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Assessing the Learning Curve of the Minimally Invasive Direct Coronary Artery By-pass Technique

Eyüp Murat Kanber[1], Mehmet Köseoğlu[2], Mazlum Şahin[3]

[1]*Private Clinic, Clinic of Cardiovascular Surgery, İstanbul, Turkey*
[2]*University of Health Sciences Turkey, Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, Clinic of Anesthesia and Reanimation, İstanbul, Turkey*
[3]*Haliç University Faculty of Medicine, Avcılar Hospital, Department of Cardiovascular Surgery, İstanbul, Turkey*

Abstract

Objective: To clarify the effect of the learning curve (LC) on minimally invasive direct coronary artery by-pass (MIDCAB) outcomes for the first time.

Methods: Patients who underwent MIDCAB were enrolled in this study. The patients' characteristics were recorded prospectively. A 75 patients were divided into three groups, with the first 25 patients undergoing MIDCAB in group 1 and the last 25 patients undergoing MIDCAB in group 3.

Results: Comparison of the groups revealed that the operation time significantly decreased after 50 cases (p=0.003). Duration for access to the pericardium was similar between groups (p=0.094), but duration for preparing vessels progressively decreased from group 1 to group 3 (p=0.001). In addition, anastomosis duration significantly decreased in group 3 (p=0.005). In addition, the hospitalization time was significantly shorter in group 3 (p=0.018). The complication rate was significantly lower in group 3 and group 2 than in group 1 (p=0.030). Additionally, major cardiovascular and cerebrovascular events (MACCE) in the first postoperative year was detected in 20% of patients in group 1 and 8% of patients in group 2 and group 3, and the statistical difference was significantly better in favour of group 2 and group 3 (p=0.043).

Conclusion: The present study is the first to define the LC for MIDCAB, and we achieved significantly lower blood loss within 24 h after operation and lower complication rates after 25 cases, and perioperative transfusion rate, operation time, and hospitalization period were significantly decreased after 50 cases. Moreover, the number of MACCEs in the first postoperative year was significantly lower after 25 cases.

Keywords: Achievement, coronary artery by-pass, complications, learning curve

INTRODUCTION

The minimally invasive direct coronary artery by-pass (MIDCAB) technique was developed for cardiac by-pass surgery to reduce the morbidity and mortality associated with conventional coronary by-pass grafting (CABG) and to prevent the negative effects of sternotomy (1). Yang et al. (2) compared 126 patients who underwent MIDCAB and CABG at a 1:1 ratio, and the authors found significant reductions in blood transfusion and hospital stay duration in favour of the MIDCAB group without any negative impact on success. In another study, Repossini et al. (3) aimed to show the efficiency and safety of MIDCAB by analyzing long-term results and found a patency rate of 96.8% using coronary angiography in ten-year follow-ups. Despite its proven efficacy, the relative technical difficulty of MIDCAB precludes its widespread use in some centers.

The learning curve (LC) is accepted as the number of surgeries a surgeon must perform to achieve acceptable success and complication rates (4). Defining the LC for each procedure is important for predicting how many cases residents should perform before becoming specialists or how many cases the surgeon

Address for Correspondence: Eyüp Murat Kanber, Private Clinic, Clinic of Cardiovascular Surgery, İstanbul, Turkey
Phone: +90 532 282 24 96 **E-mail:** em.kanber.cvs@gmail.com **ORCID ID:** orcid.org/0000-0003-0123-0409

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should perform with clinical supervision before performing the surgery on their own. It is wellknown that each procedure has its own difficulty and LC. Baytaroglu and Sevgili (5) investigated LC for percutaneous thrombosectomy in the management of lower extremity deep vein thrombosis, and the authors achieved a satisfactory success rate after 20 cases. In another study, Shen et al. (6) evaluated LC for vena cava thrombectomy due to renal tumors, and bleeding and postoperative complications were significantly decreased after 40 cases.

Although previous studies have shown the efficiency and safety of MIDCAB and investigated the LC for some cardiovascular surgeries, to our knowledge, no research has focused on the LC of MIDCAB. In this study, we aimed to clarify the effect of LC on MIDCAB outcomes for the first time.

METHODS

This study was conducted from June 2019 to January 2022, in accordance with Helsinki universal declaration of human rights. An informed consent form was obtained from all patients, and the study was approved by the Bezmialem Vakıf University Local Ethic Committe (meeting decision no: 2019/127). The purpose of the study was achieved when 75 procedures were performed. Patients who underwent MIDCAB because of ischemic coronary artery disease were enrolled in the study. All MIDCAB procedures were performed by one cardiovascular surgeon (Mazlum Şahin), who had the experience of more than 1,000 CABG surgeries. Additionally, the surgeon who performed all procedures had completed a three-month scholarship program and two-day experimental animal course on MIDCAB surgery. Indications for MIDCAB are similar to those for CABG, and the main purpose of MIDCAB is to provide left ventricle anterior wall vascularization using the left internal mammillary artery (LIMA) as the left anterior descending (LAD) artery graft. The presence of left subclavian artery occlusion and cardiogenic shock are accepted as absolute contraindications for MIDCAB. In addition, patients aged 18 years with a history of thoracotomy and chest operation, and patients with calcified LAD with diameter <15 mm were excluded from the study. The other exclusion criteria were the presence of morbid obesity, history of CABG surgery, and history of radiation therapy for the chest.

Patient characteristics including age, gender, body mass index (BMI), comorbidities, preoperative left ventricular ejection fraction (LEVF), severity of heart failure according to the New York Heart Association, myocardial infarction (MI) history, and number of lesions were recorded. In addition, the procedure was divided into three parts (access the pericardium, LIMA harvesting, and anastomosis), and the durations for each part of the operation and total operation time were noted. Moreover, the presence of perioperative blood transfusion, conversion to sternotomy, intensive care unit stay, hospital stay period, presence of postoperative pleural effusion, blood loss in 24th hour after operation, requirements for inotropic agents, complications including pneumothorax, subcutaneous emphysema, respiratory infection, wound infection, need for dialysis, atrial fibrillation, transfusion requirement, and mortality were recorded. Lastly, major cardiovascular and cerebrovascular events (MACCE) including cardiac death, non-cardiac death, MI, cerebrovascular accident, and target vessel revascularization were noted.

MIDCAB Surgical Technique

A standardized technique was used for each patient, and all operations were performed in the supine position with left chest elevation between 30 and 45 degrees. Access was obtained from 2 to 3 cm below the nipple with 5-6 cm incision through the 4th or 5th left intercostal area. The procedure is performed through a 5 cm left anterior thoracotomy located one-third medial and two-thirds lateral to the midclavicular line. The lower third of LIMA is harvested using a standard rib spreader, which allows better visualization of the distal LIMA segment. The entire length of LIMA was harvested using a Thoralift (Autosuture; US Surgical Corp, Norwalk, Conn). The LIMA was then harvested was dissected, LAD was identified, and anastomosis was performed. An end-to-end anastomosis with 7-0 or 8-0 polypropylene is performed between LIMA and LAD, preferably using a shunt. Blood flow was checked with a Doppler flow probe after opening the clamp on LIMA. A single drain was placed into the left pleural cavity, and the thoracotomy incision was closed in layers (7).

A 75 patients were divided into three groups, with the first 25 patients undergoing MIDCAB in group 1 and the last 25 patients undergoing MIDCAB in group 3. The three groups were compared according to patient preoperative characteristics, operative and postoperative results, and one-year follow-up outcomes.

Statistical Analysis

Statistical Package for the Social Sciences version 26 (SPSS IBM Corp., Armonk, NY, USA) was used for statistical analysis. The distribution of parameters was evaluated by the Shapiro-Wilk test. Continuous parameters were compared using the Kruskal-Wallis test, and continuous variables were described using median (interquartile range). If there was a significant difference between the groups, Tamhane's T2 test was used for post hoc analysis. The relationship between categorical variables was evaluated using the chi-square test and Fisher's exact test. The level of statistical significance was taken as $p<0.05$.

RESULTS

In total, 75 patients were included in the study, with 25 patients in each group. The mean age, gender ratio, mean BMI, presence of hypertension, diabetes mellitus, and chronic kidney disease rates were similar between groups (p=0.700, p=0.927, p=0.595, p=0.846, p=0.948, and p=0.869, respectively). In addition, preoperative LEVF was 58% in group 1, 57% in group 2, and 59% in group 3 (p=0.592). The preoperative characteristics of patients are summarized in Table 1.

Comparison of the groups revealed that operation time significantly decreased after 50 cases (205 minutes in group 1, 187 min in group 2, and 153 min in group 3, p=0.003). The duration for access to the pericardium was similar between groups (p=0.094), but the duration for LIMA harvesting progressively decreased from group 1 to group 3 (p=0.001). In addition, the anastomosis duration significantly decreased in group 3 (27 minutes in group 1, 24 min in group 2, and 22 min in group 3, p=0.005). No perioperative transfusion was required in group 3 (p=0.025). In addition, the hospital stay time was significantly shorter in group 3 than in groups 1 and 2 (p=0.018) (Table 2).

Postoperative blood effusion and requirements for inotropic agents were comparable between groups (p=0.507 and p=0.653). Blood loss in the first 24 h significantly decreased after 25 cases (639 mL in group 1, 485 mL in group 2, and 366 mL in group 3, p=0.007). Additionally, the complication rate was 28% in group 1, 12% in group 2, and 12% in group 3, and the complication rate was significantly lower in group 3 and group 2 compared with group 1 (p=0.030). The types of complications are presented in Table 3. Additionally, MACCE in the first postoperative year was detected in 20% of patients in group 1 and 8% of patients in groups 2 and 3, and a statistical difference was significantly better in favour of groups 2 and 3 (p=0.043). The types of MACCE are listed in Table 4.

DISCUSSION

The LC is considered as the number of cases that the surgeon should perform until the surgeon achieves competence to perform that particular surgery. Every procedure has a unique LC and it is crucial to define the LC of any procedure to ensure that the surgeon gains competence and the right to perform the procedure. Previous studies have focused on LC of different surgeries in the cardiovascular field, but to our knowledge, none of these studies have investigated the LC of MIDCAB. For the first time, our study showed that blood loss within 24th hours after operation and complication rates were significantly decreased after 25 cases, and perioperative transfusion rate, operation time, and hospital stay period were significantly decreased after 50 cases. Moreover, the number of MACCEs in the first postoperative year was significantly reduced after 25 cases.

The main goal of MIDCAB is to provide appropriate revascularization of the myocardium and ensure the patency of cardiac vessels. The correlation between LC and success was analyzed for different procedures in different medical disciplines. In a study that investigated LC for obstructed brain vessel

Table 1. Comparison of demographic characteristics of patients between groups

	Group 1 (n=25)	Group 2 (n=25)	Group 3 (n=25)	p value
Age (years)*	63.0 (57.0-69.0)	66.0 (58.5-69.0)	63.0 (56.5-68.0)	0.700
Gender Male Female	 20 (80.0%) 5 (20.0%)	 19 (76.0%) 6 (24.0%)	 19 (76.0%) 6 (24.0%)	0.927
BMI (kg/m^2)*	27.0 (23.5-31.5)	28.0 (25.0-34.0)	26.0 (22.5-32.0)	0.595
Hypertension	16 (64.0%)	14 (56.0%)	15 (60.0%)	0.846
Diabetes mellitus	13 (52.0%)	13 (52.0%)	14 (56.0%)	0.948
Chronic kidney disease	3 (12.0%)	3 (12.0%)	2 (8.0%)	0.869
Smoking	10 (40.0%)	8 (32.0%)	15 (60.0%)	0.121
Preoperative LVEF (%)*	58.0 (48.5-65.5)	57.0 (49.0-63.0)	59.0 (49.5-65.5)	0.592
NYHA classification Class 1 Class 2 Class 3 Class 4	 11 (44.0%) 9 (36.0%) 4 (16.0%) 1 (4.0%)	 10 (40.0%) 9 (36.0%) 5 (20.0%) 1 (4.0%)	 12 (48.0%) 8 () 3 () 2 ()	0.974
MI history	12 (48.0%)	7 (28.0%)	8 (32.0%)	0.297
Number of lesions	2.0 (2.0-3.0)	2.0 (1.5-3.0)	2.0 (1.0-3.0)	0.317

*Median (IQR), BMI: Body mass index, LVEF: Left ventricular ejection fraction, NYHA: New York Heart Association, MI: Myocardial infarction, IQR: Interquartile range

angiographic recanalization in acute stroke, the authors stated that 50 cases were necessary to achieve a satisfactory success rate (8). In another study, the success rate of percutaneous thrombectomy for lower extremity deep vein thrombosis significantly increased after 20 cases (5). However, none of these studies discussed the effect of LC on follow-up results. In this study, the patency rates of the groups were comparable. However, the MACCE in the first postoperative year significantly decreased after 25 cases. We believe that the improvement in surgical technique contributes to this outcome.

Achieving myocardial repercussion with minimal complications is critical for the treatment of MIDCAB. Complication rates following MIDCAB have a wide range due to the lack of standardized definition of complications, some surgeons not reporting non-serious complications or the focus only on MIDCAB success in some articles. Schauer et al. (9) investigated the role of LC in obesity surgery and concluded that the complication rate decreased by half after the first 100 cases. In another paper, Kempton et al. (10) stated that 40 procedures were sufficient to bring the complication rates to the desired level in shoulder arthroplasty. However, Baytaroglu and Sevgili (5) did not find any relationship between LC and the complication rate in percutaneous thrombosectomy for lower extremity deep vein thrombosis management. In this study, we observed significantly lower complication rates after 25-50 cases and 50-75 cases compared with the first 25 cases.

Table 2. Comparison of intraoperative and postoperative data between groups

	Group 1 (n=25)	Group 2 (n=25)	Group 3 (n=25)	p value
Operation time (min)* Reach the pericardium LIMA harvesting Anastomosis	205.0 (179.5-245.0)[a] 28 (22.0-30.5) 58 (52.5-76.0)[a] 27.0 (22.0-28.5)[a]	187.0 (159.5-221.5)[a] 27 (22.5-33.0) 56 (48.5-60.0)[b] 24.0 (18.5-28.0)[a]	153.0 (133.5-195.0)[b] 24 (28.0-33.0) 46 (39.5-54.5)[c] 22.0 (19.0-24.0)[b]	**0.003** 0.094 **0.001** **0.005**
Perioperative transfusion*	1.0 (0.5-2.0)[a]	1.0 (0-2.0)[a]	0 (0-1.0)[b]	**0.025**
Conversion to sternotomy	1 (4.0%)	1 (4.0%)	-	0.598
ICU stay (hours)*	41.0 (22.0-66.0)	17.0 (6.0-53.0)	30.0 (5.0-59.5)	0.136
Hospital stay (days)*	10 (6.5-14.0)[a]	9 (6.0 -20.0)[a]	6 (4.0-11.0)[b]	**0.018**
Hospital mortality	1 (4.0%)	-	-	0.363

Lower-case letters are used to identify the group that makes the difference. The same letters (such as [a-a]) indicate that there is no difference, different letters (such as [a-b]) indicate that there is a difference. *Median (IQR), ICU: Intensive care unit, IQR: Interquartile range, min: Minimum

Table 3. Comparison of postoperative complication data between groups

	Group 1 (n=25)	Group 2 (n=25)	Group 3 (n=25)	p value
Postop pleural effusion (mL)*	871.0 (431.0-1222.0)	654.0 (468.5-1125.5)	609.0 (438.0-1073.5)	0.507
Blood loss at 24 hour (mL)*	639.0 (472.0-716.0)[a]	485.0 (261.5-605.5)[b]	366.0 (258.0-577.5)[b]	**0.007**
Needs inotropic agents	5 (25.0%)	3 (15.0%)	3 (15.0%)	0.653
Complications Subcutaneous emphysema Respiratory infection Wound infection Need for dialysis	7 (28.0%)[a] 3 (12.0%) 2 (8.0%) 1 (4.0%) 1 (4.0%)	3 (12.0%)[b] 1 (4.0%) 1 (4.0%) 1 (4.0%) -	3 (12.0%)[b] 2 (8.0%) - 1 (4.0%) -	**0.030**

Lower-case letters are used to identify the group that makes the difference. The same letters (such as [a-a]) indicate that there is no difference, different letters (such as [a-b]) indicate that there is a difference. *Median (IQR), IQR: Interquartile range

Table 4. Comparison of patients who developed major adverse cardiovascular and cerebrovascular events in the first postoperative year between groups

	Group 1 (n=25)	Group 2 (n=25)	Group 3 (n=25)	p value
MACCE[#] Cardiac death Non-cardiac death MI CVA TVR	5 (20.0%)[a] 1 (4.0%) 1 (4.0%) 2 (8.0%) 1 (4.0%) 2 (8.0%)	2 (8.0%)[b] 1 (4.0%) - 1 (4.0%) - 1 (4.0%)	2 (8.0%)[b] 1 (4.0%) - 1 (4.0%) - 1 (4.0%)	**0.043**

[#]Some patients developed more than one event at the same time. The term complications indicate the number of patients who developed complications. Lower-case letters are used to identify the group that makes the difference. The same letters (such as [a-a]) indicate that there is no difference, different letters (such as [a-b]) indicate that there is a difference. MACCE: Major adverse cardiovascular and cerebrovascular events, MI: Myocardial infarction, CVA: Cerebrovascular accident, TVR: Target vessel revascularization

Previous reports have found significant correlations between prolonged operation time and undesired anaesthetic events, increases in procedure cost, and morbidity. In the first stages of LC, the operation time may be longer than expected due to reasons such as not knowing the surgical instruments adequately, the team not working in full harmony, and not knowing how to act in case of possible mishaps. Sahan et al. (11) analyzed the impact of surgical volume on operation time in renal stone surgery, and the authors found continuous decreases in operation time from 1st-15th case and from 46th-60th case. In another study, Baytaroglu and Sevgili (5) investigated the LC of percutaneous thrombosectomy for treating lower extremity deep vein thrombosis, and the operation time for percutaneous thrombosectomy significantly decreased until the 40th case and then reached a plateau. In this study, we found a significant decrease in the operation time after the 25th case. When we examined the duration of operation sections, the duration for LIMA harvesting continuously decreased from 1st-25th cases to 50th-75th cases, and the duration of anastomosis significantly decreased after 50 cases.

Study Limitations

Our study has some limitations. As all procedures have specific LC, each surgeon has his/her own LC. Therefore, our results should be confirmed by further studies. Second, we did not analyze the long-term results of MIDCAB; thus, we did not evaluate the effect of LC on the long-term outcomes of MIDCAB, which may be investigated in further studies. Moreover, we focused on success, complications, and operative and postoperative parameters in the present study without analyzing patient quality of life. The impact of LC on the quality of life of patients who underwent MIDCAB could be the subject of another paper. Lastly, we did not evaluate the correlation between the LC of MIDCAB and the cost-effectiveness of MIDCAB.

CONCLUSION

This study is the first to define the LC for MIDCAB, and we achieved significantly lower blood loss within 24 h after operation and lower complication rates after 25 cases, and the perioperative transfusion rate, operation time, and hospital stay period were significantly decreased after 50 cases. Moreover, the number of MACCEs in the first postoperative year was significantly lower after 25 cases.

Ethics

Ethics Committee Approval: Bezmialem Vakıf University Local Ethic Committe (meeting decision no: 2019/127).

Informed Consent: Informed consent form was obtained from all patients

Peer-review: Internally and externally peer reviewed.

Authorship Contributions

Surgical and Medical Practices: E.M.K., Concept: E.M.K., Design: E.M.K., Data Collection or Processing: M.K., Analysis or Interpretation: M.K., Literature Search: E.M.K., M.Ş., Writing: E.M.K., M.Ş.

Conflict of Interest: No conflict of interest was declared by the authors.

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