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Proposal of a new method for the skeletonized internal mammary artery harvesting: Historical, anatomical and physiological fundaments

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Acronyms
ICS: intercostal space
IMA: internal mammary artery

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ABSTRACT

In the last 30 years the interest of the cardiovascular surgeons for the skeletonized dissection of the internal mammary artery has increased, mainly stimulated by its bilateral use, to achieve the total arterial revascularization in the greater amount of patients; this, in theory, is accompanied by a higher incidence of deep infections of the sternal wound. Since 1992, the classical technique of the mammary skeletonized dissection has practically not changed. Perhaps, the only major changes have been the introduction of the harmonic cauterizer around the year 2000 and the tendency of a few groups to try to preserve intact the retrosternal venous plexus. After a thorough analysis of the historical, anatomical and physiological fundaments on which this procedure is based, and based on the practice in more than 100 patients over a period of two years, modifications are presented for the classical technique of the skeletonized dissection of the internal mammary artery that allow obtaining a healthier hemoduct in less time, greater protection against infection and ischemia of the bone and mediastinal organs, as well as the preservation of the integrity of the internal mammary vein.
Keywords: Myocardial revascularization, Internal mammary artery, Blood flow, Antibiotic prophylaxis, Spasm, Heparin

Propuesta de nuevo método para la disección esqueletizada de la arteria mamaria interna: Fundamentos históricos y anátomo-fisiológicos

RESUMEN

En los últimos 30 años se ha acrecentado el interés de los cirujanos cardiovasculares por la disección esqueletizada de la arteria mamaria interna, sobre todo estimulado por su empleo bilateral para lograr la revascularización arterial total en la mayor cantidad de pacientes; lo que, en teoría, se acompaña de una mayor incidencia de infecciones profundas de la herida esternal. Desde 1992, prácticamente no ha variado la técnica clásica de disección esqueletizada de la mamaria. Quizás los únicos cambios importantes han sido la introducción del cauterizador armónico alrededor del año 2000 y la tendencia de algunos escasos grupos de intentar conservar indemne el plexo venoso retroesternal. Después de un profundo análisis de los fundamentos históricos, anatómicos y fisiológicos sobre los que se sustenta este procedimiento, y basados en la práctica en más de 100 pacientes en un período de dos años, se presentan modificaciones a la técnica clásica de disección

esqueletizada de la arteria mamaria interna que permiten la obtención de un hemoducto más saludable en menos tiempo, una mayor protección ante la infección y la isquemia del hueso y los órganos del mediastino, así como la conservación de la integridad de la vena mamaria interna.
Palabras clave: Revascularización miocárdica, Arteria mamaria interna, Flujo sanguíneo, Profilaxis antibiótica, Espasmo, Heparina

INTRODUCTION

Since 1987, Samuel B. Keeley has been credited with being the creator of the skeletonized dissection technique of the internal mammary artery (IMA) in the myocardial revascularization surgery. However, this assertion does not seem to be historically true; the birth of this procedure allegedly occurred almost 40 years earlier. The Canadian Arthur Vineberg Martin was actually who, on April 28, 1950, was responsible for a milestone in the history of modern medicine, when implementing, for the first time, a skeletonized IMA in the left ventricular's myocardium of a human being[1], as a form, extremely revolutionary for the time, to create an extracoronary blood source for that muscle.

It is true that, since then, the mammary artery skeletonization has ceased to be a primordial anatomical technique and became a procedure totally based on physiological principles, which are the base for wonderful results obtained today in coronary surgery, but 70 years ago all it seemed to be simpler. If it is assumed, as the most primitive concept of the mammary artery skeletonization, obtaining and handling only an arterial segment, it should be noted that it was just what Vineberg needed. Unfortunately, in none of his articles the Canadian explained the technique used for the preparation of the graft, but 15 years after his first surgeries, a team from the Cleveland Clinic in Ohio, led by Willian H. Sewel, announces the project that led them to develop their "pedicle surgery" for the implantation of the IMA in the heart, and points out, as differences with the predecessor technique, the presence of soft tissue's capillaries (perivascular fat and endothoracic fascia?) and a vein in the grafted pedicle[2]. This evidence seems enough to understand that until that moment, the artery being implanted was prepared in a skeletonized way.

In 1992, Cunningham *et al*[3] publish their considerations in relation to the technique of skeletonization in the dissection of the internal thoracic artery. In just four pages, and based on their experience in more than a thousand patients, they delineated the most important features and advantages that were attributed to the technique at the time. Through the time, new benefits of this procedure may have been described, but hardly more than a quarter century later, the surgical preparation details of the skeletonized IMA during the coronary artery bypass grafting have been exposed in a more accurate way.

What follows is a new method for carrying out this procedure. On historical, anatomical and physiological bases, as well as the experience applied in a group of patients, for approximately two years. We propose then to modify some basic aspects of the technique described by Cunningham, considered the classic one for the skeletonized dissection of the IMA.

FIRST MODIFICATION

Distal occlusion of the mammary artery at the beginning of the dissection

All reviews made of any of the techniques used for the dissection of the IMA always show some common elements: prior systemic administration of heparin, once the artery is cut at the end of dissection, its light is occluded in its distal segment (by a clamp) or placing a metal clip and it will remain in that way, and wrapped in a cloth soaked up a vasodilating substance, until beginning the construction of the graft. During this period of time, of greater or lesser duration depending on the skills of the surgeons and the surgical modality that is decided to be used (with or without extracorporeal circulation), the artery will beat against the created mechanical obstacle, which will increase the hydrostatic pressure within it and will force the circumferential dilation of the hemoduct[4], further favored by the endothelial nitric oxide production[5], mediated by a forward and backward flow within the vessel distally occluded.

Interestingly, in the technique proposed by Keeley in 1987, the artery is first dissected in the form of a «generous pedicle» containing vein, fat, fascia and lymphatics; divided distally and later skeletonized with a bipolar electrocauterizer, while its end re-

mains occluded with a vascular clamp[6]. In the months after the publication of this experience, the mammary artery skeletonization technique radically changed. On November 1, 1988 began the series that Cunningham published in '92. The artery will be totally skeletonize in its original location, to be clamped and distantly cut off after being completely dissected[3]. Apparently, in the next 25 years, surgeons completely forgot that the mammary artery may remain occluded for a considerable time while being carefully prepared as hemoduct.

Therefore, the first modification proposed to the conventional technique of the mammary artery skeletonization is the distal occlusion of the artery with a clamp at the beginning of its dissection (**Figure 1**). For reasons that will be explained later, this occlusion should be done as close as possible to the bifurcation of the mammary artery in its two terminal branches, but without compromising the integrity of the communication between the superior musculophrenic and superior epigastric arteries[7]. Thus, once the IMA is displayed and open the endothoracic fascia in all the extension, or as much as possible of the longitudinal route of the vessel, the next step is to identify its terminal branch.

Sometimes, to precise this structure is difficult. One of the fundamental causes of unnecessary time consumption during the mammary artery preparation is the dissection of the artery beyond its bifurcation. Some authors[8,9] have expressed the need to use its distal segment, in either arteries, to safely reach the ideal place in the coronary to be anastomosed. However, in the case of the classic revascularization strategy of the anterior descending artery with left IMA, and in many variants in the right IMA [10,11], it is rarely required to use the hemoduct beyond its final branch (in fact, some studies suggest caution in relation to the use of this segment[5,12]); hence, what is used in its preparation will be, almost always, lost time.

Core anatomical elements to properly identify the distal bifurcation of the mammary artery are the presence of two or three branches of more importance[13,14] in the selected segment that coincides with the binding of the sternum body with its xiphoid process. It must be remembered that, in most of

Figure 1. Distal occlusion of the internal mammary artery with clamp before beginning its skeletonized dissection. The endothoracic fascia covering the hemoduct has been opened up to the level of the third intercostal space.

the population, the mammary artery ends at the level of the 6th intercostal space (ICS), although few authors place the bifurcation between the 5th and 7th ICS[14,15], a point that coincides with the aforementioned articulation. The dissection performed around the xiphoid, generally involves the musculophrenic or superior epigastric arteries; which are arteries with histological features different to the IMA, with a greater reactivity to vasoconstrictor stimuli, greater muscle content and tendency to atherosclerosis[12] and spasm[5], what can jeopardize the state of a graft, if they are used as such.

Once identified this bifurcation, the proximal clamp is placed on it and the dissection and control are started by clips on other branches. Some advantages of the mammary artery distal occlusion at the beginning of its dissection are shown in **Appendix**[16-32].

After an extensive review of the bibliography, no other surgical group in the world applies this modification in any variant of the mammary artery dissection techniques.

SECOND MODIFICATION

Control and selective division in two times of the mammary artery's lateral branches

When the experiences of different groups in the skeletonized dissection of the IMA are analyzed, there are variations in relation to the direction chosen to perform the control of its lateral branches. The artery may be prepared cephalically, (from its bifurcation into the source of the vessel), caudally (from the subclavian or first rib to the end of the artery), or it can be identified where it is best visualized (usually in its middle segment) and a bidirectional dissection is performed. Generally, whether one or the other option is chosen, each branch of the mammary artery is linked, regardless of the direction in which they are originated.

The spatial relationship established between the visual field of the surgeon and the path of the IMA allows easy control of the branches originating from its posterior wall (pericardial branches), anterior (perforating and sternal) and medial (thymic, mediastinal)[14]. Almost always, these branches are easily identified by the surgeon and because they travel generally far away from other vessels, they can be clamped and cut off without much risk of injury and accidental bleeding. On the other hand, the branches that originate in the lateral wall of the mammary artery go to the ICS, in the form of anterior intercostal arteries, in order to connect with their posterior homonyms that come from the thoracic aorta[33]. These are the most difficult branches to control, since they not only "move away" from the visual plane of the surgeon, but to be able to specify their emergency site, the IMA would have to be manipulated excessively. Furthermore, these vessels are very close to the lateral travel of the mammary vein and its tributaries, which is a frequent cause of accidental injury to these structures, when the surgeon places the distal clip or cuts an arterial branch without adequate visual control of what underlies beyond the visible parts of the stapler or scissors. The control of venous bleeding or of the lateral branches of the mammary (they are those of greater flow when receiving irrigation of two sources) is sometimes difficult, always prolongs the time of dissection and increases the risk of injury of nerves and blood and lymphatic vessels, especially if the surgeon decides to do it with the electrocauterizer[15].

Our group has designed a different method for controlling the mammary artery's branches, consisting in its selective division into two times, which has reduced the duration of dissection and the incidence of injuries to periarterial structures. Once the clamp has been positioned distally, there is started, in a cephalic direction, the division of the branches emerging from the posterior and anteromedial walls of the IMA until the most proximal, just before the exit of the thoracic cavity's artery. As Cunningham[3] pointed out in his article, during the skeletonized dissection: "a relatively constant finding is a gradual increase in the diameter of the IMA as the proximal branches are divided". This dilatation is enhanced, in our case, by the aforementioned physical effects of the clamp and the intermittent spraying of the artery, already devoid of the wrapping that offers the endothoracic fascia, with a vasodilator solution.

It is important during this first phase of the dissection, not to waste time in the control of short branches that offer little space for the placement of the clips, especially in mammary arteries with a path very close to the ribs, due to the absence of interposed fat tissue. At this time, when the dilatation of the mammary artery is still incipient, the untimely approach of those branches that have not had time to stretch can cause tearing, as well as injuries to the wall of the artery. It is advisable, therefore, to carry out a careful dissection at this stage, but to completely divide only those isolated branches with sufficient length for a quick control and without the risk of an

accident. It can be convenient, in short branches, only the placement of the proximal clip, and finish its distal control and division in the second phase (cephalocaudal) of the extraction; it is true that this strategy will momentarily obstruct the total mobilization of this segment, but –according to the aforementioned Cunningham precepts– it will contribute to arterial dilation, which will facilitate later stages of dissection.

Generally, the larger branches of the IMA are scattered between their origin and the 2nd ICS. It is also there where its dissection is hindered by the interposition of its vein and by the insufflation of the superomedial segments of the lung that significantly affect the surgeon's vision[3]. Here, in addition, the arterial branches assume a different anatomical arrangement to the collaterals of other spaces, in line with a mammary artery that now tends to separate from its layer in the thoracic wall, and move away obliquely from the operative comfort zone of the surgeon. Around the 2nd ICS, sometimes the path of the artery may be obscured (and even confused) by a close and medial layout of its vein or by the interposition of fat tissue, which covers almost all of its most proximal segment. In this circumstance, it is advisable to abandon the sense of dissection that has been followed, and try to discover the artery in a more proximal area within the aforementioned fat fascicle that surrounds it, when again its course has separated slightly from the vein. Usually, thick and long branches will be found in this segment, arranged in several directions (to various points of the thoracic wall, to thymic remains, pericardium, etc.), generally easy to control, and completing in this way, the first time of dissection of the branches (**Figure 2A**).

Once the surgeon feels that has divided all or many branches that arise from the posterior, medial and anterior walls of the mammary artery, especially those provided in the first two intercostal spaces, the dissection and division can begin in the cephalocaudal sense of the rest of the branches that remain connected to the artery. At this time, an IMA that has been devoid of most of its drain (especially the more proximal branches which are the ones with larger flow) and has remained clamped generally more than 15 minutes, and sprinkled intermittently with a vasodilator solution, its diameter, its volume of blood, and therefore, its mass has increased. This new situation will cause the artery to slowly separate ("fall"), by its own weight, of the thoracic wall, which has only been anchored by the branches –now also more dilated– that originated before from its side wall, but now, for the rotation undergone by the vessel, they seem to emerge from its front wall (**Figure 2B**).

This new anatomical arrangement that the lateral branches of the IMA have acquired, together with the ptosis of the vessel, now allows its clamping and division more easily, without jeopardizing or damaging the site where they join with vessels from the aorta, a fundamental element that justifies the mammary artery skeletonization in order to protect sternal collateral circulation[34]. Equally easier is the control of the branches, now dilated and a little longer, which should have been fully controlled in the first phase of the dissection, but because they were initially too short, it was decided to ignore them or just place the proximal clip. On the other hand, the venous collaterals have remained in their usual position, adhered to the thoracic wall, i.e. that the risk of injuring them is considerably reduced during the control of the arterial branches.

Another important advantage of the control in two times of the mammary artery's branches is that, during the second phase mainly, it considerably facilitates an adequate discrimination of the structures to be clamped (tubular, larger caliber) of other non-vascular adhesions (fat, connective tissue) that have been stretched, weakened and often end up tearing apart just by the weight of the artery. This will avoid the unnecessary placement of clips, with the usual practical advantages that this produces when handling the hemoduct.

The introduction of this modification to the classic skeletonized dissection technique of the IMA has allowed to shorten its duration and bleeding during the procedure, by considerably reducing the incidence of injuries to vascular structures.

THIRD MODIFICATION

Earlier administration of heparin

Almost all descriptions discussed in connection with dissecting the IMA, in any of its variants, indicate the almost obligatory conduct of systemic administration of anticoagulant between 3 to 5 minutes before cutting the hemoduct[7,35]. Few are those that, when accomplishing a quick pedicle dissection, request heparin when they are approximately in the middle of the procedure[36]. This lapse, sufficient for obtaining the desired number of activated clotting time, allows cutting the hemoduct (endothelial injury)

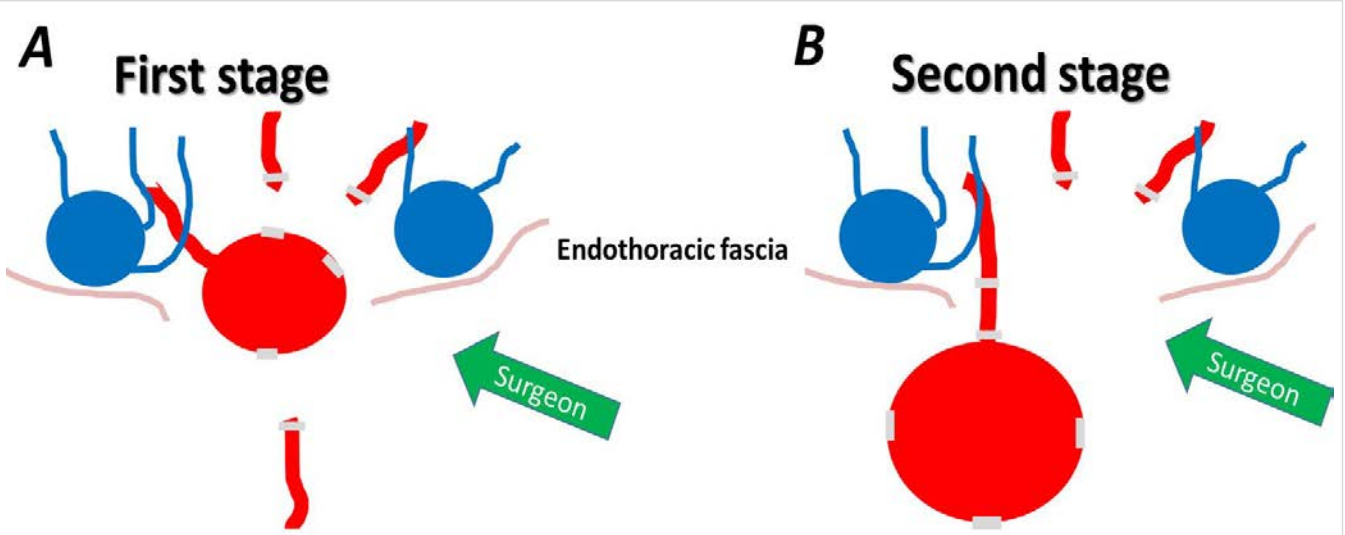

Figure 2. Transverse diagram of the anatomy of the mammary arteriovenous bundle **A.** At the end of the first mammary dissection time, the branches that emerge from their anterior, medial and posterior walls have been controlled. The black curved arrow indicates the rotation that the artery will usually make before the start of the second dissection time. **B.** During the second time, the artery has rotated and descended. The branches that were previously born from its lateral wall have now been lengthened and emerge from its "new" anterior wall, which facilitates its control. The green arrow outlines the surgeon's point of view.

without risk of thrombosis.

Obviously, it is not a mandatory condition to undertake the mammary artery dissection with the patient's normal state of coagulation. For several reasons, modern cardiovascular surgeons treat a greater number of sick people each day, who come to the surgery antiaggregated and anticoagulated, but there is almost unanimous consensus that, as far as possible, one must avoid mammary artery preparation in that state, to foresee large bleedings that would hinder the procedure and the high risk of injuring the hemoduct, which may even cause its dryness, making it useless for revascularization.

It is proposed to advance the time of administration of heparin at the end of the first time of division and control of the branches. If so far there have been met the principles that have been exposed, the dissection of the remaining branches in the cephalocaudal direction will be performed expeditiously with a minimum risk of collateral injury and bleeding, what does not justify delaying the administration of the anticoagulant.

It is the opinion of the authors, if the injury of the hemoducts is avoided, that their dissection with the anticoagulated patient offers more benefits than disadvantages; however, a deeper approach to these aspects is beyond the objectives of this work.

FOURTH MODIFICATION

Maneuver to help preserving the mammary vein

The element around the dissection of the IMA that perhaps has received less attention is the fate of its vein. When Vineberg[1] began to implant the artery, he only needed a source of oxygenated blood; unfortunately, in his available articles, no mention is made to the mammary vein. On the side, Sewel[2] considered it an important element in his pedicle technique, to act as a venous return and avoid bruising in the myocardium, a theory without much sense even at that time, because the Canadian had not found this complication in any of his cases[37]. Three decades later Cunningham[3] noted that: "it may be necessary to divide the internal thoracic vein to obtain satisfactory exposure of the proximal branches".

The extensive bibliography review made to tackle this research has ensured that most surgical groups that dissect the IMA in a skeletonized way do not spare to divide its vein, if the circumstance discussed by Cunningham takes place. Only a few articles assess the importance of conserving, insofar as possible, the integrity of the retrosternal venous return, considering its rupture as a possible risk factor for the development of complications at the surgical site[38].

Indeed, it is during the approach to the most proximal segments of the artery that there is a greater risk for the injury of its accompanying vein. According to Schipper *et al*[39], between the 2nd and 3rd ICS, in two of the four variants described by Schwabegger, this assumes a medial path, therefore it is interposed between the artery and the surgeon. Circumstance, together with other anatomical features of the area, that returns sometimes very complex arterial dissection without the need to dispense its vein.

There is proposed, when the route of the vein is too close to the hemoduct of interest and hinders its extraction, a simple maneuver consisting of placing a loop around it and separating it from the vicinity of the artery, either through a point anchored at the edge of the skin, or by using the weight of a hemostatic clip (**Figure 3**). This simple procedure will generally allow the vein to be removed from the narrow visual field of the surgeon (the procedure is usually done with magnifying glasses), which will facilitate arterial dissection without danger of injuring one or the other vessel. Once the mammary artery preparation is complete, the vein can return to its original position, without having suffered any injury. To the best of our knowledge, none of the few groups that in their articles indicate to preserve the mammary vein in performing this technique, have published experiences with similar maneuvers proposed by our team.

FIFTH MODIFICATION

Distal division of the hemoduct before concluding its dissection

All the classic mammary artery dissection techniques stipulate that the artery should be kept connected and permeable at both ends throughout the procedure. Obviously, once the distal occlusion has been made, great advantages will not be awarded to the strategy of keeping it anchored to the thoracic wall. Perhaps, the only benefit will be the need for less manipulation of the vessel while it is dissected.

It has only been found an author who, during the beginning of his pedicle dissection technique, divides the mammary artery distally to fix it with a point that allows him to pull towards one side or the

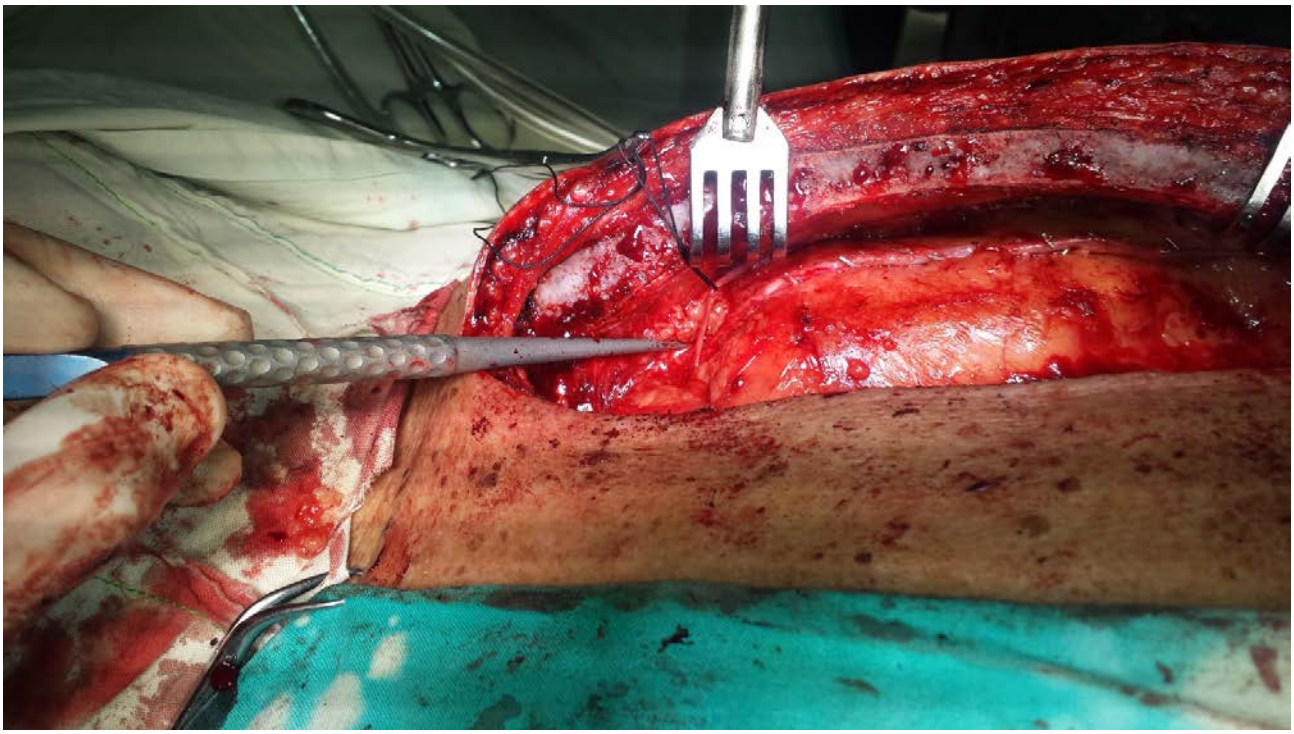

Figure 3. The mammary vein, interposed on the proximal course of the homonymous artery, has been displaced (by traction) by means of an anchoring to facilitate the dissection of the hemoduct without needing to do without it.

other during the division of the branches in a caudocephalad direction[40]. We mention this isolated experience as the physiological basis of the modification that will be proposed next, but it is not considered that the aforementioned strategy is advisable in an artery that lacks a pedicle.

However, according to the surgeon's judgment, the distal division of the hemoduct may be convenient before having finished its dissection. Above all, this tactic can be a complement to the fourth modification, already commented, with the aim of avoiding injury to the venous drainage. Sometimes, despite having separated the vein, the mobility of the artery is still deficient, and cutting it distally – after administrating the heparin– increases the possibilities of positional modifications of the hemoduct available to the surgeon, which can facilitate the division of branches that may still be difficult to access. In another scenario, the mammary vein can interpose between the artery and the coronary artery to be revascularized; the surgeon can slide the hemoduct, after cutting distally, "behind" the vein, and take at this time, if necessary, measures allowing to prolong its length, or take a straight path to the target coronary (**Figure 4**).

Before concluding, it is important to emphasize that the first three modifications presented are usually practiced in all IMA dissected by the authors of this work. The implementation of the last two is optional and obviously depend on the anatomical characteristics, especially the mammary vein.

FINAL COMMENT

The effectiveness and advantages of the modifications that have been exposed have been demonstrated during a period of two years, but in a small number of patients, when compared with the large series published by groups of centers with higher operative volumes. The authors tacitly recommend to other surgical teams the introduction of these modifications in their skeletonized dissection techniques of the IMA, but they are aware that experience is needed in a greater number of patients to arrive at more solid conclusions.

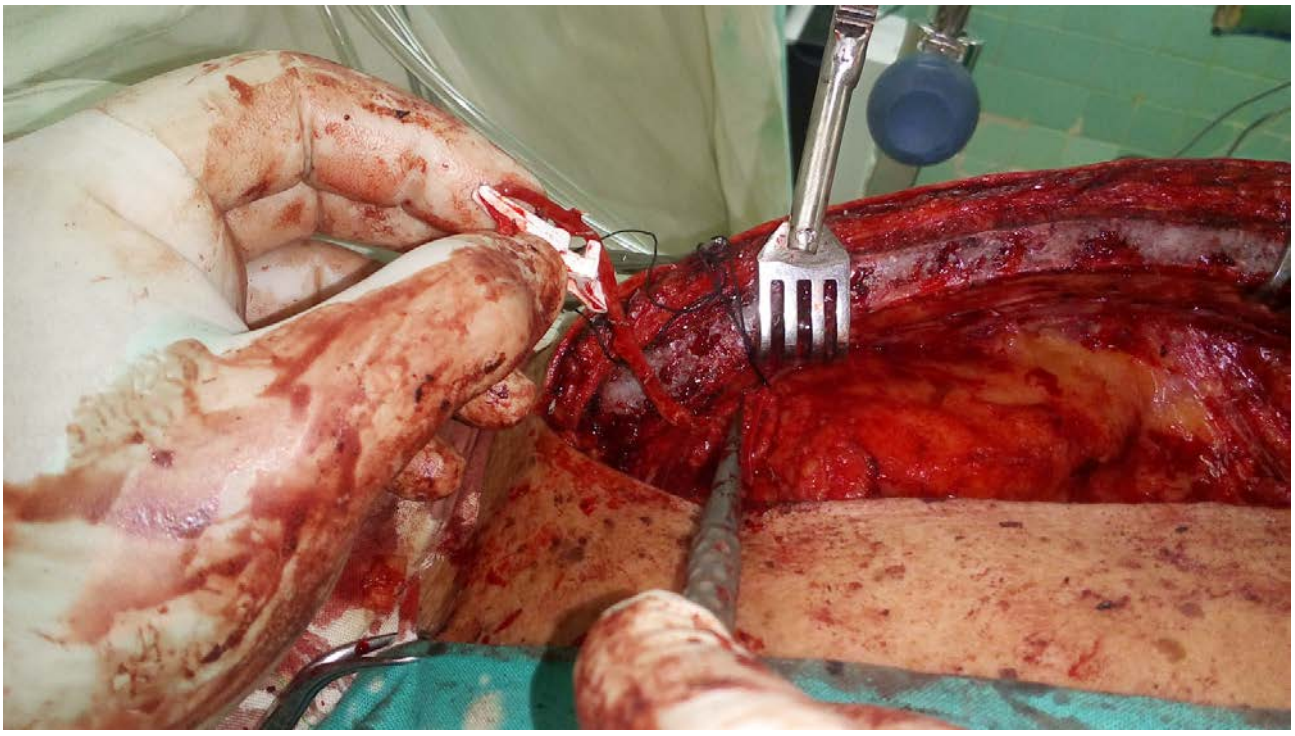

Figure 4. The mammary artery is being slipped behind the vein to facilitate dissection of the proximal segment and also to allow a more direct route to the target coronary.

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APPENDIX

Advantages of the internal mammary artery distal occlusion

1. Early start of the recognized advantages of the IMA distal occlusion: Some studies[16] have shown that mammary tumors have a low initial flow, which doubles after 15-20 minutes of increased hydrostatic pressure, favored by beats against the obstacle that the clamp represents. To move forward the occlusion time has allowed us, in many cases, to obtain hemodialysis with a flow close to or greater than 2 ml per heartbeat immediately after cutting the artery (120 ml in one minute at a heart rate of 60 beats/minute). The achievement in a shorter period of time of a hemoduct with these characteristics will allow the construction of healthier bridges with the consequent decrease in spasms, flow competition and development of the mammary hypoperfusion syndrome. It should be remembered that fluorescence imaging studies have shown that blood flow enhancement, during flow competition, begins in the native coronary artery and spreads retrograde to the mammary graft, through the anastomotic site[17]. If this is added the knowledge that the increase in the

shear forces within the vessel (derived tangential forces of friction of the blood flowing on the endothelial surface) increase the expression of endothelial synthase of nitric oxide[18] and, accordingly, the diameter of the hemoduct, then, the enormous benefits of obtaining an IMA with the highest possible flow will be understood.
These add to other undoubted advantages of high diameters and flows in these hemodialysis, in any surgical strategy that is implemented; to go deeper into them is beyond the scope of this article.

2. The increase in the diameter and flow of the IMA is also benefited by the possible local factors present in its bed. For years, several groups have studied the possible presence of nerve or humoral factors in the vessel, in the thoracic wall or mammary periarterial adipose tissue, which decrease the possibility of spasm and facilitate dilatation of the artery with a consequent greater flow[19]. The detailed analysis of these studies also exceeds the objectives of this study, but the theoretical presence of these factors has led some groups, for example, to favor pedunculated dissection of the IMA on the presumed basis that its caliber will be greater if it benefits from an anti-contractile substance present in periarterial fat. Whether or not these factors exist[20,21], the fact is that dilation of the hemoduct will be favored once it has been completely skeletonized. In theory, to move forward the clamp's placement will allow the mammary artery, over an extended period of time, adding the increased hydrostatic pressure and the benefits of possible vessel-relaxing factors present in the layer; the current techniques, when placing the clamp once the IMA has been separated from the wall, decrease the incidence of local factors on the diameter of the vessel.

3. It favors the visualization and control of branches: As the diameter and flow of the IMA increases, the same happens with the vessels that are born from it. Thus, branches with more flow and caliber also tend to get longer, making it easy to control, especially in the technique "only with clips and scissors." If the surgeon visualizes the branches better, it is easier to control them, what decreases the time of dissection.

4. Intentional increase of irrigation to organs at risk of ischemia or infection, by means of the physiological redirection of the blood flow of the IMA, during its dissection. This is perhaps the most important benefit obtained from the distal placement of the clamp. For many years, the significant potential for plasticity that the IMA can exhibit in the presence of an obstruction to the anterograde flow has been known[22]. It is also widely recognized the ability of mammary arteries to increase their diameters and flows in an important way, to serve as a collateral route for irrigation to distant organs, in diseases that are accompanied by significant stenosis of the aorta, such as Leriche syndrome[23,24]or coarctation of the aorta[25]. In this case, the occlusion of the distal end of the artery will allow, during the duration of the dissection, a redistribution and increase of blood flow in other organs, in the following ways:

- To the sternum and peristernal tissues. While there are sternal or perforant branches without clamping, the flow of the IMA, not having –in those circumstances– its distal drain, will be redirected in that sense. An additional advantage of this new increase in blood flow is that it is accompanied by the antibiotic administered as prophylaxis. Perhaps, the biggest inconvenience, apparently never studied, of allowing the integrity of the mammary flow during its dissection, is that a significant amount of the antibioprophylaxis is irremediably removed from the operative field, which is totally counterproductive since the only function of this dose of antimicrobial is precisely to avoid infection of the surgical site. One study[26] has at least indicated that the smaller peak concentration of antibioprophylaxis is reached in the hemisternum being dissected one hour after the administration of 4 grams of cefazolin (a higher dose than that used in our mean); from that minute, a constant decrease in concentration begins. The premature distal occlusion of the mammary artery will force the antibiotic that runs through it, from that moment, to impregnate the sternum and other mediastinal tissues, which will then be subjected to a high risk of infection, especially when dissecting both IMA[27,28].
- To the heart: The occlusion of the mammary before its bifurcation favors an increase of the non-coronary collateral blood flow to the heart, in two ways:
  - Anterograde: Through the pericardiofranic branch. Since the 1930s, it has been known that this artery is the main source of extracardiac irrigation of the heart[29]. Until 1959, several surgeons used distal ligation of the mammary arteries as a way to increase the irrigation of the heart, on the basis that a local hyperten-

sive status would produce an increase in perfusion pressure within channels, especially the pericardiophrenic, which would reach the myocardium[22]. Presumably, the development of the extracorporeal machine and other ethical issues slowed this practice, but the theory on which it is based is still valid, to the point that recently, this option has again been considered in situations where other therapeutic variants cannot be applied[30].

- Retrograde: Through the connections of the inferior and superior epigastric arteries, musculophrenic, phrenic and pericardiophrenic at the level of the diaphragm[14]. The existing communication between the superior and inferior epigastric arteries[31] that is well known, constitutes the aforementioned important collateral route to the lower limbs. Conversely, there is therefore a retrograde flow from the common iliac artery, through both epigastric to the internal mammary system that can be used to bridge distal segments of the anterior descending artery[32].

Because the proximal clamp was placed to the bifurcation and it is retained, therefore the full communication between the upper and musculophrenic[7], epigastric branches is guaranteed –in addition to the accentuation of the diameter of the distal end (to follow the same principles of increasing retrograde hydrostatic pressure)–, an increase in the irrigation of the heart through the already mentioned anastomosis between the musculophrenic and pericardiophrenic artery at the diaphragm level. On the right side must be added another source of consistent retrograde blood flow in branches' anastomosis of the hepatic artery through the falciform ligament with small branches of the right mammary artery[14].

5. Ischemic preconditioning of the heart? This possible advantage needs to be deeply studied. The extensive collateral relationships that are established around the IMA make the development of ischemia by distal vessel occlusion unlikely, but if it occurs at some level, an ischemic preconditioning mechanism would favor the heart earlier as it occurs in the case of the classic skeletonization technique.