

Technical considerations in robotic internal thoracic artery harvesting: a series of clinical cases

Roman N. Komarov, Ilya V. Lutsenko, Oleg O. Ognev, Andrey N. Dzyundzia, Nikolay O. Kurasov, Lala Z. Faradzheva, Sofia S. Kazakova, Artem A. Romanovskii

Russian Federation

Corresponding author: Artem A. Romanovskii,
romanovskiy_a_a1@student.sechenov.ru

Received 26 November 2025. Revised 15 April 2026.
Accepted 5 May 2026.

How to cite: Komarov R.N., Lutsenko I.V., Ognev O.O., Dzyundzia A.N., Kurasov N.O., Faradzheva L.Z., Kazakova S.S., Romanovskii A.A. Technical considerations in robotic internal thoracic artery harvesting: a series of clinical cases. *Patologiya krovoobrashcheniya i kardiokhirurgiya = Circulation Pathology and Cardiac Surgery*. 2026;30(3):78-87. (In Russ.)
<https://doi.org/10.21688/1681-3472-2026-3-78-87>

Informed consent

The patient's informed consent to use the records for medical purposes is obtained.

Funding

The study did not have sponsorship.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

The authors express their gratitude to Polina A. Kovaleva, an operating room nurse in the Department of Minimally Invasive and Robotic Cardiovascular Surgery, University Clinical Hospital No. 1, Sechenov University, for her high level of professionalism and outstanding performance of her duties during high-technology surgical procedures.

Contribution of the authors

Conception and study design: R.N. Komarov, I.V. Lutsenko, O.O. Ognev

Data collection and analysis: I.V. Lutsenko, O.O. Ognev, L.Z. Faradzheva, S.S. Kazakova

Statistical analysis: I.V. Lutsenko, A.A. Romanovskii

Drafting the article: all authors

Critical revision of the article: R.N. Komarov, O.O. Ognev, A.N. Dzyundzia, N.O. Kurasov

Final approval of the version to be published: all authors

ORCID

R.N. Komarov, <https://orcid.org/0000-0002-3904-6415>

I.V. Lutsenko, <https://orcid.org/0000-0003-3222-6963>

O.O. Ognev, <https://orcid.org/0000-0002-9305-2250>

A.N. Dzyundzia, <https://orcid.org/0000-0003-1133-8106>

N.O. Kurasov, <https://orcid.org/0000-0001-6269-2207>

L.Z. Faradzheva, <https://orcid.org/0009-0003-7098-3372>

S.S. Kazakova, <https://orcid.org/0009-0002-7023-2387>

A.A. Romanovskii, <https://orcid.org/0009-0004-2300-6795>

Sechenov First Moscow State Medical University (Sechenov University),
Moscow,

Abstract

Introduction: One of the main trends in modern cardiac surgery is the reduction of the invasiveness of surgical procedures. Robotic technologies enable a broad range of operations to be performed without sternotomy, thereby accelerating patient recovery and reducing the risk of postoperative complications.

Objective: To describe the essential steps and technical considerations of robot-assisted coronary artery bypass grafting (CABG) that ensure the convenience, safety, and reproducibility of this myocardial revascularization technique.

Methods: The technique of robot-assisted CABG described in this article is based on experience with 50 minimally invasive CABG procedures performed using robotic technology in the Cardiac Surgery Department of University Clinical Hospital No. 1. Most patients were men – 47 (94%). The median age was 63 years [59–66], with the largest proportion of patients belonging to the 60–69-year age group (52%). The mean body mass index was 28.6 ± 5.6 kg/m². All procedures were performed electively, and no conversions were required.

Results: All surgical procedures were completed successfully. In three cases, the internal thoracic artery (ITA) was injured during mobilization. At the current stage of our program, we have adopted a strategy of limiting the robotic stage to ITA harvesting without performing the distal anastomosis. The modular structure of the learning process for totally endoscopic coronary artery bypass grafting (TECAB) allows each component of the procedure to be practiced sequentially. As our experience has accumulated, we have gradually expanded the scope of the intervention.

Conclusion: Robot-assisted CABG, in which the ITA is harvested robotically and the anastomosis is constructed through a thoracotomy, provides a reliable foundation for mastering and subsequently implementing complete TECAB. It is important to recognize that outcomes improve as the surgical team gains relevant experience. Stepwise acquisition of robotic coronary surgery skills makes it possible to perform these procedures during the early stages of the learning curve without exposing patients to undue risk.

Keywords: internal thoracic artery; minimally invasive coronary artery bypass grafting; robotic surgery; surgical technique



Нюансы роботического выделения внутренней грудной артерии: серия клинических случаев

Р.Н. Комаров, И.В. Луценко, О.О. Огнев, А.Н. Дзюндзя, Н.О. Курасов, Л.З. Фараджеева, С.С. Казакова, А.А. Романовский

Для корреспонденции: Артем Андреевич Романовский, romanovskiy_a_a1@student.sechenov.ru

Поступила в редакцию 26 ноября 2025 г. Исправлена 15 апреля 2026 г. Принята к печати 5 мая 2026 г.

Цитировать: Комаров Р.Н., Луценко И.В., Огнев О.О., Дзюндзя А.Н., Курасов Н.О., Фараджеева Л.З., Казакова С.С., Романовский А.А. Нюансы роботического выделения внутренней грудной артерии: серия клинических случаев. *Патология кровообращения и кардиохирургия*. 2026;30(3):78-87. <https://doi.org/10.21688/1681-3472-2026-3-78-87>

Информированное согласие

Получено информированное согласие пациентов на использование медицинских данных в научных целях.

Финансирование

Исследование не имело спонсорской поддержки.

Конфликт интересов

Авторы заявляют об отсутствии конфликта интересов.

Благодарность

Коллектив авторов выражает признательность Полине Александровне Ковалевой, операционной медсестре отделения малоинвазивной и роботической сердечно-сосудистой хирургии УКБ № 1 Сеченовского Университета, за высокий профессионализм и отличное исполнение трудовых обязанностей при проведении высокотехнологичных операций.

Вклад авторов

Концепция и дизайн работы: Р.Н. Комаров, И.В. Луценко, О.О. Огнев

Сбор и анализ данных: И.В. Луценко, О.О. Огнев, Л.З. Фараджеева, С.С. Казакова

Статистическая обработка данных: И.В. Луценко, А.А. Романовский

Написание статьи: все авторы

Исправление статьи: Р.Н. Комаров, О.О. Огнев, А.Н. Дзюндзя, Н.О. Курасов

Утверждение окончательного варианта статьи: все авторы

ORCID

Р.Н. Комаров, <https://orcid.org/0000-0002-3904-6415>

И.В. Луценко, <https://orcid.org/0000-0003-3222-6963>

О.О. Огнев, <https://orcid.org/0000-0002-9305-2250>

А.Н. Дзюндзя, <https://orcid.org/0000-0003-1133-8106>

Н.О. Курасов, <https://orcid.org/0000-0001-6269-2207>

Л.З. Фараджеева, <https://orcid.org/0009-0003-7098-3372>

С.С. Казакова, <https://orcid.org/0009-0002-7023-2387>

А.А. Романовский, <https://orcid.org/0009-0004-2300-6795>

© Комаров Р.Н., Луценко И.В., Огнев О.О., Дзюндзя А.Н., Курасов Н.О., Фараджеева Л.З., Казакова С.С., Романовский А.А., 2026

Федеральное государственное автономное образовательное учреждение высшего образования Первый Московский государственный медицинский университет имени И.М. Сеченова Министерства здравоохранения Российской Федерации (Сеченовский Университет), Москва, Российская Федерация

Аннотация

Актуальность. Одной из основных тенденций современной кардиохирургии является уменьшение инвазивности оперативного вмешательства. Роботические технологии позволяют выполнять широкий спектр операций без стернотомии, что существенно ускоряет восстановление пациента и снижает риск послеоперационных осложнений.

Цель. Описать необходимые этапы и нюансы робот-ассистированного коронарного шунтирования, обеспечивающие удобство, безопасность и воспроизводимость данной методики реваскуляризации миокарда.

Методы. В основу описываемой в данной статье техники выполнения робот-ассистированного коронарного шунтирования положен опыт проведения 50 операций мини-инвазивного коронарного шунтирования с применением роботических технологий в кардиохирургическом отделении Университетской клинической больницы № 1. Среди пациентов преобладали мужчины – 47 (94 %). Возрастная медиана – 63 года [59; 66], при этом наибольшая доля пациентов относилась к возрастной категории 60–69 лет (52 %). Средний индекс массы тела составил $28,6 \pm 5,6$ кг/м². Все вмешательства выполнялись в плановом порядке, случаев конверсии не наблюдалось.

Результаты. Все оперативные вмешательства были успешно завершены, в трех случаях внутренняя грудная артерия была повреждена на этапе ее мобилизации. На текущем этапе в нашей практике принято стратегическое решение ограничиться робот-ассистированным выделением внутренней грудной артерии (ВГА) без формирования дистального анастомоза. Модульная структура освоения полностью эндоскопического коронарного шунтирования (Totally Endoscopic Coronary Artery Bypass, TECAB) позволяет последовательно отрабатывать каждый компонент вмешательства. По мере накопления опыта нами постепенно расширяется объем вмешательства.

Заключение. Робот-ассистированное коронарное шунтирование, при котором роботически выделяется ВГА, а формирование анастомоза осуществляется через торакотомный доступ, представляет собой надежный фундамент для освоения и последующего внедрения полноценного TECAB. При этом важно понимать, что результаты улучшаются с приобретением соответствующего опыта. Пошаговое овладение роботической коронарной хирургией делает возможным выполнение данных операций на ранних этапах кривой обучения без лишнего риска для пациентов.

Ключевые слова: внутренняя грудная артерия; мини-инвазивное коронарное шунтирование; роботическая хирургия, техника операции



Introduction

The origins of robotic cardiac surgery date back more than 25 years, to the late 1990s [1]. In recent years, the number of robotic cardiac procedures has increased. From the 2010s to the present, their proportion has risen from less than 1% to approximately 3% [2; 3]. The use of robotic technology in cardiac surgery reduces surgical trauma and, consequently, decreases the severity of postoperative pain and the incidence of surgical-site infection. This contributes to faster patient recovery and an earlier return to daily activities.

In particular, robotic harvesting of the internal thoracic artery (ITA), the principal conduit used in surgery for coronary artery disease, enables meticulous dissection of the vessel and minimizes the risk of injury. This may improve graft patency and the long-term outcomes of coronary artery bypass grafting (CABG) [2; 4]. In this article, we systematize the practical features and technical considerations of ITA mobilization identified during the acquisition of clinical experience.

Methods

Patient cohort

At the Cardiac Surgery Department of University Clinical Hospital No. 1, 50 minimally invasive CABG procedures were performed using robotic technology. Informed consent was obtained from all patients. Most patients were men – 47 (94%). The median age was 63 years [59–66], and the largest proportion of patients belonged to the 60–69-year age group (52%). The mean body mass index was 28.6 ± 5.6 kg/m². All procedures were performed electively, and no conversions were required.

It should be emphasized that robotic ITA harvesting should be introduced using a stepwise approach, with sufficient experience being accumulated at each stage. The purpose of this article was to describe the essential

steps and technical considerations that ensure the convenience, safety, and reproducibility of this procedure.

Patient positioning on the operating table

Patients were placed in the supine position. A foam roll was positioned beneath the left scapular region and pelvis (Fig. 1). This elevated the patient's left side by 30–45°, while the right side remained in contact with the operating table, facilitating subsequent port placement.

The right arm was secured alongside the body, whereas the left arm was flexed at the elbow and secured only at the level of the pelvis. This positioning of the left upper extremity allowed unrestricted movement of the right robotic arm.

Anesthetic management

For lung isolation, a right-sided double-lumen endobronchial tube was used to collapse the left lung and provide adequate visualization of the surgical field. The possibility of immediate conversion to two-lung ventilation in the event of complications should also be considered. Therefore, bronchial isolation using a double-lumen endobronchial tube is regarded as the gold standard for robot-assisted cardiac surgery.

Strict cardiovascular monitoring was maintained throughout the procedure, including invasive blood pressure measurement and electrocardiographic monitoring. Carbon dioxide insufflation into the pleural cavity and displacement of mediastinal structures toward the contralateral side may result in significant hemodynamic changes.

An endocardial pacing lead was inserted through the jugular or subclavian vein and positioned in the right ventricle. The effects of capnothorax on gas exchange should also be taken into account.

Analgesia, sedation, and neuromuscular blockade must be adequate for the surgical procedure and tailored to

Fig. 1. Patient positioning:
1, foam roll;
2, positioning of the left upper extremity;
3, endocardial pacing lead;
4, external defibrillation pads

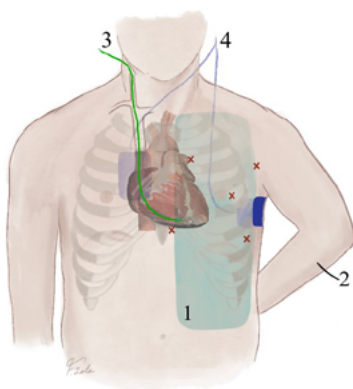
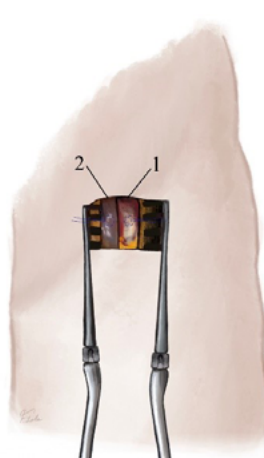
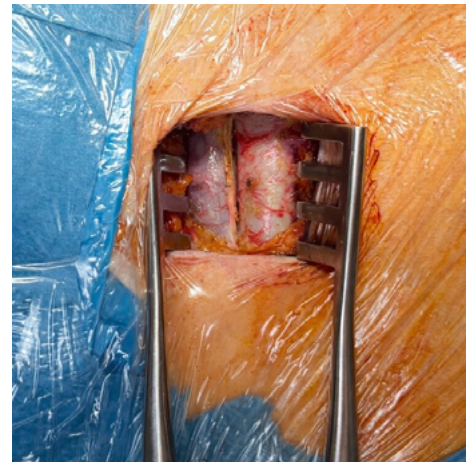


Fig. 2. Femoral vessel exposure:
1, common femoral artery;
2, common femoral vein



the individual characteristics of each patient. Unplanned recovery of consciousness or muscle tone – even minimal diaphragmatic movement during surgery – may cause serious injuries from surgical instruments.

External adhesive defibrillation pads were applied before preparation and draping of the surgical field. One pad was placed along the left midaxillary line at the level of the fifth intercostal space, and the other was placed in the right paravertebral region at the level of the second to fourth intercostal spaces. This positioning allows emergency electrical defibrillation or cardioversion without interfering with the port sites, compromising the sterility of the surgical field, or converting the surgical approach.

Peripheral cardiopulmonary bypass

After patient preparation, the first step was exposure of the left common femoral artery and common femoral vein in the femoral triangle in case peripheral cardiopulmonary bypass (CPB) had to be initiated (Fig. 2). The left side was selected because the robotic system was subsequently positioned on the patient's right side.

Although CPB is generally not required for this minimally invasive procedure, we used a dual-safety strategy. This approach was related to the early stage of our experience with robot-assisted CABG and the need to minimize risks in the event of intraoperative complications, such as uncontrolled bleeding or hemodynamic instability.

Port placement

Port placement during robot-assisted CABG is a crucial step that determines the surgeon's working conditions, the quality of visualization, and, consequently, the safety of the procedure (Fig. 3). Ports were placed through the second to seventh intercostal spaces along the

anterolateral surface of the chest, depending on the findings of the preoperative radiographic examination.

After collapse of the left lung, a Veress needle was first inserted into the fourth or fifth intercostal space between the midclavicular and anterior axillary lines. The needle was used to insufflate carbon dioxide at an initial pressure of 10–12 mm Hg and a flow rate of 8–10 L/min.

This approach, combined with separate endobronchial intubation, enables safe displacement of the left lung, provides optimal exposure of the anterior mediastinum, and reduces the risk of injury to intrathoracic structures during subsequent port placement.

Pleural pressure was continuously monitored in real time because an increase in pressure may compress the right-sided cardiac chambers, reduce preload, and consequently decrease cardiac output.

A 12-mm camera port, designated as port 1, was then placed at the site of the Veress needle. Correct positioning of this port is important because it not only provides optimal visualization of the intrathoracic structures but also frequently serves as the site for subsequent thoracotomy. To prevent cardiac injury, the camera port was directed inferiorly and laterally during insertion. All subsequent manipulations within the pleural cavity were performed under camera guidance.

Two 8-mm working ports were placed 7–10 cm above and below the camera port. One was placed in the second or third intercostal space on the left, between the midclavicular and anterior axillary lines; this was port 2 for the right robotic arm. The second was placed in the sixth or seventh intercostal space along the same line; this was port 3 for the left robotic arm.

Port 2 should be positioned slightly closer to the anterior axillary line than port 3. This arrangement prevents the right robotic arm from conflicting with the patient's shoulder.

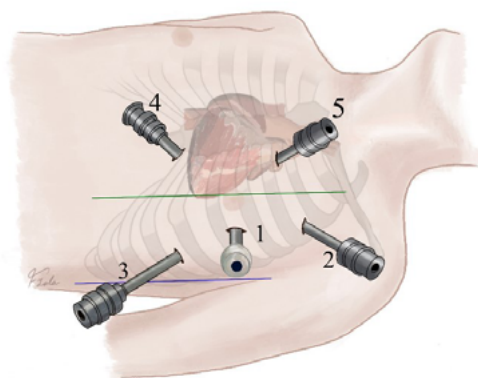


Fig. 3. Port placement: port 1, camera port; port 2, port for the right robotic arm; port 3, port for the left robotic arm; port 4, stabilizer port; port 5, assistant port. The midclavicular and anterior axillary lines are shown in green and blue, respectively

In some cases, an auxiliary port was placed at Larrey's point to accommodate an endoscopic stabilizer or atrial retractor and improve visualization during ITA harvesting. An assistant port was also placed in the second intercostal space on the left along the parasternal line. This port allowed the necessary auxiliary instruments or suture material to be introduced into the chest.

The instrument used for ITA harvesting was inserted through port 2. All robotic instruments described below were manufactured by Intuitive Surgical, California, USA.

At the beginning of our experience with this technique, we used the monopolar Permanent Cautery Hook. The ITA was injured on three occasions while this instrument was being used, necessitating the use of a saphenous vein graft in those procedures. Therefore, we subsequently switched to the monopolar Permanent Cautery Spatula for ITA harvesting. Its flat tip allows gentler manipulation of the surrounding tissues and more precise and controlled handling of the ITA. Since the introduction of this instrument at our institution, no ITA injuries have been observed.

This port was also used to introduce the Small Clip Applier for clipping large intercostal branches and either Potts Scissors or Curved Scissors.

Port 3 was used primarily for tissue traction. Initially, because the necessary equipment was not readily available, we used the Maryland Bipolar Forceps and Large Needle Driver. In our opinion, both instruments are cumbersome for cardiac surgery because of their large size.

Subsequently, the Black Diamond Micro Forceps was used for more delicate traction of the artery and

surrounding tissues. Its miniature teeth and favorable manipulation characteristics enabled the artery to be grasped safely without endothelial injury.

At present, we use the Micro Bipolar Forceps connected to a bipolar coagulation unit. This instrument allows delicate tissue grasping and, when necessary, the application of electrocautery.

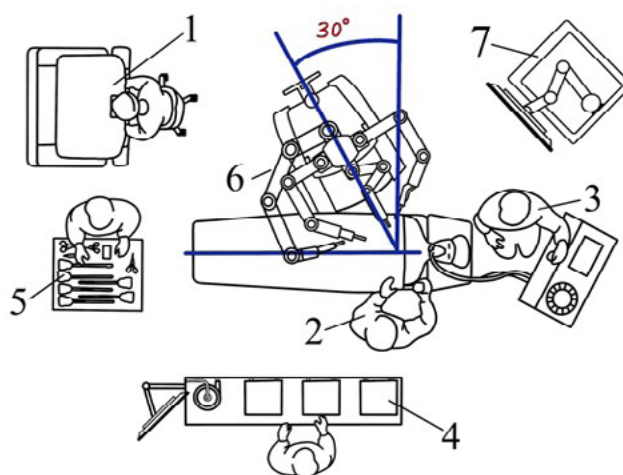


Fig. 4. Position of the surgical team and equipment in the operating room: 1, surgeon's console; 2, assistant; 3, anesthesiologist; 4, heart-lung machine; 5, operating room nurse; 6, robotic system; 7, robotic vision cart

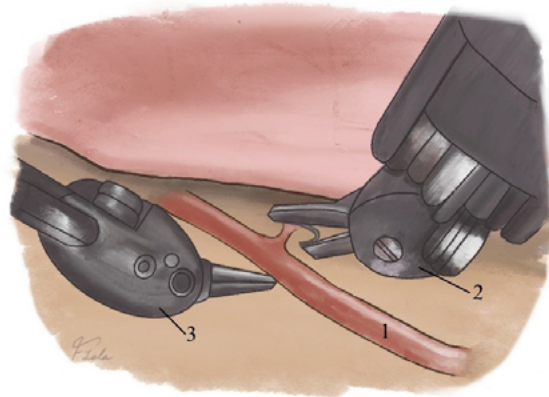
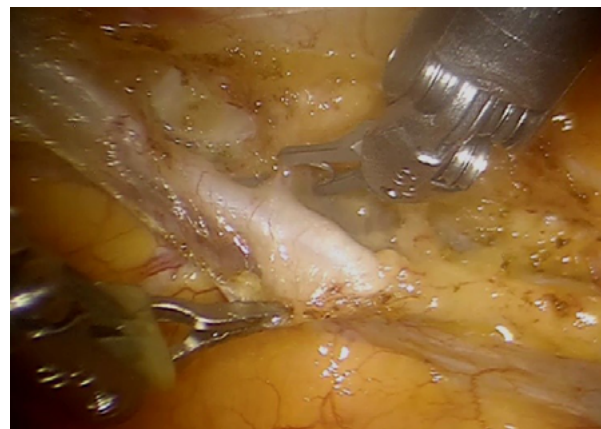


Fig. 5. Clipping of a lateral branch of the internal thoracic artery: 1, internal thoracic artery; 2, Small Clip Applier; 3, Micro Bipolar Forceps

Port 4 was placed at Larrey's point and used to introduce the endoscopic stabilizer or atrial retractor (EndoWrist Stabilizer or Atrial Retractor). At the current stage of our experience, port 5 is used when pharmacological dilation of the ITA is required.

After placement of the required ports, docking was performed. The robotic system should be positioned at a slight angle relative to the operating table – approximately 30° toward the patient's feet (Fig. 4). This configuration increases the maneuverability of the robotic arm connected to port 4.

Internal thoracic artery harvesting

The robotic system provides 10- to 12-fold magnification, substantially improving the visualization of anatomical landmarks and increasing the safety of dissection.

During bilateral ITA grafting, harvesting of the right internal thoracic artery (RITA) should preferably be performed first because initial harvesting of the left internal thoracic artery (LITA) carries a risk of injury during subsequent manipulation. In addition, the mobilized LITA may obstruct visualization while working in the right hemithorax.

To harvest the RITA, intrapleural pressure was increased to 18 mm Hg, and the right mediastinal pleura was widely incised.

We used a skeletonized harvesting technique, which increases the functional length of the ITA by 2–3 cm. Combined with robotic mobilization, this technique enables the artery to be harvested along its entire length

and allows CABG to be performed without additional saphenous vein graft extensions.

In the presence of pronounced post-radiation infiltrative and fibrotic tissue changes, the ITA may be harvested as a pedicled graft without skeletonization, preserving the fascial-muscular sheath and perivascular tissue.

Intercostal branches with a diameter of 1 mm or less were coagulated. Larger branches were clipped using the Small Clip Applier, which applies titanium clips (Fig. 5).

After clipping the branches, the tissues were divided using Potts Scissors. The branches should be divided between the clips using several controlled cutting movements. This technique makes it possible to verify the correct placement of the clips and, in the event of bleeding, to reapply the clips or use bipolar coagulation.

Instrument exchange should be performed strictly under direct visual control to avoid injury to internal organs and other intrathoracic structures.

In the proximal segment of the RITA, one of the right venae comitantes frequently crosses the artery. To obtain the maximum graft length, this vein should be dissected and divided. It is first mobilized and coagulated to reduce its caliber and is then clipped and divided.

Distally, the artery is harvested to the level of its bifurcation into the musculophrenic and superior epigastric arteries. If the vessel diameter distal to the bifurcation is adequate, mobilization of the ITA may be continued beyond the bifurcation.

Without transecting the RITA, harvesting of the LITA is then performed according to the same principles.

After systemic heparinization, clips are applied to the distal ends of the arteries. The tip of the ITA is incised with scissors but is not completely transected, allowing blood flow to be assessed.

If blood flow is unsatisfactory, pharmacological dilation with papaverine solution is performed. An epidural catheter and a DeBakey-type bulldog vascular clamp secured with a suture to prevent accidental loss of the instrument are introduced through the assistant port.

The proximal end of the ITA is occluded with the clamp, and the epidural catheter is inserted into the distal end of the artery. The assistant then injects papaverine solution through the other end of the catheter. This procedure is more conveniently performed while the ITA remains untransected and under tension.

After satisfactory blood flow is confirmed, the artery is clipped and transected.

The arteries are positioned and secured to the edge of the pericardium using clips. Because visualization of the thoracic and pericardial cavities through an anterolateral minithoracotomy is limited, this maneuver prevents displacement of the arteries.

The final robotic step consists of inspection and achievement of hemostasis in the ITA beds and at the port sites. Undocking, including removal of the robotic instruments, is then performed, followed by thoracotomy through the fourth or fifth intercostal space, depending on the patient's anatomical and topographical features.

Increasing the operative workspace

CABG performed using minimally invasive techniques is associated with limited visualization. Robotic technology helps overcome these limitations through improved instrument maneuverability and video imaging.

We identified several maneuvers that increase the operative workspace and thereby improve access to both ITAs, particularly their distal and proximal segments.

Before starting ITA harvesting, we perform a posterior pericardiotomy, allowing the heart to descend slightly. For this purpose, the camera is rotated to a 30° downward position. The pericardium is then opened over a length of 4–5 cm parallel to the left phrenic nerve and 1–2 cm posterior to it using Micro Bipolar Forceps and Curved Scissors connected to a bipolar electrocautery unit.

In this setting, the use of monopolar electrocautery may cause cardiac arrhythmias and necessitate immediate conversion.

Anterior pericardiotomy, with removal of the pericardial fat overlying the target artery – most

commonly the left anterior descending artery – is performed in the same manner.

The operative workspace can also be enlarged using instruments placed through Larrey's point. These instruments create additional space in the thoracic cavity by displacing the right ventricle.

The endoscopic stabilizer is a scarce and expensive instrument because production of the device for the da Vinci Si system used at our institution has been discontinued. During ITA harvesting, we observed no differences in functionality between the endoscopic stabilizer and the atrial retractor.

These instruments should be used with caution because they may compromise hemodynamics.

Statistical analysis

The distribution of quantitative variables was assessed using the Shapiro–Wilk test. When the assumption of normality was met, the mean and standard deviation were calculated. Otherwise, the data were presented as medians with the first and third quartiles [Q1–Q3]. Categorical variables were presented as absolute values and percentages.

Results

All surgical procedures were completed successfully. In three cases, the LITA was injured during mobilization, and a saphenous vein graft was therefore used. The robot-assisted stage was performed by the same surgeon in all procedures. The intraoperative parameters are presented in Table 1.

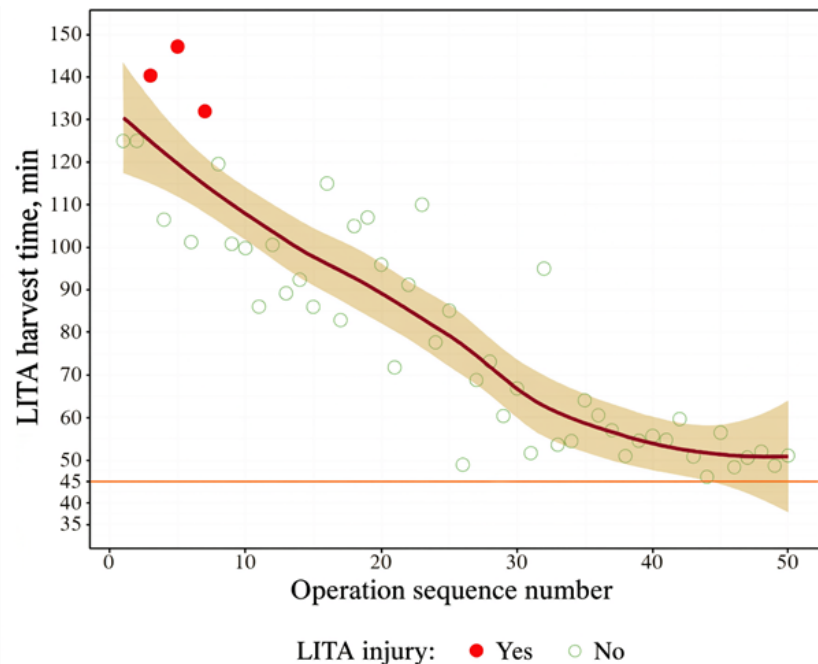
Table 1. Intraoperative Parameters (*n* = 50)

Parameter	Value
Operative time, min	299 ± 71
Use of cardiopulmonary bypass	
Off-pump, <i>n</i> (%)	35 (70.0)
Parallel CPB, <i>n</i> (%)	15 (30.0)
LITA harvesting time, min	76 [54–101]
LITA injury, <i>n</i> (%)	3 (6.0)
RITA injury, <i>n</i> (%)	0 (0.0)
Bilateral ITA grafting, <i>n</i> (%)	12 (24.0)
Blood loss, mL	100 [100–275]
Conversion, <i>n</i> (%)	0 (0.0)

Note. CPB, cardiopulmonary bypass; LITA, left internal thoracic artery; RITA, right internal thoracic artery.

Fig. 6. Time required for left internal thoracic artery harvesting

Note. LITA, left internal thoracic artery.



At the beginning of our experience with the robotic technique, approximately 120 minutes were required for ITA harvesting. At present, the duration of this stage approaches 45 minutes when no ITA injury occurs (Fig. 6).

Discussion

At the current stage of our program, we have adopted a strategy of limiting the procedure to robotic ITA mobilization without performing the distal anastomosis.

The modular structure of the TECAB learning process – ITA harvesting, pericardiotomy, identification of the target coronary artery, and anastomosis – allows each component of the procedure to be practiced sequentially, given that each stage has its own learning curve. This stepwise approach has also been described in several international publications [5–8]. Attempting to perform all surgical stages at the beginning of the learning curve is associated with unjustifiably high risks [9].

As our experience accumulated, we gradually expanded the scope of the procedure. Bilateral ITA mobilization was performed, making it possible to treat patients with hemodynamically significant disease involving multiple coronary arteries.

In addition to the basic techniques, we introduced anterior and posterior pericardiotomy to optimize visualization and ensure reliable identification of the target arteries. We also introduced pharmacological dilation of the ITAs *in situ* to improve the perfusion characteristics of the intended graft.

Mastery of these components brings the surgical team closer to performing complete TECAB with an acceptable risk profile.

As our experience increased, we also decided to gradually reduce the number of proximal anastomoses to the ascending aorta. This was achieved through more extensive use of composite grafts and an increase in the proportion of bilateral ITA grafting.

The effectiveness of both approaches is well documented in the literature. In a study by Kim et al., saphenous vein Y-composite grafts were shown not to be inferior to free RITA grafts when angiographic outcomes were compared one year after surgery. Furthermore, no statistically significant between-group differences were found in overall survival or the incidence of cardiovascular events at 1 and 4 years after surgery ($p = 0.998$ and $p = 0.597$, respectively) [10].

One of the key indicators of progress is a reduction in ITA harvesting time. Similar trends have been described in the international literature: the duration of robot-assisted LITA mobilization decreases significantly as experience accumulates, with the most pronounced improvements occurring during the first 15–20 procedures [11; 12].

When minimally invasive surgical techniques are discussed, postoperative length of stay is one of the most important outcome measures. Rapid recovery and an early return to daily activities are major goals of contemporary cardiac surgery.

According to our data, the postoperative hospital stay was 10 [8–15] days. By comparison, Gofus et al. reported a postoperative hospital stay of 6 [5–7] days in the robot-assisted CABG group [13]. Jonsson et al. reported a series of 1,000 consecutive robot-assisted CABG procedures with a postoperative hospital stay of 4.4 ± 2.5 days [14].

It should be noted that the range of patients undergoing robotic revascularization has expanded in recent years. Obesity, advanced age, and redo surgery are no longer considered limiting factors when selecting patients for robot-assisted procedures [15–17].

Conclusion

Robot-assisted CABG, in which the ITA is harvested robotically and the anastomosis is constructed through a thoracotomy, provides a reliable foundation for mastering and subsequently implementing complete TECAB.

It is important to recognize that outcomes improve as the surgical team gains relevant experience. Stepwise acquisition of robotic coronary surgery skills makes it possible to perform these procedures during the early stages of the learning curve without exposing patients to undue risk.

References

1. Loulmet D, Carpentier A, D'Attellis N, Berrebi A, Cardon C, Ponzio O, Aupecle B, Relland J.Y. Endoscopic coronary artery bypass grafting with the aid of robotic assisted instruments. *J Thorac Cardiovasc Surg.* 1999;118(1):4-10. PMID: 10384177. [https://doi.org/10.1016/S0022-5223\(99\)70133-9](https://doi.org/10.1016/S0022-5223(99)70133-9)
2. Algoet M, Melvin T, Cerny S, Bonatti J, Singh S, Folliguet T, Modi P, Franke U, Gianoli M, Agnino A, Casselman F, Oosterlinck W. How to advance from minimally invasive coronary artery bypass grafting to totally endoscopic coronary bypass grafting: challenges in Europe versus United States of America. *Ann Cardiothorac Surg.* 2024;13(5):397-408. PMID: 39434975; PMCID: PMC11491180. <https://doi.org/10.21037/acs-2023-rcabg-0210>
3. Whellan D.J., McCarey M.M., Taylor B.S., Rosengart T.K., Wallace A.S., Shroyer A.L., Gammie J.S., Peterson E.D. Trends in Robotic-Assisted Coronary Artery Bypass Grafts: A Study of the Society of Thoracic Surgeons Adult Cardiac Surgery Database, 2006 to 2012. *Ann Thorac Surg.* 2016;102(1):140-6. PMID: 27016838. <https://doi.org/10.1016/j.athoracsur.2015.12.059>
4. Gaudino M., Bakaeen F.G., Sandner S., Aldea G.S., Arai H., Chikwe J., Firestone S., Fremes S.E., Gomes W.J., Bong-Kim K., Kisson K., Kurlansky P., Lawton J., Navia D., Puskas J.D., Ruel M., Sabik J.F., Schwann T.A., Taggart D.P., Tatoulis J., Wyler von Ballmoos M. Expert systematic review on the choice of conduits for coronary artery bypass grafting: endorsed by the European Association for Cardio-Thoracic Surgery (EACTS) and The Society of Thoracic Surgeons (STS). *Eur J Cardiothorac Surg.* 2023;64(2):ezad163. PMID: 37535847. <https://doi.org/10.1093/ejcts/ezad163>
5. Cheng N., Gao C., Yang M., Wu Y., Wang G., Xiao C. Analysis of the learning curve for beating heart, totally endoscopic, coronary artery bypass grafting. *J Thorac Cardiovasc Surg.* 2014;148(5):1832-6. PMID: 24629222. <https://doi.org/10.1016/j.jtcvs.2014.02.002>
6. Bonatti J., Schachner T., Bernecker O., Chevtchik O., Bonaros N., Ott H., Friedrich G., Weidinger F., Laufer G. Robotic totally endoscopic coronary artery bypass: program development and learning curve issues. *J Thorac Cardiovasc Surg.* 2004;127(2):504-10. PMID: 14762361. <https://doi.org/10.1016/j.jtcvs.2003.09.005>
7. Schachner T., Bonaros N., Wiedemann D., Weidinger F., Feuchtnner G., Friedrich G., Laufer G., Bonatti J. Training surgeons to perform robotically assisted totally endoscopic coronary surgery. *Ann Thorac Surg.* 2009;88(2):523-7. PMID: 19632405. <https://doi.org/10.1016/j.athoracsur.2009.04.089>
8. Bonatti J., Schachner T., Bonaros N., Rützler E., Weidinger F., Schistek R., Feuchtnner G., Friedrich G., Pachinger O., Laufer G. Robotic technology-probably a safe tool for development of completely endoscopic coronary revascularization procedures. *Innovations (Phila).* 2008;3(3):139-41. PMID: 22436855. <https://doi.org/10.1097/IMI.0b013e31817ea8ed>
9. de Cannière D., Wimmer-Greinecker G., Cichon R., Guliemos V., Van Praet F., Seshadri-Kreaden U., Falk V. Feasibility, safety, and efficacy of totally endoscopic coronary artery bypass grafting: multicenter European experience. *J Thorac Cardiovasc Surg.* 2007;134(3):710-6. PMID: 17723822. <https://doi.org/10.1016/j.jtcvs.2006.06.057>
10. Kim K.B., Hwang H.Y., Hahn S., Kim J.S., Oh S.J. A randomized comparison of the Saphenous Vein Versus Right Internal Thoracic Artery as a Y-Composite Graft (SAVE RITA) trial: One-year angiographic results and mid-term clinical outcomes. *J Thorac Cardiovasc Surg.* 2014;148(3):901-7. PMID: 24973924. <https://doi.org/10.1016/j.jtcvs.2014.03.057>
11. Hemli J.M., Henn L.W., Panetta C.R., Suh J.S., Shukri S.R., Jennings J.M., Fontana G.P., Patel N.C. Defining the learning curve for robotic-assisted endoscopic harvesting of the left internal mammary artery. *Innovations (Phila).* 2013;8(5):353-8. PMID: 24346584. <https://doi.org/10.1097/IMI.0000000000000017>
12. Boutros C.S., Kim M.J., Diasty M.E. The learning curve of robotic cardiac surgery: a scoping review. *J Robot Surg.* 2025;19(1):476. PMID: 40788514; PMCID: PMC12339607. <https://doi.org/10.1007/s11701-025-02427-w>
13. Gofus J., Cerny S., Shahin Y., Sorm Z., Vobornik M., Smolak P., Sethi A., Marcinov S., Karalko M., Chek J., Harrer J., Vojacek J., Pojar M. Robot-assisted vs. conventional MIDCAB: A propensity-matched analysis. *Front Cardiovasc Med.* 2022;9:943076. PMID: 36110419; PMCID: PMC9468449. <https://doi.org/10.3389/FCVM.2022.943076>

14. Jonsson A., Binongo J., Patel P., Wang Y., Garner V., Mitchell-Cooks D., Halkos M.E. Mastering the Learning Curve for Robotic-Assisted Coronary Artery Bypass Surgery. *Ann Thorac Surg.* 2023;115(5):1118-1125. PMID: 36848999.
<https://doi.org/10.1016/j.athoracsur.2023.02.045>
15. Nisivaco S., Bhasin R., Kitahara H., Patel B., Coleman C., Grady K., Oh W.H., Balkhy H.H. Bilateral internal thoracic artery grafting in robotic beating-heart totally endoscopic coronary artery bypass: 10-year outcomes. *Ann Cardiothorac Surg.* 2024;13(4):354-363. PMID: 39157183; PMCID: PMC11327409.
<https://doi.org/10.21037/acs-2024-rcabg-0016>
16. Balkhy H.H., Nisivaco S.M., Hashimoto M., Torregrossa G., Grady K. Robotic Total Endoscopic Coronary Bypass in 570 Patients: Impact of Anastomotic Technique in Two Eras. *Ann Thorac Surg.* 2022;114(2):476-482. PMID: 34890572.
<https://doi.org/10.1016/j.athoracsur.2021.10.049>
17. Zhou Z., Dilip K.A., Gleboff A., Nazem A., Green G.R., Cherney A., Lutz C.J. Comparison of Robot-Assisted Multivessel Minimally Invasive Direct Coronary Artery Bypass and Hybrid Revascularization. *Ann Thorac Surg Short Rep.* 2023;2(2):226-230. PMID: 39790165; PMCID: PMC11708408.
<https://doi.org/10.1016/j.atssr.2023.11.029>