Original Article

Learning Curve of Thoracoscopic Nonrobotic Harvest of the Left Internal Mammary Artery in Minimally Invasive Coronary Artery Bypass Grafting

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Abstract

Objective: Harvest of the left internal mammary artery (LIMA) is a technically demanding element of minimally invasive coronary surgery. We aimed to evaluate the learning curve of thoracoscopic, nonrobotic LIMA harvest during endoscopic coronary artery bypass (Endo-CAB) surgery. **Methods:** Eighty patients undergoing Endo-CAB surgery were included. LIMA harvest was performed using commonly available video-assisted thoracoscopic instruments. Time from incision until heparin administration was defined as total LIMA harvest time (this includes opening of the pericardium and identification of coronary targets). LIMA harvest times ($N = 80$) and total procedure times for single-vessel grafting ($n = 51$) were analyzed. **Results:** The mean LIMA harvest time was 58 ± 19 min, ranging from 15 to 113 min. The mean procedure time was 150 ± 39 min. Significant reductions in both LIMA harvest and total Endo-CAB procedure times were observed with increasing experience (logarithmic regression $Y = 109 - 14.9*\log(x)$, $P < 0.001$; $Y = 227 - 24.4*\log(x)$, $P < 0.001$, respectively). No damage to the LIMA occurred during thoracoscopic harvesting. **Conclusions:** Total thoracoscopic (nonrobotic) LIMA harvest is an efficient technique with a steep learning curve using routine instruments. More patients might benefit from minimally invasive coronary surgery using thoracoscopic LIMA harvest techniques.

Central Message

Thoracoscopic nonrobotic left internal mammary artery harvest is an efficient technique with a steep learning curve using routine endoscopic instruments. This procedure is safe with satisfactory procedure times.

Keywords

endoscopic, MIDCAB, Endo-CAB, LIMA harvest

Introduction

Coronary artery bypass grafting is the standard-of-care treatment for many patients. Traditionally, this is performed through a median sternotomy. Minimally invasive coronary revascularization offers the long-term benefits of bypass grafts with reduced surgical trauma and early recovery.[1,2] Harvesting of the left internal mammary artery (LIMA) is a technically demanding element of this approach. It can be performed under direct vision using a chest wall retractor, robotically or with video-assisted thoracoscopic techniques.[3] Robotic LIMA harvest is a very efficient method; however, the limited availability of the system and increased procedure costs can confine a more widespread introduction of minimally invasive coronary surgery.[4] Video-assisted thoracoscopic techniques with more commonly available instruments could overcome these limitations.

The aim of this paper is to evaluate procedure times and safety of total thoracoscopic LIMA harvest during endoscopic coronary artery bypass (Endo-CAB) procedures.

Methods

Eighty patients undergoing Endo-CAB surgery at our institution from July 2021 until December 2022 were included in this analysis. Patients with bilateral mammary artery harvest and

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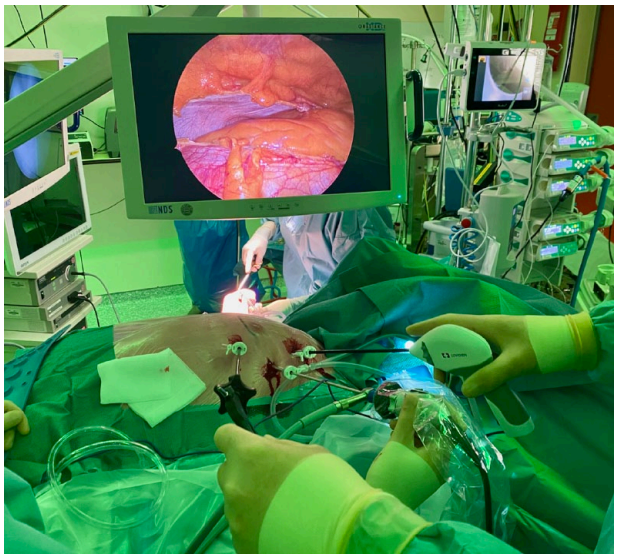

Fig. 1. Photograph of the procedural setup. Three 5 mm endoscopic ports are visible on the left side of the thorax. A 5 mm zero-degree endoscopic camera was used. The pericardium was opened to identify the coronary targets. During this procedure, simultaneous endoscopic radial artery harvesting was performed for multivessel grafting. Informed consent of the patient was obtained prior to publication.

concomitant cardiac procedures were excluded. All included procedures were performed by one of the authors (F.A.). Patients requiring either single or multiple bypass grafts were analyzed. The data were collected in a prospective registry. The study was approved by the local medical ethics committee, which waived the need for informed patient consent (W23.029).

Endo-CAB: Description of Operative Technique

All procedures were performed under general anesthesia in a supine position. Patients received arterial and central venous lines and standard endotracheal tube. Through the endotracheal tube, a selective endobronchial blocker (Teleflex, Wayne, PA, USA) was placed to facilitate unilateral ventilation. A pillow was placed underneath the left scapula to elevate the left hemithorax.

A 5 mm endoscopic port was placed at the third intercostal space at the midaxillary line, and a capnothorax was created (8 to 12 mm Hg). A 5 mm zero-degree 2-dimensional camera was introduced (Karl Storz GmbH, Tuttlingen, Germany). During LIMA harvest, both lungs were ventilated. Two additional 5 mm endoscopic ports were placed at the second and fourth intercostal space at the anterior axillary line. This setup is demonstrated in Figure 1. Standard long-shafted video-assisted thoracic surgery instruments and the Ligasure Maryland device (Medtronic, Dublin, Ireland) were used. First, the pericardium was opened anteriorly to the left phrenic nerve, and the coronary targets were identified. Afterward, the LIMA was harvested. The endothoracic fascia was incised and removed, and the LIMA was harvested with its adjacent veins (semi-skeletonized fashion), proximally until the level of the phrenic nerve and distally until its bifurcation. LIMA side branches were ligated either with electrocautery or with the Ligasure device. After harvesting the entire length of the LIMA, heparin was administered with an aimed activated clotting time of >300 seconds. Two minutes after heparin administration, the distal LIMA was clipped using titanium clips (Endo Clip, Medtronic) and divided. The place of the minithoracotomy was marked above the coronary target using a transthoracic needle (usually the third or fourth intercostal space). The intrathoracic pressure was released to identify the position of the heart in the absence of a capnothorax. The endoscopic ports were removed, and unilateral lung ventilation was initiated. The minithoracotomy was created with use of a soft tissue retractor (Alexis, Applied Medical, Rancho Santa Margarita, CA, USA). With assistance of epicardial stabilizing systems, the coronary targets were stabilized (Octopus Nuvo, Medtronic; Acrobat-I, Getinge, Göteborg, Sweden). All procedures were performed off pump and coronary arteries shunted during the anastomosis. After completion of the anastomosis, protamine was administered. Transit time flow measurements (TTFM) were performed to access graft function (Medistim, Oslo, Norway). A 28 Fr chest tube was placed in the left pleural cavity. Local anesthetic (ropivacaine) was administered at 3 intercostal levels. The pericardium and intercostal space were closed. The skin was closed with an intradermal suture.

Table 1. Patient Characteristics.

	$N = 80$
Male	64 (79)
Age, years	66 ± 9
Length, cm	174 ± 9
Weight, kg	82 ± 16
Hybrid coronary revascularization	17 (21)
Single-vessel procedure	65 (80)
Diagonal-LAD jump graft	14 (17)
Multivessel procedure	17 (21)
Urgent surgery	31 (38)
Left ventricular function	
Good	70 (86)
Moderate	8 (10)
Poor	3 (4)

Abbreviation: LAD, left anterior descending.
Data are presented as mean ± SD or *n* (%).

Data Collection and Statistics

Total procedure time and time from incision start until heparin administration were registered, as documented in our electronic anesthesia records. The latter was defined as total LIMA harvest time, and data were analyzed from all patients. Total

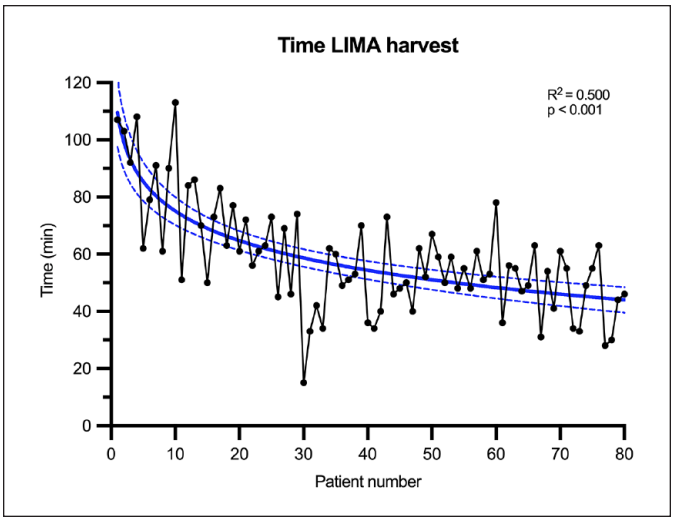

Fig. 2. Plot of the procedure times until complete harvest of the LIMA in consecutive patients. Each dot represents an individual patient. A logarithmic regression line with the 95% confidence interval is presented with a blue line. LIMA, left internal mammary artery.

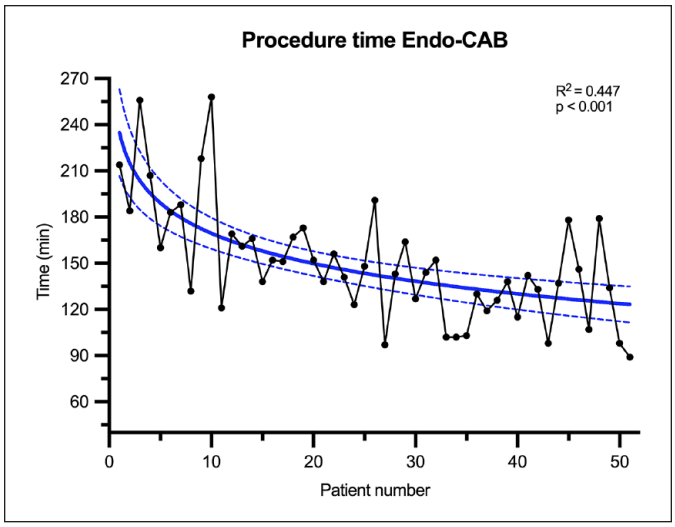

Fig. 3. Plot of the total procedure times for the Endo-CAB procedures with left internal mammary artery to left anterior descending artery. Each dot represents an individual patient. A logarithmic regression line with the 95% confidence interval is presented with a blue line. Endo-CAB, endoscopic coronary artery bypass.

procedure times were analyzed only from single-vessel Endo-CAB procedures (without diagonal jump grafts, multivessel revascularization, or concomitant procedures) for standardization purposes.

The data were analyzed by IBM SPSS Statistics for Windows, Version 29 (IBM Corp, Armonk, NY, USA). The results for continuous variables are illustrated in mean ± standard deviation and categorical variables in number (%). Logarithmic regression analysis was used to analyze the learning curves based on surgical time. These curves were plotted with 95% confidence intervals for both LIMA harvest and total Endo-CAB procedure times. An alpha level of <0.05 was considered statistically significant.

Results

In total, 80 LIMA grafts were harvested. Baseline parameters are presented in Table 1. The mean procedure time until heparin administration after complete LIMA preparation was 58 ± 19 min, ranging from 15 to 113 min. Figure 2 shows a statistically significant learning curve pattern for the LIMA harvesting time ($Y = 109 - 14.9*\log(x)$, $P < 0.001$). Intrathoracic adhesions were present in 2 patients, but after thoracoscopic adhesiolysis, the Endo-CAB procedure could still be performed. No damage to the LIMA occurred requiring conversion to sternotomy.

In total, 51 single-vessel Endo-CAB LIMA to left anterior descending artery procedures were analyzed. The mean procedure time was 150 ± 39 min. These procedure times also significantly decreased with experience, as demonstrated in Figure 3 ($Y = 227 - 24.4*\log(x)$, $P < 0.001$). There were no postoperative revisions for bleeding. The mean LIMA flow measured with TTFM was 41 ± 25 mL, the pulsatility index was 3.0 ± 1.2, and the diastolic blood flow was 71% ± 8%.

Discussion

In this paper, we described our experience with total thoracoscopic (nonrobotic) LIMA harvest for Endo-CAB procedures, using commonly available thoracoscopic instruments. We observed a steep learning curve in both LIMA harvest times and total procedure times. After skin incision, the time until heparin administration ranged between 30 and 60 min, with total procedure times around 120 min. Our experience was that thoracoscopic LIMA harvest was safe, reproducible, and had satisfactory procedure times. We believe that the presence of a robotic system is not required for a minimally invasive coronary program and more patients might benefit from endoscopic coronary surgery using thoracoscopic LIMA harvesting techniques.

Our purpose in coronary artery bypass surgery is to offer a safe, simple, and reproducible revascularization strategy. During Endo-CAB surgery, careful harvesting of the mammary artery is an important part of the procedure. Different approaches have been described in the literature for LIMA harvest, with each technique having benefits and drawbacks.

1. Direct, nonthoracoscopic harvesting offers the advantage of using routine surgical equipment combined with a specially designed retractor.[5,6] Proximal mammary artery harvest can be challenging, and the retractor is more traumatic to the chest wall.

2. Thoracoscopic LIMA harvest offers the advantage of excellent intrathoracic view, making the mammary artery and its side branches clearly visible on the entire length. This may be even further improved using 3-dimensional thoracoscopy. Trauma to the chest wall is minimal, as only three 5 mm ports are placed. During the harvest, the surgeon has tactile feedback from the thoracoscopic instruments, avoiding excessive force to the chest wall or mammary artery. Our experience concurs with prior publications that it is a safe and efficient technique with a steep learning curve.[7–9]
3. Robotic LIMA harvest is an elegant technique as well. It offers a great intrathoracic (3-dimensional) view with proper ergonomics for the surgeon on the console. The average reported harvest times are around 40 to 50 min, and it might facilitate convenient harvesting of the right internal mammary artery as well, since the very proximal part is quite challenging thoracoscopically.[6,10–12] However, it requires larger thoracic ports (8 to 12 mm) compared with the endoscopic technique with lack of tactile feedback.[13] Increased torque on the intercostal space or pressure on the LIMA or its side branches is not directed to the surgeon. Furthermore, limited availability and increased expenses can limit its more widespread implementation.

We believe that with endoscopic techniques, more patients could benefit from minimally invasive coronary surgery.

Conclusions

Total thoracoscopic (nonrobotic) LIMA harvest is an efficient technique with a steep learning curve. This procedure is safe with satisfactory procedure times, and routine thoracoscopic instruments can be used. We believe that a robotic system is not a necessity for a minimally invasive coronary program, and more patients might benefit from these procedures using endoscopic techniques.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

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