Chapter

Right Internal Thoracic Artery with an Anteroaortic Course

Maurilio O. Deininger, Orlando G. Oliveira, Daniel M.S. Magalhães and Eugenia Di G. Deininger

Abstract

Coronary artery bypass graft surgery remains the procedure of choice to revascularize patients with complex multivessel coronary artery disease. The left internal thoracic artery and saphenous vein are the most commonly utilized conduits in coronary artery bypass graft surgery. The left internal thoracic artery is widely accepted as the conduit of choice for coronary artery bypass grafting. Accumulated evidence in recent years has demonstrated the superiority of bilateral internal thoracic artery grafting over single internal thoracic artery grafting in terms of event-free survival, freedom from reintervention and survival. The survival benefit seen with bilateral internal thoracic artery grafting has been associated particularly with grafting the myocardium supplied by the left coronary artery system. Many surgical strategies have been tested in order to achieve left-sided myocardial revascularization with bilateral internal thoracic artery grafting. These include directing the right internal thoracic artery through the transverse sinus in a retroaortic course, free graft connected proximally either to the left internal thoracic artery (composite grafting) or to the ascending aorta. Another technical option is in situ right internal thoracic artery to the left anterior descending and left internal thoracic artery to circumflex marginal branches; in this chapter we will comment on this technique.

Keywords: bilateral internal thoracic artery, coronary artery bypass grafting, right internal thoracic artery, myocardial revascularization, coronary artery disease

1. Introduction

The treatment of coronary artery disease (CAD) is one of the most studied topics in medicine. Surgery for coronary artery bypass grafting (CABG) remains an excellent therapeutic option for the management of obstructive CAD, even with the development of new drugs and better results obtained with percutaneous treatment [1].

Although the saphenous vein is still widely used for aortic/coronary graft, due to the ease of harvest, preparation, and its use for making multiple grafts, this graft may develop intimal hyperplasia and atherosclerotic lesion, with occlusion rates of 10–15% in the first year after surgery; still, after one decade only 60% of vein grafts are patent, and of these only 50% are free of significant stenosis. Among some causes for the failure of the graft, we can cite the presence of valves in the veins and the risk of dilatation (varicosities). In addition to this, complications may occur

in the lower limb where its harvest was performed. The internal thoracic artery (ITA) rarely develops atherosclerosis, and its diameter is normally compatible with coronary artery to be revascularized [2].

Recently, several studies corroborate the superiority of the use of both internal thoracic arteries (ITAs) instead of the use of only one, especially the use of the left internal thoracic artery (LITA) to the left anterior descending branch (LAD), considered to be the gold standard in CABG as a consequence of the excellent long-term patency. However, the use of right internal thoracic artery (RITA) offers similar results to those obtained with the use of LITA when used for the LAD [1, 3]. Some authors consider that RITA is better as a second arterial graft than the radial artery (RA), particularly in relation to the occurrence of cardiac events such as perioperative myocardial infarction (MI) as a consequence of vasospasm, which can occur in up to 10% of patients [4].

The use of RITA for the right coronary artery (RCA) and its branches showed different results when compared to using left coronary (LC) system, with patency similar to the saphenous vein. For this reason, RITA became more used for LC as a compound graft with the LITA, also as a free graft, or at retroaortic position for branches of the circumflex coronary artery (CX) [3], and another alternative strategy is in situ RITA to LAD [1, 3, 5, 6].

Complete revascularization with arterial grafting shows better long-term outcomes after CABG. The superiority of the ITAs compared to other arterial grafts is already well accepted with excellent long-term results as can be seen widely in the literature [7].

2. Right internal thoracic artery with an anteroaortic course

Rene Favaloro published his first paper in April 1968 describing CABG surgery [8]. Since then, CABG has been with no doubt the most widely studied surgical procedure. But one important controversy that persists until now is about the ideal graft for revascularization, and mainly, whether the use of multiple arterial grafts results in significant improvement in long-term outcomes.

Multiple arterial conduits are used aiming to reduce the likelihood of future reoperations, especially both ITAs. But, there is still a fear of using both ITAs in some subgroups of patients, such as elderly, obese, and diabetic. However, some authors have observed that the skeletonization of ITAs and CABG surgery when performed without cardiopulmonary bypass (CPB) cause a reduction in the incidence of sternal infection. This benefit is more evident in diabetic patients, where there may be a 60% reduction in the occurrence of this complication, allowing removal of both ITAs, without offering additional risk for infectious complications of the sternum [9, 10]. Others noted that the use of pedicled ITA and CPB are independent risk factors for mediastinitis in surgery for CABG [11].

When we use the antegrade RITA, in single or sequential graft, for the LAD territory, we could use the LITA to the territory of CX. With this technique the entire left coronary system is revascularized with arterial grafts only (RITA and LITA), all in situ. To turn this surgery into a frequent treatment possible, the RITA to the anterior region of the heart needs to show the same good results as the LITA when used for its purpose, a result confirmed by a randomized study conducted by us [1]. **Figure 1** shows details using the two ITAs for the territory of the left coronary artery and video 1 available from https://www.dropbox.com/s/0p2mcch5qw67clf/Video%201%20-%20Animation%20RITA%20and%20LITA.mp4?dl=0 (animation showing the use of both ITAs for the left coronary artery).

On the other hand, if we use the ITA combined with another compound graft, with "Y" anastomosis, for example, all the blood flowing to the grafted coronary

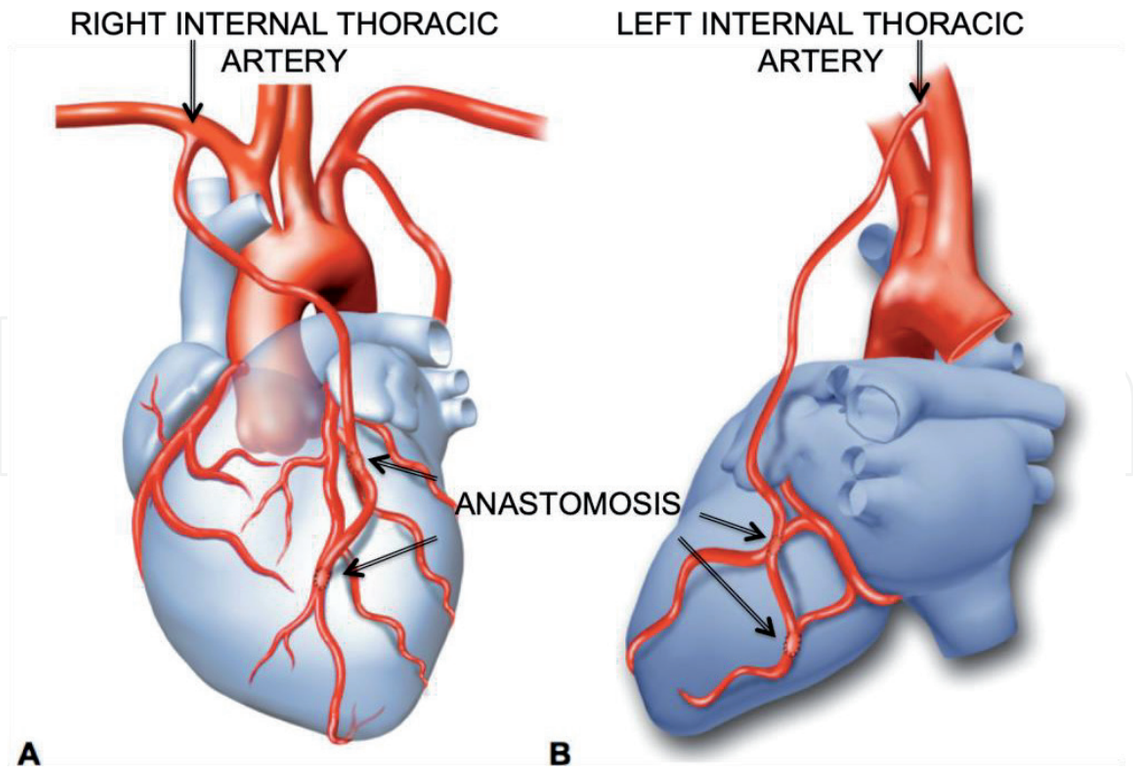

Figure 1.
(A) This schematic drawing shows the anterior view of the heart with the RITA being used anterograde, in sequential anastomosis for diagonal and LAD coronaries. (B) Lateral view of the heart showing LITA being used in situ, in sequential anastomosis for two left marginal branches. RITA: Right internal thoracic artery; LAD: left anterior descending; LITA: left internal thoracic artery.

ends up being from only one source of supply, usually the LITA. A reduction in its flow, due to spasm, can result in drastic consequences such as global ischemia of the left coronary territory [12].

We performed a randomized prospective study where we evaluated the patency of the LITA compared to the RITA when used for the territory of the anterior interventricular branch. The aim of this technique is to use the antegrade RITA, in single or sequential graft, for the LAD territory, and to use the LITA to the territory of CX. Due to the good long-term results when using both ITAs and to the fact that, as a consequence, the entire left coronary system is revascularized with arterial grafts only, i.e., RITA and LITA, all in situ, allowing two sources of blood supply, this could reduce the chance of reoperation for a new myocardial revascularization.

The primary aim of our study was to assess the patency of the pedicled RITA used in CABG, in the anteroaortic position in anastomosis to the LAD compared with LITA used in the same position. The secondary aim was to assess the occurrence of death or cardiac events such as myocardial infarction (MI) and recurrent angina or need for reintervention (reoperation for CABG or coronary angioplasty), as well as to assess the patency of other grafts. The patency was evaluated by multislice coronary angiotomography at the sixth postoperative month.

This study project was presented and approved by the Ethics and Research Committee of the Lauro Wanderley University Hospital, which belongs to Federal University of Paraíba, and Ethics Committee for Analysis of Research Projects (CAPPesq) of the Clinical Board of the Clinics Hospital and the Faculty of Medicine of the University of São Paulo, with the research protocol number 0844/08, CAPPesq, December 17, 2008. This project was performed with the approval of these committees and under the supervision of the Surgical Unit of Coronary Surgery Division of Heart Institute at Clinics Hospital of the Faculty of Medicine, University of São Paulo.

For randomization purposes, patients or guardians have to agree and sign the written informed consent, after being informed of it by a staff member. This study involved 100 patients who underwent cardiac surgery for off-pump coronary artery bypass (OPCAB), prospectively, randomized by computer before the beginning of the study. The surgeon knew the selected group only at the beginning of surgery, that is, which graft would be placed in the LAD territory (RITA or LITA). Patients did not know which technique would be used. The number of patients was calculated according to the probability of a difference of 15% occlusion higher than the standard, LITA to the LAD, for a value of probability error of 0.05 and a power of 80% sample with P of 0.05%.

There was no conflict of interest of any of the researchers involved in this research project.

Patients were selected after doing coronary angiographies. These exams were evaluated by at least two surgeons and should reveal coronary artery disease in at least two vessels of the left coronary artery territory with significant stenosis (> 70%), presenting angina (stable or unstable) and left ventricular ejection fraction (LV-EF) higher than 30%. Patients with coronary artery bypass grafting combined with another procedure, circulatory assistance for cardiogenic shock, the use of intra-aortic balloon pump, LV-EF less than 30%, and reoperations were excluded. Obese or diabetic patients were not excluded; age limit has not been established. Since these criteria have been fulfilled, the patient was selected and invited to participate in the research. In order to provide similarity between the groups, we draw two strategies for the use of BITA and allocated patients in Group-1 (G-1) and Group-2 (G-2), both with 50 randomized patients. The patency of the right and left internal thoracic arteries was comparatively studied.

In G-1, LITA was used in situ with anastomosis to LAD (single or sequential anastomosis), and complementing revascularization with the free RITA to the CX territory, used in sequential anastomosis when needed, and another graft to the RC territory (saphenous vein or RA). In G-2, RITA was used in situ, anterograde with anastomosis to LAD (single or sequential anastomosis) and complementing revascularization with LITA; also in situ for the CX territory, used in sequential anastomosis when needed; and another graft to the RC territory (saphenous vein or RA). Video 2 is available from https://www.dropbox.com/s/e1g89hucaukjv0z/Video%202%20-%20RITA%20Sequencial%20anastomosis.mp4?dl=0 (demonstrating technical details of the sequential anastomosis from RITA to LAD and diagonal artery).

Clinical aspects were cataloged during the preoperative period to assess the similarity between the two groups. The occurrence of perioperative MI was assessed considering ST segment elevation greater than 1 mm at the limb leads or 2 mm at precordial leads at least two contiguous leads or some area of necrosis that did not exist at preoperative ECG. We also analyzed elevation of creatine kinase-MB (CK-MB) above 100 IU/l and troponin I level above 2.5 ng/mL within 48 hours after surgery.

To assess the coronary graft patency, patients of both groups were submitted to multislice CT angiography studies with 128 channels at 6 months after surgery. We used a Philips CT scanner (Brilliance CT), with schemes of 120 kV and 800–1000 mA of irradiation; 0.67 mm cuts were performed, using wherever possible the 75% stage. The time of apnea to capture images was around 15 seconds. In patients with heart rate (HR) above 65 beats per minute (bpm), a beta-blocker (metoprolol) at a dose of 2.5–15 mg (titrating to achieve HR less than 65 bpm) was used. Since patients had already undergone coronary artery bypass grafting, calcium score was not performed.

We performed median sternotomy. Special attention was given to the pericardiotomy; it was opened longitudinally, between the ascending aorta and

the superior vena cava, where we made a tunnel through the thymic fat for the passage of the ATID. The ATIs were dissected using skeletonization and used in situ for the LAD territory depending on the group that was allocated. **Figures 2** and **3** show details of the opening of the pericardium and RITA's positioning. Video 3 available from https://www.dropbox.com/s/4myr68cb1lfu3m8/Video%203%20-%20Opening%20of%20the%20pericardium.mp4?dl=0 shows surgical technical detail.

Initially we performed the anastomosis of the ATI to LAD (single or sequential anastomosis), then we performed the anastomosis (saphenous or radial artery) to RC artery territory. This strategy provides more security to bring the heart medially and expose the sidewall. Sometimes this maneuver can lead to hemodynamic instability. For better exposure of the coronary arteries, we used Lima's point [13], suction stabilizer, and intracoronary shunt to allow more comfort during anastomosis.

The RITA was positioned across the mediastinum anteriorly. We made a tunnel using blunt dissection through the pericardial and pleural fat, anterior to the right phrenic nerve at the most cranial portion of the aorta. This way, the RITA is covered with mediastinal fat, previously isolated, making a tunnel on the aorta, allowing the RITA to stay on the free space between the aorta and the sternum, eliminating

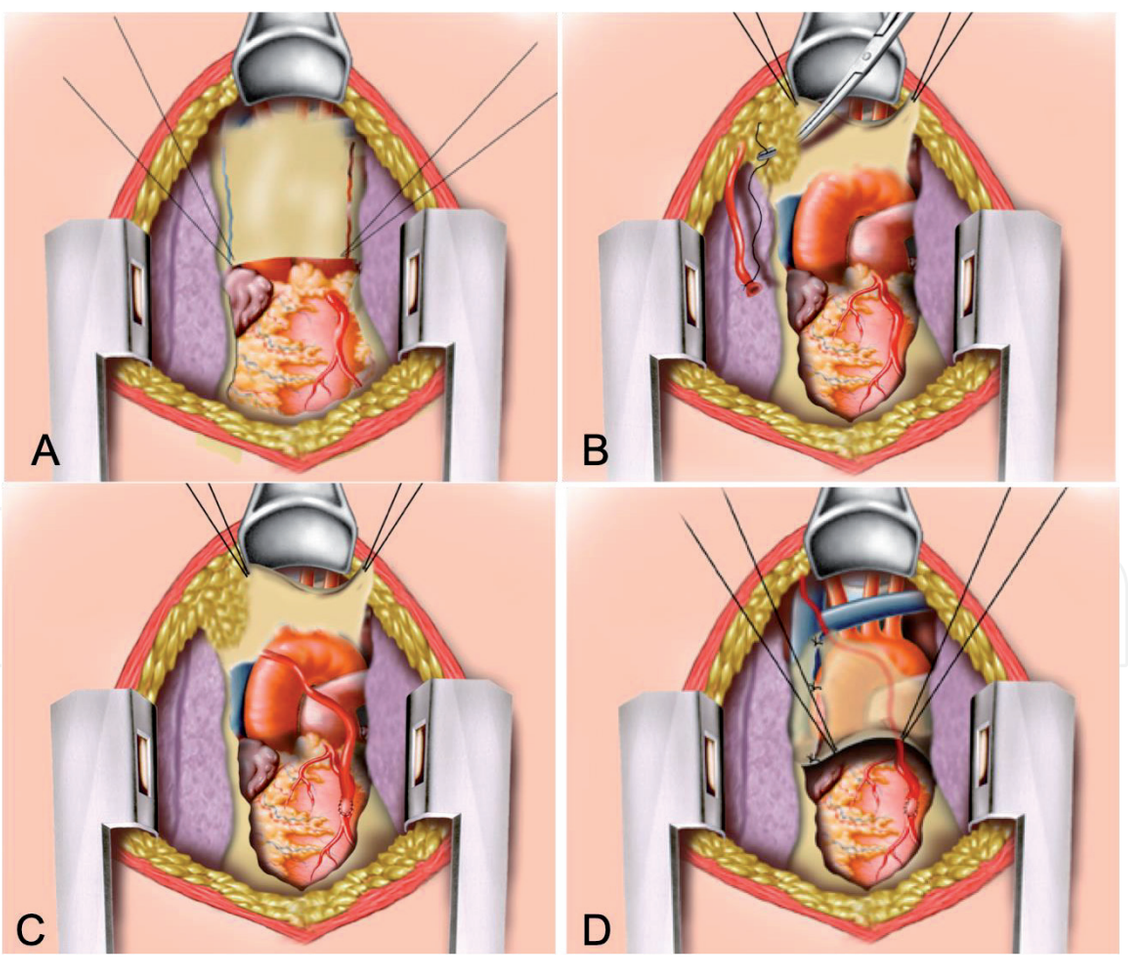

Figure 2.
(A) Schematic drawing showing the preservation of the pericardium and adjacent fat tissue, which will be used later to cover the RITA when crossing the mediastinum at the level of the ascending aorta. (B) Schematic drawing showing the pericardium and the adjacent tissue being used to perform a tunnel with a clamp through the mediastinal fat to pass the RITA. (C) Schematic drawing showing the pericardium and adjacent fat tissue, being moved aside to show the RITA after anastomosis to the LAD. (D) Drawing showing the RITA crossing the mediastinum and being covered by the mediastinal fat, preventing it from adhering to the sternum bone. RITA: Right internal thoracic artery; LAD: left anterior descending.

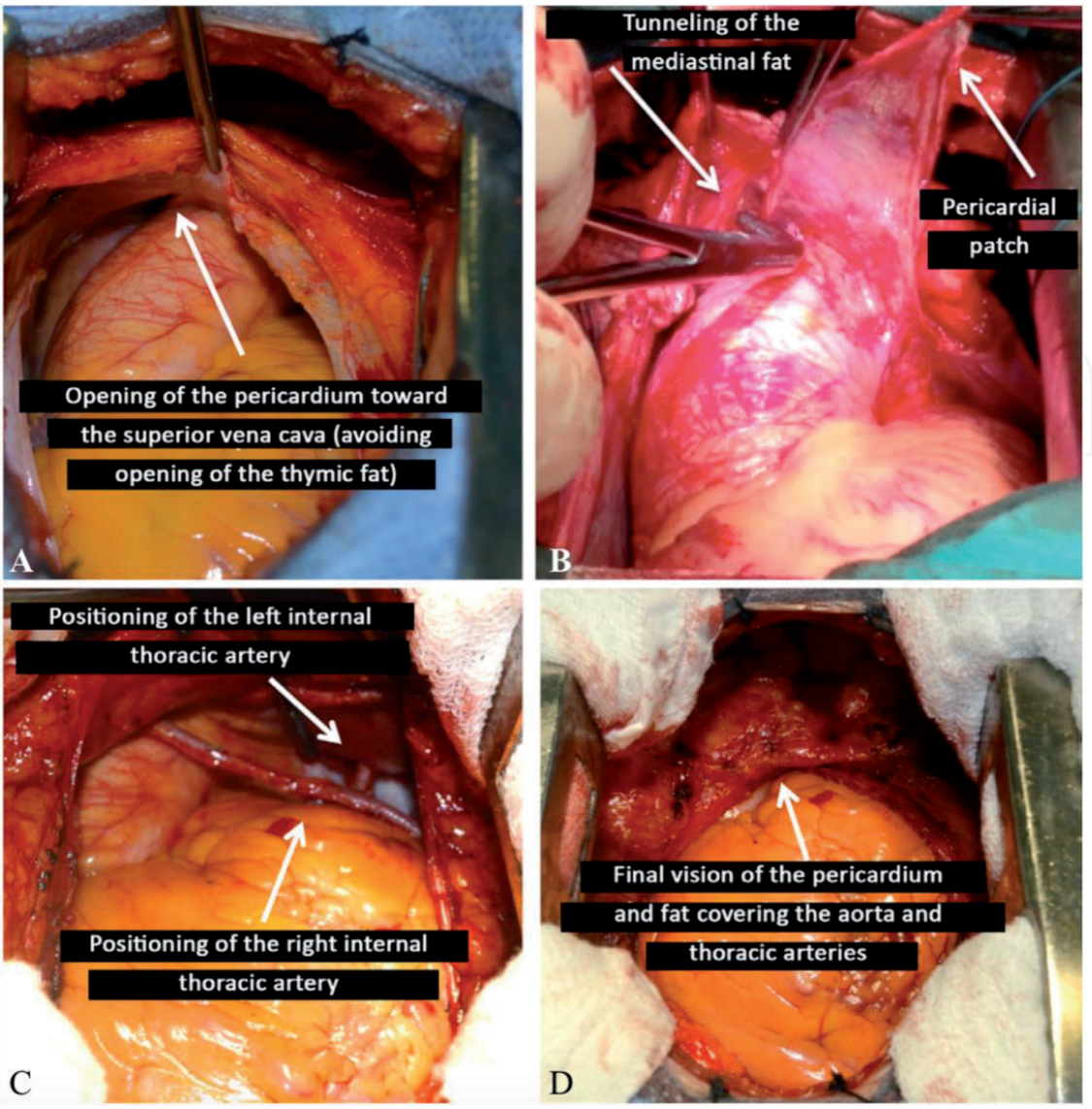

Figure 3.
(A) Surgical photo showing the opening of the pericardium until the limit of the superior vena cava, preserving all the thymic fat. (B) Surgical photo showing the pericardium being moved aside to performing a tunnel with clamp. (C) Surgical photo showing the positioning of the RITA crossing the mediastinum through the mediastinal fat and positioned on the cranial portion of the ascending aorta. A small segment of LITA is seen penetrating the pericardial cavity through a window on the left lateral side of the pericardium. (D) Surgical photo showing the final view where mediastinal fat and pericardium cover the entire ascending aorta and RITA. RITA: Right internal thoracic artery; LITA: left internal thoracic artery.

the possibility of the first to attach the latter. **Figures 4** and **5** show multislice coronary angiotomography images showing the positioning of the RITA. Video 4 available from https://www.dropbox.com/s/0vwao9267x3fd71/Video%204%20%20Tunnel%20through%20the%20pericardial%20and%20pleural%20fat.mp4?dl=0 and video 5 available from https://www.dropbox.com/s/lfa2b8xdf4kv7mc/Video%205%20-%20Positioning%20of%20RITA%20and%20LITA.mp4?dl=0, demonstrating surgical technical details.

High levels of troponin I after CABG do not necessarily indicate that the graft is occluded, but only that there was a significant myocardial injury during or after the procedure. We performed off-pump surgery in 95% of patients in this series. In several patients we performed four arterial anastomoses to LC artery territory, which was possibly due to the sequential anastomosis using both ITAs. This shows that with a good surgical strategy, it is possible to perform a full OPCAB using both ITAs [1].

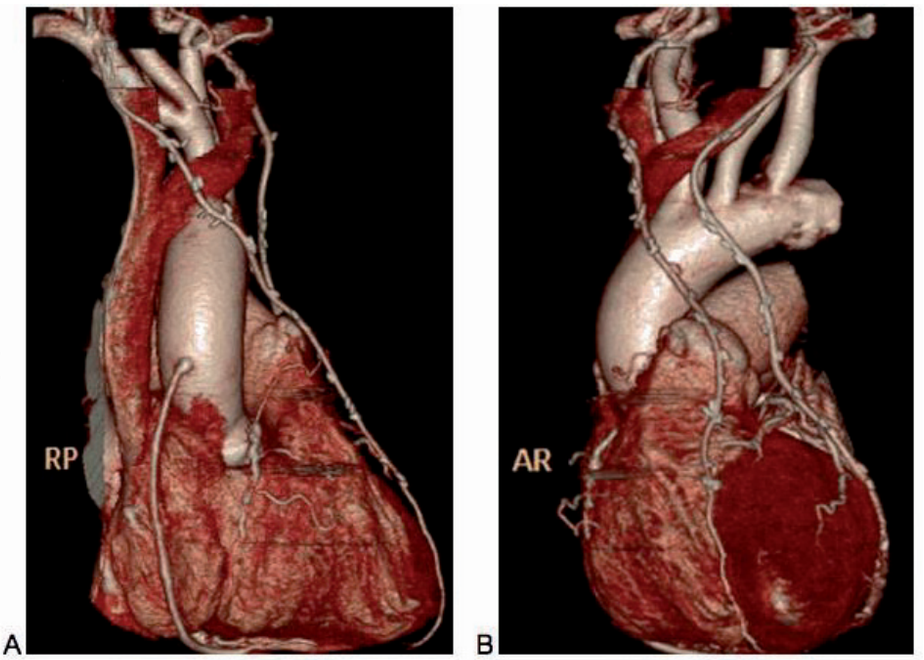

Figure 4.
(A) Multislice coronary angiotomography image shows the RITA position at cranial portion of the ascending aorta, anastomosed to the LAD, and saphenous vein graft anastomosis to the posterior descending artery. (B) Multislice coronary angiotomography image shows the RITA position at the cranial portion of the ascending aorta, anastomosis to the left anterior descending, and LITA anastomosis to the left marginal branch. RITA: Right internal thoracic artery; LAD: left anterior descending; LITA: left internal thoracic artery.

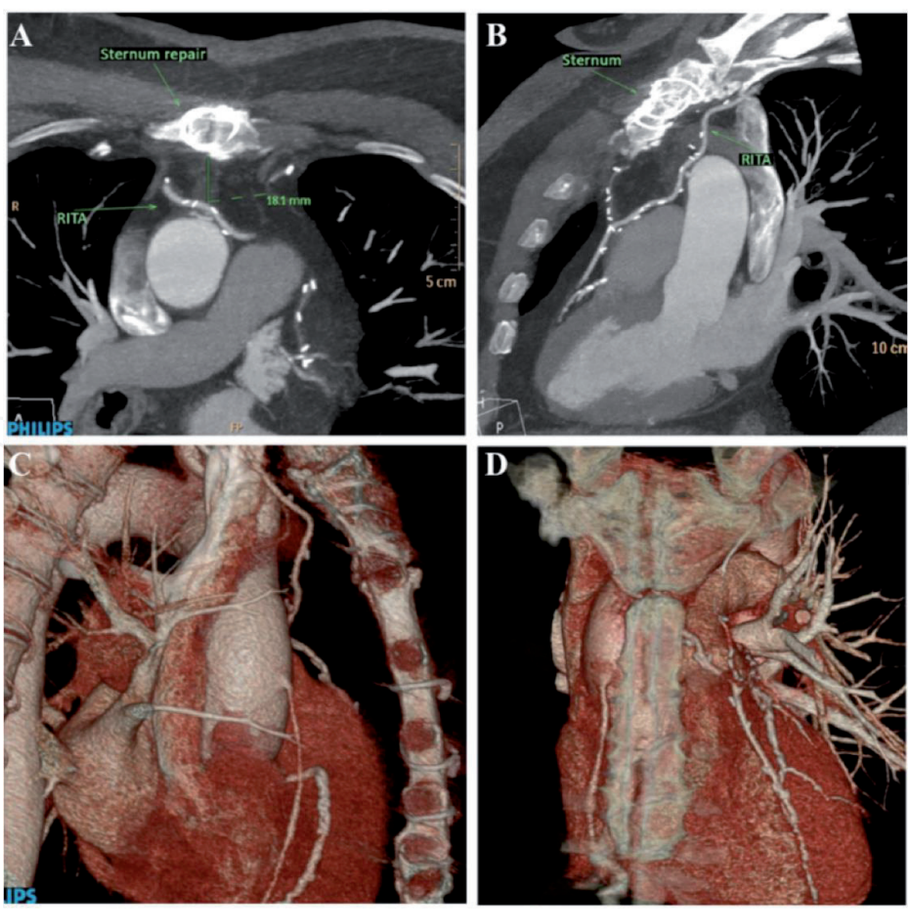

Figure 5.
(A) and (B) Multislice coronary angiotomography images show the positioning of the RITA highlighting its distance from the sternum (18.1 mm). (C) and (D) Multislice coronary angiotomography images show the positioning of the RITA at the cranial portion of the ascending aorta anastomosed to the left anterior descending. We also observe the saphenous vein graft to the posterior descending artery.

The primary endpoint was the graft patency of ITAs used to graft the LAD, and the secondary endpoint was the occurrence of death or cardiac events such as MI, recurrent angina, and need for reoperation. The observation period was 6 months after surgery until angiotomography was performed. For statistical analysis, Chi-square and Fisher's exact test were used to compare proportions and Student's t-test for numeric values with results expressed as mean and standard deviation. The software used was GraphPad Prism 5.2.

There was no death in any group, nor any permanent neurological complication, or need for revascularization, percutaneous or surgical, in any patient in the two groups during the observation period of 6 months. Multislice coronary angiotomography was performed at 6 months after surgery in 96 of the 100 patients. None of the ITAs (RITA or LITA), grafted in LAD, showed occlusion or stenosis [1].

After the good results obtained with this technique, we started to use it routinely. We already use RITA for the territory of the LAD branch and LIMA for the circumflex territory in more than 1500 patients.

3. Comment

Despite the good results, this surgery is not frequently used in major centers around the world. It is known that, in addition to the fear of the risk of sternal infection or severe bleeding, using both ITAs increases surgical time and requires more refined technique. As there are still doubts and controversies regarding the best surgical strategy, the use of both ITAs is still not routinely performed in all services and in all subgroups of patients. Consequently, the utilization rates of ITAs range from 4 to 30%, even in countries like the USA, Japan, and some European countries [14]. Evidence clearly shows the superiority of the use of both ITAs in CABG surgery. Evidence from observational studies is being incorporated into the guidelines of cardiac surgery societies, making the use of arterial grafts recommended in CABG by the American and European guidelines and in a more recent position paper by the Society of Thoracic Surgeons [15].

Some authors showed that the use of anteroaortic RITA or LITA has similar patency when grafted to the LAD [1, 16, 17]. When we use anteroaortic RITA to LAD, this technique allows the entire left coronary system to be revascularized with two independent sources of blood supply, using both ITAs in situ, that is, RITA for LAD territory and LITA for CX territory. However, one of the limitations for the use of this technique is the crossing of the mediastinum by the ATID, which may cause graft injury in the case of reoperation, due to the risk of the ATID adhering to the sternum. To minimize this risk, some authors advocate the use of a PTFE tube or a pedicled thymic fat to protect the LITA when crossing the mediastinum [1, 5]. Another limitation to the use of RITA to LAD is the difficulty to achieve the desired anastomosis site, in the event of the need to perform a distal anastomosis. Based on some authors' experience, this limitation occurs in 6% of the cases, and, in these cases, a RITA "Y" composite graft with LITA can be performed [1]. When we use the skeletonized ITA, the length of this artery increases compared to the pedicle artery, thus allowing RITA to reach the LAD (20.1 vs. 16.4 cm, $P < 0.001$.); in addition there was a reduction of infectious complications in the diabetic patients' sternum (2.2 vs. 10.0%, $P < 0.05$) [18]. The reduction of the risk of sternal osteomyelitis with this technique is due to the preservation of the blood supply and lymphatic drainage, and consequently leading to increased flow compared to the non-skeletonized ITA [7].

Some authors observed that using saphenous vein graft for the RC territory brings results as satisfactory as RITA for that same region of the heart [5, 6].

The long-term benefit can be obtained when both ITAs are used to irrigate the LC territory [1, 19, 20]. The other option to use both in situ ITAs to the left coronary system is the retroaortic RITA for CX territory [4, 7]. However, some authors cite limitations on using this technique because the RITA length cannot reach two or three LM branches for sequential anastomosis, especially in off-pump surgery. When we use this technique and the CABG is performed without CPB, the confection of this anastomosis is impaired by the need to bring the heart to expose the coronary branches of lateral wall, distancing the coronary artery from the graft. On the other hand, at anteroaortic position this mentioned difficulty does not occur. The course of retroaortic RITA may present some disadvantages, such as difficulty to control the bleed of any branch or aortic artery compression or kinks not detected [20]. Another technique that can be used is bilateral ITA in "Y" composite graft (free RITA joined to the side of the LITA). Video 6 available from https://www.dropbox.com/s/c71rbgpy7bzfwjs/Video%206%20%20%22Y%22anastomosis.mp4?dl=0 shows coronaryography of a patient undergoing this technique. A meta-analysis of the studies comparing in situ with "Y" graft ITA configurations showed no significant difference in clinical outcomes [21].

The presentation and publication in November 2016 of the planned 5-year interim analysis (of 10-year survival, a primary outcome) of the Arterial Revascularization Trial (ART) of the American Heart Association left the community of cardiac surgeons around the world surprised. The trial ART is the largest randomized study using arterial grafts, involving 28 centers in 7 countries and 3102 patients randomized to receive single internal thoracic arteries (SITAs) or bilateral internal thoracic arteries (BITAs). There are several potential limitations to ART trial, for example, near 20% of patients receiving a SITA graft also received a radial artery graft, which may have further narrowed any potential differences between SITA and BITA [22]. Despite these limitations, ART trial remains the most solid available evidence comparing SITA versus BITA grafts. Furthermore, although the results of ART trial contradict much of the results of published observational studies, they are consistent with Cleveland Clinic results of nearly 20 years ago reporting a survival benefit of BITA grafts after 5 years; this benefit becomes more evident over the years [23].

After evaluating ITA remodeling, some authors cite predictors of occlusion: large accessory branches leading to theft of flow, flow through the native coronary bed, and quality of the distal coronary bed. When using both ITAs, the best results are obtained when they are used in the LC territory, preferably in occluded arteries or significant obstructive lesions. Patency is therefore determined by the flow competition, the nature of the graft, and the degree of stenosis of the coronary territory. Therefore, the graft deterioration is related to the degree of coronary branch obstruction when it is less than 75%. Competitive flow reduces the patency of arterial grafts after coronary bypass surgery. This competitive flow is dynamic, relative, and in a certain way inevitable. The preoperative assessment of the coronary stenosis severity and the prediction of competitive flow can be improved with the addition of fractional flow reserve (FFR) measurements to coronary angiography, but the potential for minimizing the effects of competitive flow by different graft configurations seems limited [24].

Regarding the CABG procedure itself, there is a significant gender differentiation, because only a small percentage of women receive complete arterial revascularization, as reported in the STS database (2.3% of women who underwent CABG from 2002 to 2005 received BITA grafting vs. 4.7% of men) [25]. Some authors do not use gender [1], obesity, or the presence of diabetes as exclusion criteria to use BITA grafting, but some consider females a risk factor, decreasing their chances to receive the best revascularization approach, BITA grafting. The long-term survival benefit of the

systematic use of BITA grafting among women remains unclear. Lately, some authors have shown that women had a similar 10-year survival compared to men when BITA grafting was used. Others have shown that women who underwent CABG in which BITA grafting was used had better survival than the group that used SITA, especially in patients older than 65 years. Thus, it was demonstrated that the best results obtained with the use of BITA grafts are gender independent [26].

Several studies have shown that the use of bilateral in situ internal thoracic arteries provides excellent probabilities of event-free survival and cardiac event-free survival during follow-up of 15 and 20 years. More studies including elderly patients with severe comorbidities are needed. Results from studies with 15–20 years of total arterial revascularization suggest that cardiac surgeons should prefer total arterial grafts in order to reduce the risk of long-term cardiac events, especially during the second decade after surgery in relatively young and healthy patients. Despite the absence of a randomized control trial, there is evidence that the BITA graft is not only safe in the immediate postoperative period, but it has a supremacy over SITA use over long-term survival and absence of cardiac events. This is the reason why the use of RITA as a second arterial graft with LITA has acquired a Class IIa, evidence B indication at the European and American guidelines on myocardial revascularization [27, 28]. Total arterial revascularization using both ITAs is the best revascularization strategy that a cardiovascular community can offer for their patients with multivessel disease [29].

4. Conclusion

Coronary artery bypass grafting using antegrade in situ RITA for LAD territory, compared to the in situ LITA, anastomosed in the same region, presents the same results in an evaluation period of 6 months, assessed by multislice coronary angiotomography, as demonstrated by some authors [1]. The results demonstrated 100% grafts' patency. The OPCAB surgery that used both ITAs for LC territory proved to be safe, effective, and feasible, even in patients with multivessel disease.

The main reasons for the reluctance to use BITA grafts are its technical challenge, because it requires a high level of skill, experience, and concentration. The duration of surgeries is longer and may be associated with a minor increased risk of deep sternal wound infection in severe cases of diabetes, obesity, and/or chronic obstructive pulmonary disease. Another reason is the lack of convincing evidence of a randomized controlled trial. All these difficulties/problems can be overcome with the use of ITAs skeletonization. We should always bear in mind Lytle's statement made in 1999: "two internal thoracic artery grafts are better than one." Some studies already postulate the use of three arterial grafts in order to obtain better late survival.

The CABG off-pump surgery leads to less cell injury than the conventional method of CABG surgery (on-pump) [1, 10, 19]. Based on randomized and observational trials that have compared off- versus on-pump CABG, there is one point that most surgeons would agree with the following: surgeons have to be experienced and routinely use off-pump techniques to have comparable results with off- versus on-pump CABG. The best results with off-pump CABG come from centers with large volume of surgical patients [19].

Conflict of interest

The authors declare no conflict of interest.

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