

Imaging findings of myocardial revascularization at multidetector computed tomography – where are the bypass grafts?: an iconographic essay*

Achados de imagem da revascularização do miocárdio pela tomografia computadorizada por múltiplos detectores – onde estão os enxertos?: ensaio iconográfico

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Abstract Multidetector coronary computed tomography angiography is a precise method for evaluating post-coronary revascularization arterial and venous bypass grafts, and is somehow superseding coronary catheterization that is an invasive and more expensive technique. The present iconographic essay is aimed at anatomically demonstrating the bypass grafts most frequently utilized, how to differentiate between arterial and venous grafts and how to find them. The studies were performed in 64-row multidetector computed tomography equipment, with breath hold, controlled heart rate and appropriate protocols with later MPR, MIP and 3D reconstructions according to electrocardiogram. The localization of the bypass grafts and anastomoses at computed tomography studies focused on chest and coronary arteries may represent a difficulty in the images analysis by the radiologist who is not familiar with the matter, so the knowledge of the surgical techniques adopted and possible courses of the saphenous bypass grafts and arterial grafts can aid in the analysis of both studies, avoiding diagnostic errors.

Keywords: Multidetector coronary computed tomography angiography; Saphenous bypass graft; Coronary artery bypass graft.

Resumo A angiotomografia por multidetectores de coronárias constitui um método preciso para avaliação dos enxertos venosos e arteriais pós-revascularização coronariana e vem substituindo em parte o cateterismo, o qual é um método invasivo e de maior custo. Este ensaio iconográfico tem como objetivo a demonstração anatômica dos enxertos mais comumente utilizados, como diferenciar enxertos venosos e arteriais e como localizá-los. Os exames foram realizados em aparelhos de tomografia computadorizada *multislice* de 64 fileiras de detectores, com apneia, frequência cardíaca controlada e protocolos adequados com posterior reconstruções MPR, MIP e 3D, de acordo com o eletrocardiograma. A localização dos enxertos e anastomoses em tomografias computadorizadas direcionadas para as artérias coronárias e para o tórax pode dificultar a análise do exame pelo radiologista não familiarizado, sendo que o conhecimento das técnicas cirúrgicas utilizadas e dos possíveis trajetos das pontes de safena e enxertos arteriais ajuda na análise de ambos os exames, evitando também erros diagnósticos.

Unitermos: Angiotomografia das coronárias por multidetectores; Ponte de safena; Enxerto arterial coronariano.

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INTRODUCTION

Coronary artery disease (CAD) is one of the main causes of death in the world and surgical management by means of vascu-

lar bypass grafts is the technique of choice, particularly in cases of diffuse or multivascular disease. Annually, recurrence of symptoms of ischemia is observed in 4% to 8% of patients, and is closely related to the grafts patency^(1,2).

Currently, coronary cineangiography still remains as the gold standard in the postoperative follow-up of vascular bypass

grafts. However, the assessment of patency of arterial and saphenous grafts utilized in the management of CAD has been performed by means of coronary computed tomography (CT) angiography since the introduction of multidetector CT equipment. Recently, a meta-analysis demonstrated the high accuracy of this method, with 98% sensitivity, 97% specificity, 93% positive predictive value, and 99% negative predictive value⁽³⁾.

Notwithstanding, one of the difficulties faced by the investigator during the analy-

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sis of chest images either focused on the evaluation of myocardial revascularization or not, is the identification and localization of the bypass graft course as well as the respective anastomoses that may vary among patients and according to the cardiac surgeon's experience and technique.

The present essay includes a description of the main types of arterial grafts (right and left internal thoracic artery graft – RITA and LITA) and venous grafts (saphenous vein graft – SVG) through images reconstruction and coronary CT angiography images.

The present iconographic essay is aimed at demonstrating the most frequent sites of arterial and venous bypass grafts for coronary arteries by reviewing coronary CT angiography studies performed in 64-row multidetector CT equipment in the postoperative follow-up of patients with previous history of myocardial revascularization.

All the studies were performed in an Aquilion 64-row multidetector CT scanner (Toshiba Medical Systems; Tokyo, Japan) with ECG-gating and inspiratory breath-holding⁽⁴⁾. The heart rate was previously controlled with beta-blocker, in accordance with the standard protocol of the institution. The images were acquired after 100–120 ml nonionic iodinated contrast (350 mg/ml) injection into antecubital vein at a rate of 5.0 ml/s. Later, the images were processed on a Vitrea workstation (Vital Images; Minnesota, USA), with multiplanar and 3D reconstructions.

DESCRIPTION OF THE GRAFTS

CAD can be surgically managed with either venous or arterial bypass grafts.

Venous grafts

Among the venous grafts, the most frequently utilized is the SVG, because of its availability, easy harvesting, favorable and widely utilized surgical technique⁽⁵⁾ (Figure 1).

Arterial grafts

Internal thoracic artery (ITA) – The LITA is most frequently utilized because of its anatomic proximity, surgical technique, improved survival and extent of the graft patency. Generally, the RITA requires more time to be displaced and anastomosed than



Figure 1. A: Axial images and 3D reconstruction of coronary CT angiography demonstrating SVG (arrows) from the origin of the aorta to the anastomosis in left marginal branch. **B:** Axial images and 3D reconstruction of coronary CT angiography demonstrating SVG (arrows) from the origin of the aorta to the anastomosis in the anterior descending artery. **C:** Axial images and 3D reconstruction of coronary CT angiography demonstrating SVG (arrows) from the origin of the aorta to the anastomosis in the distal third of the right coronary artery.

the LITA does, and seems to be most frequently associated with mediastinal infection⁽⁵⁾ (Figures 2, 3, 4 and 5).

ITA grafts can be anastomosed with more than one vessel, with sequential, latero-lateral or latero-terminal techniques (Figure 6).

Radial artery – Some authors consider the radial artery graft as the second most relevant in myocardial revascularization. Thrombosis resulting from flow competition and spasm constitute complications that must be considered by the surgeon in the selection of the graft⁽⁵⁾.

Gastroepiploic artery – The right gastroepiploic artery is very useful as *in situ* graft combined with other grafts in procedures without extracorporeal circulation where clamping of aorta is not required (Figure 7). Limitations include: variable extent, vulnerability to flow competition

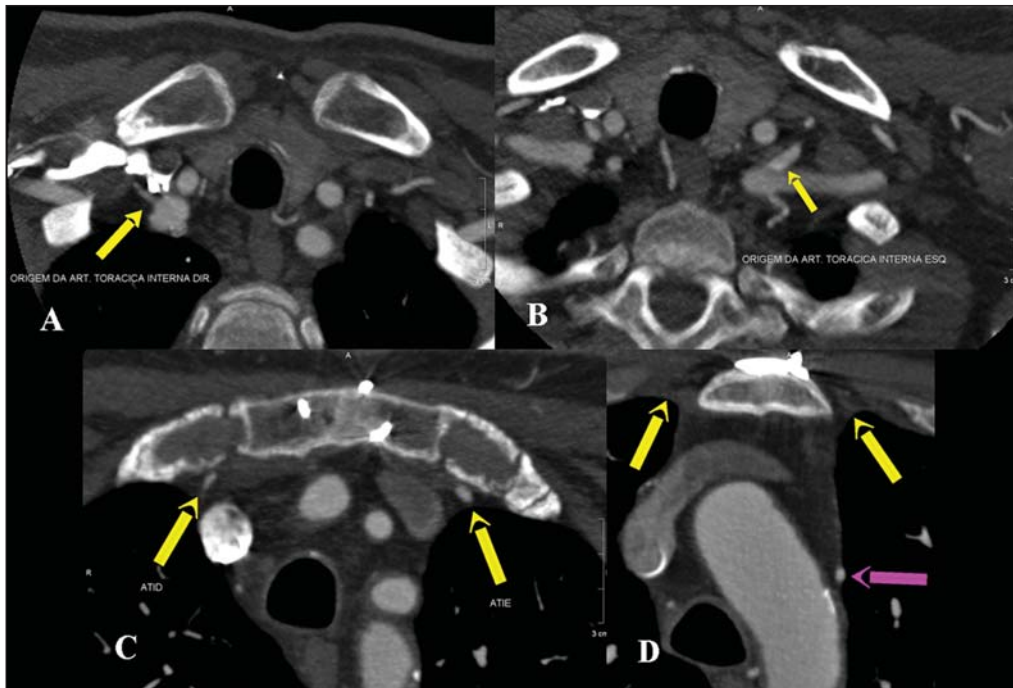


Figure 2. A,B,C: Yellow arrows indicate the course of the internal thoracic arteries from their origin in the respective subclavian arteries. **D:** Note the absence of internal thoracic vessels in the usual routes and the presence of an artery adjacent to the lateral wall of the aortic arch (pink arrow), indicating the presence of myocardial revascularization through the LITA.

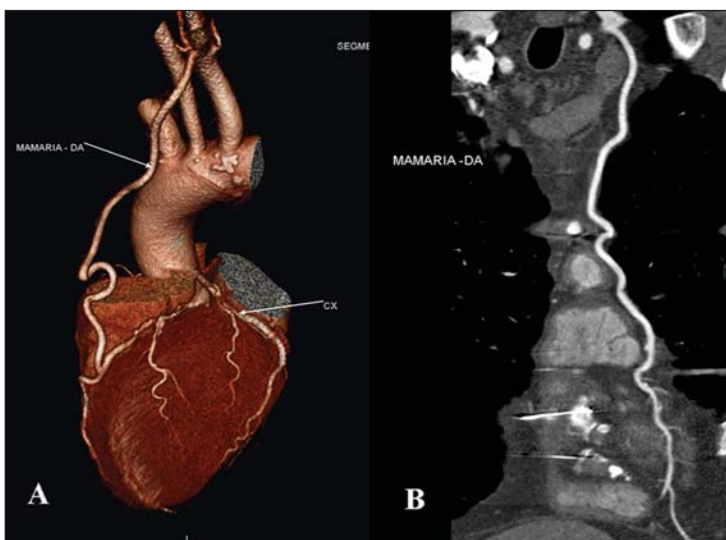


Figure 3. 3D reconstruction and curved MIP demonstrating LITA anastomosis with the normal anterior descending artery (DA) with more than 20 years after surgery.

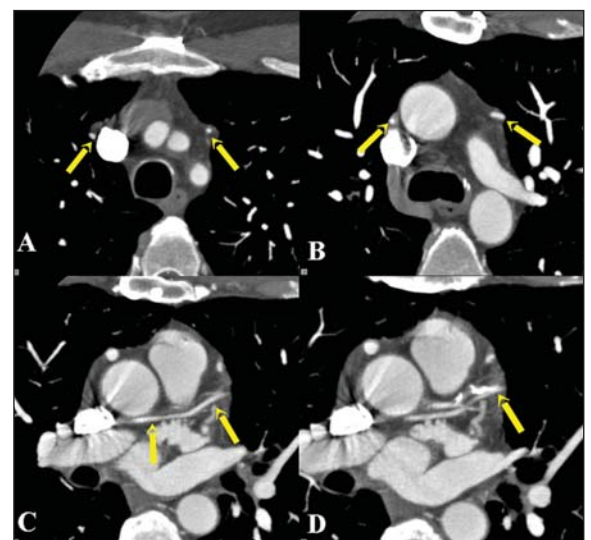


Figure 4. A,B,C: Axial images demonstrating the absence of RITA and LITA in their respective native beds, but found in oblique routes in the mediastinum (arrows) **D:** Note the distal anastomosis of the RITA with diagonal branch (arrow).

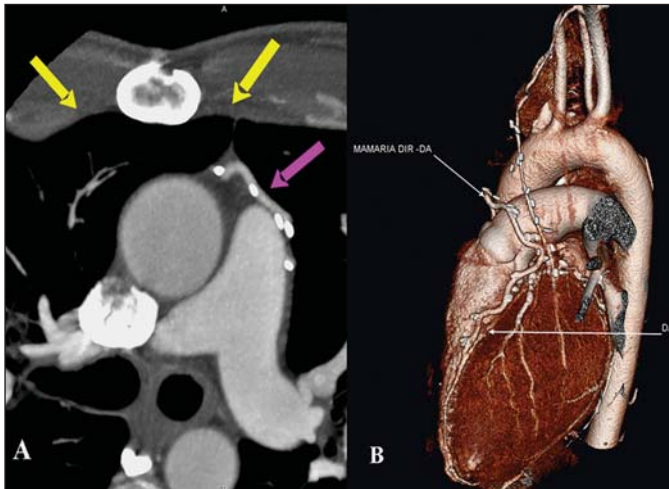


Figure 5. A: Axial image showing free arterial graft (pink arrow) and absence of image of the internal thoracic arteries in their native beds (yellow arrows). **B:** 3D reconstruction demonstrating the normal aspect of RITA anastomosis with the anterior descending artery and of the LITA with marginal branch.

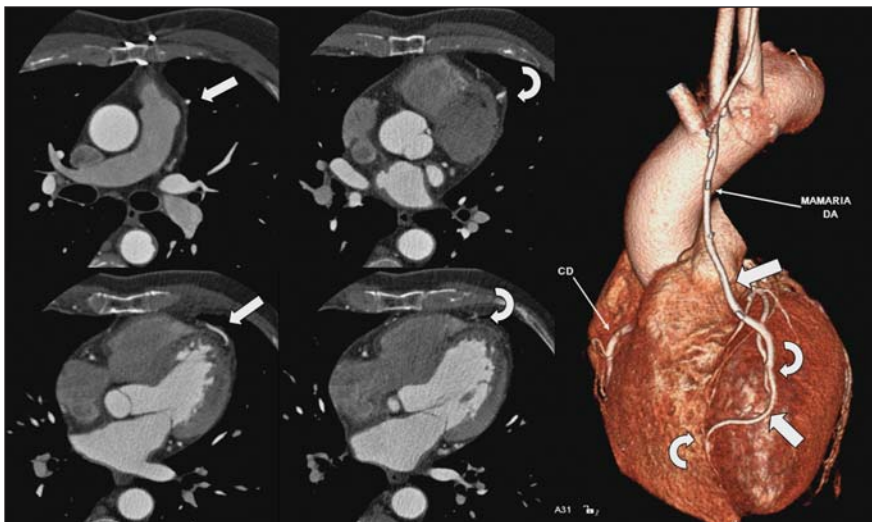


Figure 6. Axial images and 3D reconstruction of coronary CT angiography showing LITA (straight arrows) with sequential anastomosis (curved arrows) in diagonal branch and in the anterior descending artery.

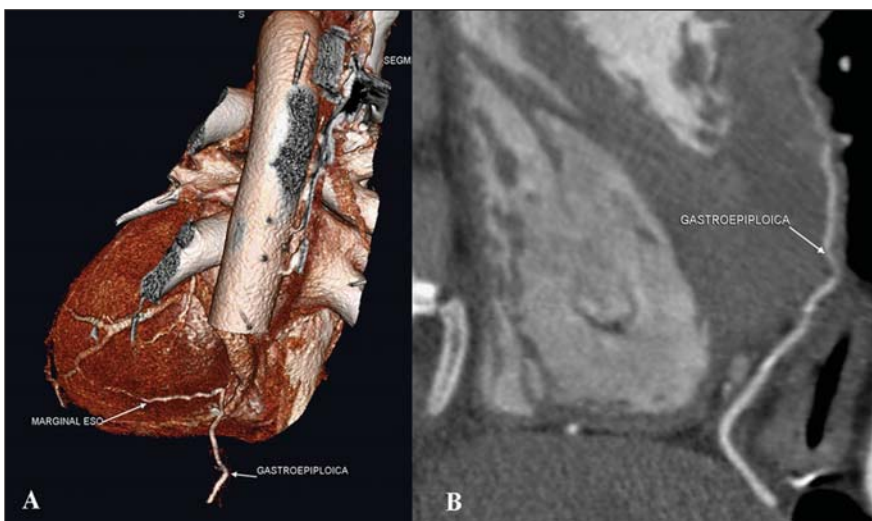


Figure 7. 3D reconstruction and curved MIP demonstrating right gastroepiploic artery anastomosis with marginal branch displaced from the respective native bed.

and more extensive involvement of its origin by atherosclerosis, as compared with the ITA⁽⁵⁾.

DISCUSSION

Studies demonstrate rates of coronary artery graft occlusion ranging from 10% to 30% within 1 to 2 years, and from 45% to 55% within 10 to 12 years⁽⁶⁾.

Coronary cineangiography is the gold standard for demonstrating coronary artery grafts patency. However it is an invasive, highly expensive method that exposes the patients to some procedure-inherent risks such as acute myocardial infarct, cerebral vascular accident and ventricular arrhythmia, with estimated procedure-related mortality rate between 1% and 2%⁽⁷⁾. Additionally, the absence of data regarding the grafts utilized in the patient interferes directly in the study, since the hemodynamicist will take more time, besides contrast agent and radiation exposure to search for and catheterizing the ITAs and SVGs.

Coronary cineangiography and coronary CT angiography were compared by several studies, both for validating the new method in relation to the gold standard and for statistical comparison of the methods. This comparison demonstrates similar sensitivity and specificity in the visualization and characterization of grafts stenosis^(5,7-9). In spite of the absence of data on the grafts utilized in the patient interfering in the analysis of the CT angiography study, it does not imply an increase in the radiation or contrast agent dose, affecting only the

time required for the analysis of the images, since axial images provide all the mediastinal fields required for the search for grafts in a single acquisition.

Thus, the localization of grafts and respective anastomoses on a study focused on coronary arteries and on general studies of the chest by computed tomography may represent a difficulty in the analysis of the images by a radiologist who is not familiar with the matter, since the knowledge on the surgical techniques utilized and the possible (usual and unusual) routes of the saphenous vein grafts and arterial anastomoses are useful in the analysis of both imaging methods, besides avoiding wrong diagnoses.

The present iconographic essay also demonstrates some differences that allow the differentiation between arterial and venous grafts: arterial grafts generally present smaller caliber than venous grafts and frequently are associated with the presence of metal clips placed in the origin of their small branches. Venous grafts generally are calibrous and may present gross

parietal calcifications associated with natural degeneration, besides fibrolipidic or "mixed" plaques^(3,10).

Therefore, the evaluation of the native bed of the internal thoracic arteries is relevant as a first step in this differentiation.

CONCLUSION

Technical developments of CT equipment allow the identification of coronary artery and vein grafts on studies with and without ECG-gating so the knowledge on coronary grafts by radiologists is increasingly relevant.

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