 1). Their branches were ligated using 4-0 cotton thread and the artery was catheterized with a number 6 Nelaton-type catheter in their initial and terminal portions after which it was immersed in saline solution.

The artery was submitted to an angiographic study. It was taken to the hemodynamics laboratory of the Santa Lucinda Hospital where an ionized contrast (Telebrix ®) was injected into the artery under controlled pressure with the distal end of the radial artery connected to a mercury column (Figures 2 and 3), and the pressure maintained at 80 mmHg during a contrasted radiological examination.

The aspect of its lumen was analyzed, in respect to obstructions. The vessel was rotated through 90 degrees and again the aspect of its lumen was observed.

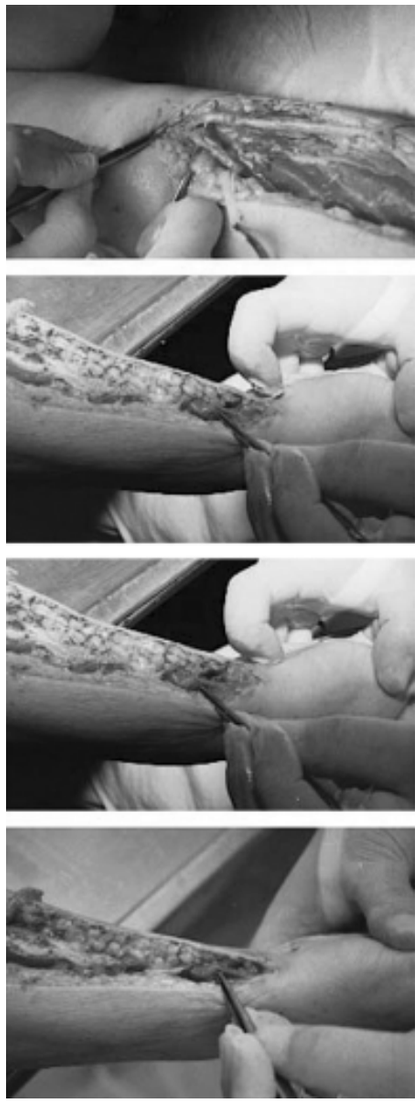

Fig. 1 – Removal of the radial artery. Identification of the superficial palmar artery. The palmar arch to the hand is normally formed at the wrist. This is the distal end of the radial artery

Residual contrast was removed rinsing with saline solution injections and subsequently three segments (distal, medial and proximal) were resected and immersed in a 10% buffered formaldehyde solution and embedded in paraffin. Five-micron thick histological sections were cut using a rotating microtomy, and these were subsequently stained by the Harris method with hematoxylin-eosin [22]. During microscopy, the diameters of these arteries were measured using an intra-ocular ruler. This ruler, with millimeters split in 100 divisions, was placed on a 10x lens for measurement.

Fig. 2 – Preparation for arteriography. Position of the radial artery for the injection of contrast

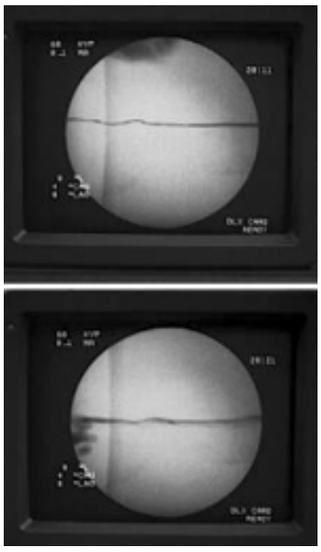

Fig. 3 – Arteriography: aspect of the radial artery after contrast injection

The measurement of the lumen was made by placing the ruler between the end of the endothelium at one side and the start of the endothelium at the other. For standardization, the widest section of lumen was always chosen.

The results of the contrasted examinations, macroscopy of the sample and the microscopic study of the artery were assessed in respect to the risk factors. The non-parametric Mann-Whitney test was utilized with a p-value < 0.05 considered statistically significant.

RESULTS

The right and left radial artery were removed from 29 cadavers giving a total of 58 arteries for the study. Ages varied from 35 to 86 years old with a mean of 55 years and 10 months (standard deviation ± 14.5 years). Eighteen cadavers (62.10%) were male and 11 (37.90%) female. According to the patients' histories 18 (58.62%) had suffered from systemic hypertension, 3 (10.34%) from diabetes and 14 (48.27%) patients had been smokers.

The lengths of the arteries ranged from 14 to 23 cm (mean 18.55 cm). In men the mean was 19.22 cm and in women 17.45 cm. The mean diameter was 1.79 mm (1.87 mm in men and 1.72 mm in women). The dimensions of the arteries are shown in Tables 1 and 2.

The body mass indexes (BMI) varied from 20.01 to 35.52 (mean = 25.13) – Table 3.

The causes of death are shown in Table 4.

In the study using an injection of contrast under a controlled pressure of 80 mmHg, no obstructive lesions were identified.

In the microscopic study, four cadavers presented with histopathological alterations compatible with the process atheroma formation, which were: thickening of the endothelium with signs of atherosclerosis such as deposit of fat on the endothelium and the intima layer, in three cadavers (two women; one of 72 and the other of 86 years old and one man of 62 years old). One of the cadavers (an 86-year old man) presented with deposits of calcium in the intima layer and infiltration to the muscle layer as well as thickening of the endothelium (Figures 4 and 5). The lesions appeared, with small variations of intensity, in both left and right arteries of the cadavers with greater intensity in the distal segments.

Based on the microscopic findings, the aforementioned risk factors were correlated with evidence of atheromatous lesions.

The age was identified as a significant risk factor for the presence of atheromatous lesions (p-value = 0.008).

Hypertension (p-value = 0.139), gender (p-value = 0.622), precordialgia (p-value = 0.552), diabetes (p-value = 0.371), smoking (p-value = 0.598), presence of atheromatous

plaques in the thoracic artery (p-value = 0.279) or in the coronary arteries (p-value = 0.568), causa mortis (cardiac or non-cardiac causes – p-value = 0.238) and obesity (p-value = 0.546) were not considered statistically significant.

Table 1. Dimensions of the radial arteries in female cadavers

	Age	Length R	Length L	Diameter
Female	80	15.00	16.50	2.30
	86	16.00	16.00	1.28
	71	16.00	16.00	1.60
	40	16.00	16.00	2.25
	68	17.00	16.00	1.25
	68	17.00	19.00	1.80
	72	17.00	17.00	2.10
	45	18.00	18.00	1.80
	44	18.50	19.00	1.40
	53	19.00	19.00	1.90
	62	21.00	21.00	1.30
Mean	62,64	17.32	17.59	1.73

Length R – Length of right radial artery
Length L – Length of left radial artery

Table 2. Dimensions of the radial arteries in male cadavers

	Age	Length R	Length L	Diameter
Male	55	14.00	16.00	1.90
	58	18.00	19.00	1.80
	59	18.00	17.00	1.85
	72	18.00	18.50	2.20
	51	18.00	20.00	2.25
	66	19.00	18.00	1.75
	47	19.00	18.50	1.80
	62	19.00	19.00	1.85
	43	19.00	19.00	2.05
	35	19.00	19.00	2.10
	45	20.00	20.00	1.40
	43	20.00	19.50	1.60
	36	20.00	21.00	1.65
	49	20.00	19.00	1.65
	39	20.00	21.00	1.80
	38	20.50	20.00	1.80
	86	22.00	20.00	2.30
	48	23.00	21.00	1.15
Mean	51,78	19.25	19.19	1.83

Length R – Length of right radial artery
Length L – Length of left radial artery

Table 3. Weight

Distribution	Total
Normal	17
Overweight	10
Obese	2
Morbid Obesity	0
Total	29

Table 4. Causa mortis of the cadavers

Causa mortis	Total	%
Stroke	5	17.2%
Dissection of thoracic aorta	2	6.9%
Acute lung edema	3	10.3%
Acute lung edema + acute myocardial infarction	1	3.4%
High digestive tract hemorrhage + Cirrhosis	1	3.4%
Indeterminate	1	3.4%
Acute myocardial infarction	6	20.7%
Peritonitis	2	6.9%
Rupture of abdominal aorta aneurism	2	6.9%
Rupture of abdominal aorta aneurism + dissection of thoracic aorta	1	3.4%
Rupture of thoracic aorta aneurism	1	3.4%
Cranioencephalic Traumatism	1	3.4%
Pulmonary thromboembolism	2	6.9%
Mesenteric Thrombosis	1	3.4%

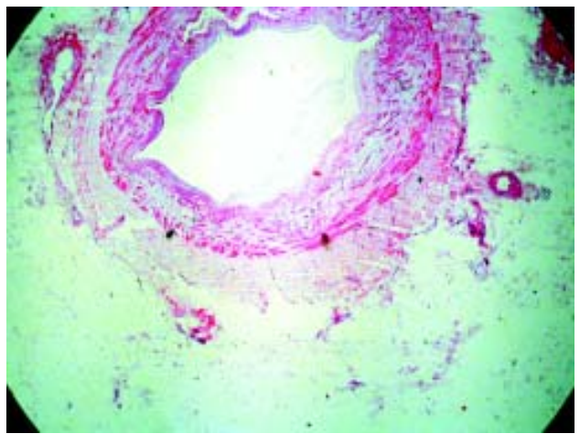

Fig. 4 – Microscopy of the arteries. Radial artery with deposit of fat in the endothelium, and infiltration to the muscle layer – staining hematoxylin-eosin

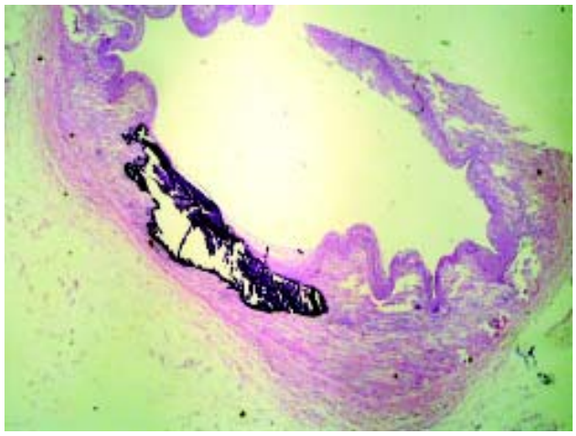

Fig. 5 – Microscopy of the arteries. Calcified atheroma plaque with invasion to the muscle layer without causing obstruction of the lumen of the vessel – staining hematoxylin-eosin

DISCUSSION

The great increase in the use of the radial artery since the publication of Acar et al. [4] is due to the idea that, being an arterial graft, its longevity is greater than venous grafts and similar to the life of internal thoracic artery grafts, which are considered to be the best graft for coronary arteries, a fact that was proved by several works over a medium-term follow up period [23,24]. Tatoulis et al. [25] reported that the patency of the radial artery at 1 year is 96.0% and at 4 years it is 89%.

Several authors [26-29] considered the radial artery to be better than the right internal thoracic artery. However, the above studies show that the patency of the left internal thoracic artery is always better, varying from 92 to 98%.

However, Khot et al. [30] reported that, in patients that present with symptoms and signs of myocardial ischemia after CABG surgery and who were submitted to coronary cineangiographic studies, the rate of occlusion of the radial graft was higher than other coronary grafts, including the saphenous vein. The authors had several hypotheses to explain this observation: the occurrence of occlusion was higher in women, the distal bed of the vessel to be revascularized, the degree of stenosis of the lesion, the way the radial artery was used (whether direct in the aorta or in 'T' or 'Y' grafts). In this same article, the "possibility of developing atherosclerosis of the graft" and the "necessity of researching the possibility of pre-existent atherosclerosis in the radial artery, before CABG surgery" were discussed.

The above text, as well as others previously cited [15,18], motivated this investigation as previous studies evaluated only segments of radial arteries not utilized in the CABG and did not analyze the radial artery as a whole.

Individuals are submitted to CABG due to the development of coronary atherosclerotic disease and can, logically, develop atherosclerotic plaques in other arteries including in the radial arteries.

Removing the radial artery using the standard technique, with its conjunctive tissue and satellite veins, we tried to copy as far as possible the conditions of a real surgical procedure even trying to detect at the time of removal, possible externally visible atheroma plaques. In none of the arteries atheromatous lesions were macroscopically seen or suspected.

Our series was relatively small (29 cadavers) which explained why we did not find obstructive lesions in any of the arteries. If we consider our investigation as representative of the larger population and calculate the possibility of there being obstructive lesions in radial arteries, we have a 95% possibility that up to 11.9% of the population would have visible obstructive lesions in a contrasted study (within an estimation based on the confidence interval of binomial distribution). In order to define a possibility within a smaller range (varying from 0 to 11.9%) it would be necessity to study a larger sample.

The fact that we did not find any obstructions along the entire length of the 58 arteries included in this study, of cadavers with ages which ranged from 38 to 86 years old, leads us to the conclusion that the radial artery is an arterial graft that may be used with some safety as the coronary artery with atherosclerosis is not being replaced with another artery with preexistent obstructive lesions. Obviously necessary precautions should be taken to prevent spasms and the artery should be well evaluated in patients with diabetes.

The increase in the incidence of microscopic atherosclerotic lesions in the elderly should be taken into account when using radial arteries in these patients. In respect to its longevity, more time is required with long term studies including in respect to the influence of atherosclerotic lesions seen at microscopy.

Another important finding was that we obtained a measurement for the length and diameter of radial arteries: the length was 19.22 cm for men and 17.45 cm for women, and the diameter, measured by means of an intra-ocular ruler during the histological examination and hence without pressure was 1.87 mm for men and 1.72 mm for women. Barry et al. [31] studied the diameters of radial arteries of 20 cadavers by introducing probes; the mean result was 2.2 mm (a variation of 1 mm to 2.5 mm).

CONCLUSION

No obstructive atherosclerotic lesions were found in the cadavers. The estimated probability of finding obstructive

lesions in the radial artery by contrasted studies is low. The presence of atherosclerotic lesions seen by microscope is dependent on the age of the cadavers.

REFERENCES

1. Carpentier A, Guermonprez JL, Deloche A, Frechette C, DuBost C. The aorta-to-coronary radial artery bypass graft: a technique avoiding pathological changes in grafts. Ann Thorac Surg. 1973;16(2):111-21.

2. Curtiss JJ, Stoney WS, Alford WC, Burrus GR, Thomas CSJ. Intimal hiperplasia: a cause of radial artery aortocoronary bypass graft failure. Ann Thorac Surg. 1975;20(6):628-35.

3. Fisk RL, Brooks CH, Callaghan JC, Dvorkin J. Experience with the radial artery graft for coronary bypass. Ann Thorac Surg. 1976;21(6):513-8.

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

5. Dietl CA, Benoit CH. Radial artery graft for coronary revascularization: technical considerations. Ann Thorac Surg. 1995;60(1):102-10.

6. Costa FDA, Costa IA, Poffo R, Abuchaim D, Gaspar R, Garcia L et al. Myocardial revascularization with the radial artery: a clinical and angiographic study. Ann Thorac Surg.1996;62(2):475-80.

7. Manasse E, Sperti G, Suma H, Canosa C, Koe A, Martinelli L et al. Use of the radial artery for myocardial revascularization. Ann Thorac Surg. 1996;62(4):1076-83.

8. Calafiore AM, Teodori G, Di Giammarco G, D'Annunzio E, Angelini R, Vittola G et al. Coronary revascularization with the radial artery: new interest for an old conduit. J Card Surg. 1995;10(2):140-6.

9. Buxton B, Fuller J, Gaer J, Liu JJ, Mee J, Sinclair R et al. The radial artery as a bypass graft. Curr Opin Cardiol. 1996;11(6):591-8.

10. Dallan LA, Oliveira SA, Jatene FB, Corso R, Iglésias JC, Prates N et al. Artéria radial na ampliação do uso de enxertos arteriais para revascularização do miocárdio: considerações anatômicas e tática cirúrgica. Rev Bras Cir Cardiovasc. 1996;11(2):75-81.

11. Souza LCG, Souza JM, Berlinck M, Oliveira SA. Artéria gastroepiplóica direita na cirurgia de revascularização do miocárdio. Rev Bras Cir Cardiovasc. 2000;15(1):16-22.

12. Sisto T. Atherosclerosis in internal mammary and related arteries. Scand J Thorac Cardiovasc Surg. 1990;24(1):7-11.

13. Vink A, Schoneveld AH, Poppen M, Kleijin DP, Borst C, Pasterkamps G et al. Morphometric and immunohistochemical characterization of the intimal layer throughout the arterial system of elderly humans. J Anat. 2002;200(Pt 1):97-103.

14. Kaufer E, Factor SM, Frame R, Brodman RF. Pathology of the radial and internal thoracic arteries used as coronary artery bypass grafts. Ann Thorac Surg. 1997;63(4):1118-22.

15. Ruengsakulrach P, Sinclair R, Komeda M, Raman J, Gordon I, Buxton B et al. Comparative histopathology of radial artery versus internal thoracic artery and risk factors for development of intimal hyperplasia and atherosclerosis. Circulation. 1999;100(19 suppl):II-139-44.

16. Kane-Toddttall SM, Taggart SP, Clements-Jewery H, Roskell DE. Pre-existing vascular disease in the radial artery and other artery bypass conduits. Eur J Med Res. 1999;16(4):11-4.

17. Sobral MLP, Santos GG, Santos LAS, Haddad VLS, Avelar Júnior SF, Stolf NAG. Estudo comparativo randomizado da evolução imediata dos pacientes com artéria radial anastomosada proximalmente na aorta ou como enxerto composto. Rev Bras Cir Cardiovasc. 2006;21(1):35-41.

18. Nicolosi AC, Pohl LL, Parsons P, Cambria RA, Olinger GN. Increased incidence of radial artery calcification in patients with diabetes mellitus. J Surg Res. 2002;102(1):1-5.

19. Ruengsakulrach P, Brooks M, Sinclair R, Hare D, Gordon I, Buxton B et al. Prevalence and prediction of calcification and plaques in radial artery grafts by ultrasound. J Thorac Cardiovasc Surg. 2001;122(2):398-9.

20. Deshpande RP, Chukwuemeka A, Iqbal A, Desai JB. Dystrophic calcification of the radial artery. Ann Thorac Surg. 2000;69(6):1939-40.

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

22. Hessess CS, Mullick SG. Tecnica de la hematoxilina-eosina,utilizando hematoxilina de Harris y eosina amarilla. Metodos histotecnologicos. Washington:A.S.I.T.;1995. p.58-9.

23. Weinschelbaum EE, Macchia A, Caramutti VM, Machain HA, Rafaelli HA et al. Myocardial revascularization with radial and mammary arteries: initial and long-term results. Ann Thorac Surg. 2000;70(4):1378-83.

24. Iaco 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.

25. Tatoulis J, Buxton BF, Fuller JA. Patencies of 2127 arterial to coronary conduits over 15 years. Ann Thorac Surg. 2004;77(1):93-101.

26. Borger MA, Cohen G, Buth KJ, Rao V, Bozinovski J, Liaghati-Nasseri N et al. Multiple arterial grafts: radial versus right internal thoracic arteries. Circulation. 1998;98(19 suppl):II7-14.

27. Caputo M, Reeves B, Marchetto G, Mahesh B, Lim K, Angelini GD. Radial versus right internal thoracic artery as a second arterial conduit for coronary surgery: early and midterm outcomes. J Thorac Cardiovasc Surg. 2003;126(1):39-47.

28. 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.

29. 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.

30. Khot UN, Friedman DT, Pettersson G, Smedira NG, Li J, Ellis SG. Radial artery bypass grafts have an increased occurrence of angiographically severe stenosis and occlusion compared with left internal mammary arteries and saphenous vein grafts. Circulation. 2004;109(17):2086-91.

31. Barry MM, Foulon P, Touati G, Ledoux B, Sevestre H, Carmi D et al. Comparative histological and biometric study of the coronary, radial and left internal thoracic arteries. Surg Radiol Anat. 2003;25(3-4):284-9.