Endoscopic harvesting of the left internal mammary artery

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Minimally invasive coronary artery bypass grafting via left anterior small thoracotomy is routinely performed on patients with single coronary artery disease, but recently has been expanded to a larger population as a part of a hybrid treatment in multivessel coronary artery disease. While the methods of internal mammary artery harvesting used in these operations can be different, the endoscopic method is more advantageous than operations performed by direct vision, and thus should be used as a technique of choice. In this article, we present detailed description of endoscopic mammary artery harvesting focusing on anatomical and technical aspects.

Keywords: Minimally invasive coronary artery bypass grafting; endoscopic mammary artery harvesting; minimally invasive cardiac surgery

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Introduction

Minimally invasive direct coronary artery bypass (MIDCAB) grafting via an anterolateral thoracotomy was first introduced into clinical practice in 1967, thanks to the pioneering work by Dr. Kolesov (1). However, this novel approach was not widely adopted in the following years, given the degree of technical complexity and the poor quality of the anastomoses performed as a consequence of the inadequacy of the technological armamentarium.

During the past two decades, a revived interest in off-pump coronary artery surgery led to the introduction of a considerable number of tools such as heart stabilizers and shunts, which have consistently improved the quality of anastomoses being performed as well as the overall feasibility of the procedure. Despite considerable improvements in transcatheter techniques and the introduction of drug-eluting stents, a wide scientific consensus has confirmed an unparalleled patency rate of the left internal mammary artery (LIMA) compared to left anterior descending (LAD) coronary artery bypass graft. This fostered a renewed interest in the possibility to perform such operations via a minimally invasive approach, particularly through a left anterior small thoracotomy (2-5). Several reports have confirmed the safety and efficacy of such an approach, also in the long term (6-12). Moreover, the possibility of performing minimally invasive LIMA-LAD operations has been recently expanded to a larger population other than patients with single-vessel disease of the LAD, i.e., as a part of a hybrid treatment in multivessel coronary artery disease with the LAD being surgically grafted with a LIMA and the remaining vessels by means of a transcatheter technique (13-17). Finally, minimally invasive revascularization of the LAD has been proved to be a safe procedure with comparable results to conventional sternotomy procedures in terms of graft quality (18).

Surgical techniques

The endoscopic harvesting of the left internal thoracic artery (LITA) can be routinely performed by means of a simple and easily reproducible set-up:

(I) *Endoscopic camera*: we routinely prefer a 10 mm, 30° angled endoscope (Karl Storz, Tuttlingen, Germany);

(II) *Trocars*: reusable, stainless steel with CO_2 insufflation (Karl Storz, Tuttlingen, Germany); one 11 mm and two 6 mm are utilized;

(III) *Harmonic scalpel*: either the curved or hook blade thoracoscopic device can be utilized (Ethicon Endosurgery, Cincinnati, OH).

The patient is positioned supine with a 30° rotated decubitus towards the right side, by means of a rolled towel, gel pads or inflatable mattress placed parallel to the spine beneath the left scapula. The left arm is elevated over the head of the patient. This position is of paramount importance since the degree of traction to the arm can create an excess of tension of the latissimus dorsi muscle and therefore influence the maneuverability of the superior trocar (utilized for the harmonic scalpel). Moreover, improper placement of the left upper limb can also lead to brachial plexus palsy. Finally, in all patients undergoing endoscopic atraumatic coronary artery bypass grafting (EACAB), external pads for emergency defibrillation are placed.

The routine trocar arrangement is achieved by placing one 6 mm trocar at the level of 3^{rd}-4^{th} intercostal space and the other 6 mm trocar at the 6^{th}-7^{th} intercostal space, on the medial-posterior axillary line. These trocars will be utilized for an endoscopic grasper and the harmonic scalpel, while the 11 mm trocar for the endoscopic camera will be positioned in 5^{th}-6^{th} intercostal space at the level of the anterior axillary line. The trocars' configuration should be adjusted according to the specific patient's chest anatomy. For example, the trocars for the grasper and the harmonic scalpel could be placed well apart from each other (e.g., on the 3^{rd} and 7^{th} intercostal spaces) in taller patients with a longer cephalad-caudal chest distance, but placed closer together in patients with smaller chest. Moreover, the presence of large breasts in women, the width of the ribs and intercostal spaces, and also potential cardiac enlargement may also affect the location of trocars and the minithoracotomy incision itself. It is important to place the skin incision for the trocars directly in the middle of corresponding intercostal space to avoid unnecessary pressure on the rib by the endoscopic instrument during dissection.

The intended incision for the mini-thoracotomy is performed through the 4^{th} or 5^{th} intercostal space based on the chest anatomy and heart orientation on X-ray.

After exclusion of the left lung, the first 11 mm trocar (for the endoscopic camera) is inserted and CO_2 insufflation is started. We routinely use a CO_2 flow of 3 L/min and a target pressure of 8 mmHg. If required, these settings can be adjusted and improved, albeit without jeopardizing the hemodynamic status of the patient due to an iatrogenic hypertensive pneumothorax, especially in patients with a decreased left ventricular ejection fraction.

After inserting the endoscopic camera, the course of the LIMA can be assessed. Usually, the LIMA is visualized close to the lateral left internal thoracic vein. In the presence of massive pleural adhesions, the thoracoscopic harvesting could be impossible, or at least extremely hazardous and time-consuming. Instead, limited adhesions can be easily dissected by means of the harmonic scalpel. In its proximal portion, the LIMA is lateral to the subclavian vein and is crossed by the phrenic nerve.

Once the overall visualization has been completed, the 6-mm trocars and endoscopic instruments are inserted. In case of poor LIMA visualization due to an excess of adipose tissue on the chest wall, this must be first dissected free from the endothoracic fascia. Routinely, the endothoracic fascia is longitudinally dissected along the internal mammary artery course first from the medial side and then on the lateral side, from the prominence of the first rib and distally down to the muscular part of the LIMA course. At this level (usually the 3^{rd}-4^{th} rib), the LIMA runs superficial to the transversus thoracic muscle and may not be directly visible, although its course can usually be drawn by observing the pulsation of the vessel itself. Therefore, we recommend at this level to leave a slightly larger margin (0.5-1 cm) of tissue from the expected course of the artery.

By retracting the prepared LIMA pedicle, a gentle spatulation with the harmonic scalpel allows for tissue separation and identification of the LIMA side branches, which are then sealed and divided by means of ultrasonic energy only. If enough time is allowed for tissue coagulation, vessel sealing can be safely accomplished and no additional maneuver (such as the use of endoscopic scissors) are required. Moreover, in our experience, the need for additional application of endoscopic clips was extremely rare.

In the occurrence of bleeding, the first recommendation is to avoid any attempt to coagulate in a "blind" fashion within a bloody area, as it may lead to inadvertent injury of the LIMA itself. Instead, the application of a gentle pressure for few minutes at the site of bleeding (by holding the pedicle against the chest wall) can significantly improve the endoscopic vision in the majority of cases.

Of note, a proper orientation of the endoscopic camera throughout the harvesting procedure is of utmost importance. In particular, the level of zoom should be minimal, so as to allow for a wide visualization of the LIMA site at all times. By the same token, an excessive zoom can lead to an improper endoscopic view of the artery and thereby lead to its injury.

In proximity to the first rib, it is often possible to find a larger amount of fat tissue, which can be safely dissected free by gently pulling the LIMA downward while coagulating the tissue close to the rib with a harmonic scalpel. At this site, it is important to avoid damage to neighboring anatomical structures such as the phrenic nerve and the subclavian artery.

When endoscopic LIMA harvesting is properly performed, the conduit should hang "freely" in an arc-like fashion as the procedure is being completed. The distal limit of LIMA harvesting can be individualized, but the LIMA should have enough length to avoid any potential stretching following the anastomosis to the LAD. Several options are available in order to assess proper LIMA length. Often, the pericardium is opened and the target vessel visualized so as to verify if the conduit yields enough length. Alternatively, another helpful maneuver is accomplished by inserting a transthoracic needle through the site of planned thoracotomy and assessing its position endoscopically in comparison with the distal end of the harvested LIMA. Finally, another option is to simply visualizing the distal end of the conduit in comparison with the apex of the heart. To ensure a proper LIMA length, division of the conduit endoscopically is avoided. Instead, completion of this maneuver after the minithoracotomy is preferred. Rarely, the LAD may have an intramuscular course thereby requiring a more distal anastomosis. In such instances, an extra-length of the LIMA is harvested under direct vision beyond the thoracotomy itself.

Comments

The technique of internal mammary artery harvesting can vary according to the revascularization approach utilized, i.e., either MIDCAB or EACAB. In the former instance, the LIMA is harvested under direct vision through the left thoracotomy while in the latter, the procurement of the graft is achieved via a fully endoscopic approach, with each technique associated with potential advantages and drawbacks. Generally, the endoscopic approach allows for a full-length harvesting of the LIMA graft, in particular at the proximal level. In fact, LIMA harvesting under direct vision via the left thoracotomy can be cumbersome when dealing with the proximal portion of the graft, and it is potentially associated with a "steal syndrome" in relation to inadequate division of the proximal side branches.

An additional benefit of the endoscopic approach is related to the considerable reduction of postoperative pain when compared to the direct-vision approach (19). Indeed, endoscopic harvesting does not require such a consistent degree of ribs lifting and traction at the time of LITA preparation and may even allow for a more limited thoracotomy.

While we have experience with both techniques, we believe that endoscopic harvesting should be the technique of choice. We have previously demonstrated that the endoscopic approach does not jeopardize the quality of coronary anastomosis and late graft patency (20). In contrast, LIMA harvesting under direct vision was associated with a potentially higher risk of incomplete separation of the proximal side branches. Therefore, harvesting under direct vision is utilized only as a bailout strategy if the endoscopic approach fails.

The use of ultrasonic energy yields several advantages compared to the conventional diathermy and consistently facilitates endoscopic harvesting as previously reported (21-23). In our practice, we have used different kinds of endoscopic blades, including curved or hook blades. The curved blade is usually more comfortable and safer for preparation the thoracic artery, but the hook is more useful in coagulating and dividing the side branches. Although each type yields unique advantages and drawbacks, our preference is for the curved blade version of the harmonic scalpel.

Appropriate patient selection is of utmost importance for safe and successful endoscopic harvesting of the LITA especially in early stages of the learning curve. Generally, obese patients (BMI >34) are not good candidates for minimally invasive artery bypass grafting and for thoracoscopic LITA preparation in particular. The presence of a large amount of adipose tissue in some instances may completely prevent a clear endoscopic visualization of the thoracic artery course. Still, endoscopic harvesting is also feasible in obese patients if the adipose tissue is generously removed from endothoracic fascia along the course of the artery itself. If such a maneuver is cumbersome, mammary harvesting under direct vision through the anterolateral thoracotomy is usually still doable.

Although endoscopic LIMA harvesting is routinely performed with a double-lumen endotracheal tube allowing for complete exposure of the left lung, this approach is potentially also feasible with a conventional intubation. During LIMA harvesting, the tube is advanced into the right bronchus therefore blocking the left one. Alternatively, another option is using a ventilation protocol with reduced tidal volumes and increased breathing rate per minute.

The position of the trocars has been widely debated in the past with several options available (23). We found that the set-up described above is reproducible in the majority of cases with minimal adjustments being required.

In our experience, endoscopic LIMA harvesting was feasible in over 95% of cases. Once the plateau phase of the learning curve has been reached, harvesting time usually ranges from 20 to 30 minutes and therefore does not impact the overall duration of the surgical procedure.

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