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RESEARCH ARTICLE

Impact of minimally invasive multivessel coronary artery bypass grafting on early outcome

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Abstract:

Objective: To appreciate the potential value of minimally invasive multivessel coronary artery bypass surgery (MICS-CABG) in order to discuss the uptake and early outcomes of this procedure through left anterior thoracotomy. ***Patients and Methods:*** This study included 30 patients with ischemic heart disease of both genders who were operated upon through MICS-CABG at Kasr Alainy Hospitals in the period between February 2023 and 2024. ***Results:*** Mean age in studied patients was 57.67±7.42 years in which 28 patients were males and 2 patients were females. Mean cross clamp time was 109.64±23.16 minutes and the Mean bypass time was 175.23±30.84 minutes. Regarding the use of inotropes among studied patients, 12 (40.0%) patients were off inotropes, Noradrenaline was needed in 13 patients, Adrenaline was needed in 11 patients, While Nitroglycerin was needed in 4 patients. Mean pain score was 2.30±0.79. Postoperative superficial wound infection was reported in 2 (6.7%) patients. No postoperative need for IABP, re-exploration, or postoperative mortality were reported in the study. Mean time of Intubation was 5.60±0.77 hours and the Mean duration of ICU stay was 2.63±0.49 days. Mean duration of hospital stay was 5.90±0.92 days. ***Conclusion:*** Based on our findings, patients who underwent MICS-CABG in Kasr Alainy Hospitals had favorable outcome without postoperative need for IABP or re-exploration. In addition, MICS- CABG had early recovery times (Mechanical ventilation, ICU and hospital stay) with low pain scoring giving the opportunity for early return to work and normal daily activities. The wound appeared cosmetically better with low incidence of infection been reported. Therefore, MICS-CABG is safe in properly selected patients with low risk profile and more studies with large cohort are needed.

Keywords: Minimally invasive; MICS-CABG; left anterior thoracotomy; early outcome.

INTRODUCTION

Coronary artery bypass grafting (CABG) has been the surgical treatment of choice for patients with coronary artery disease until its inception in 1964. Cardiopulmonary bypass (CPB) and median sternotomy are two of the main drawbacks of conventional CABG. Both of these procedures increase the risk of wound problems and other complications related to cardiopulmonary bypass (such as coagulopathy as well as organ affection). Endovascular therapies and better medical care have made invasive surgery a thing of the past, giving patients a safe alternative. [1]

Therefore, techniques for coronary artery disease surgery have been refined to offer the same therapeutic benefit with fewer side effects, improved patient comfort, quicker recovery, less intrusive alternatives that meet patients' expectations, and the best potential results. The procedure's success is contingent upon the right patient selection in addition to the learning curve and technological familiarity. Results have to be similar with the long-established methods of traditional coronary artery bypass grafting in regard to both early morbidity and mortality and long-term outcomes; it is not enough that the technique be feasible. [1]

Since its introduction, the invasiveness of coronary artery bypass grafting (CABG) on the chest has not diminished. There is currently no procedure that can reduce the invasiveness of CABG without compromising the essential principles of full revascularization or its broad applicability for multivessel or diffuse CAD; the only exceptions to this are a handful of specialty procedures. Simply put, this method seeks to achieve the same results as the conventional full sternotomy procedure while reducing the incidence of wound infection, transfusion, postoperative pain, recovery time, and sternal dehiscence. [2.3]

The purpose of this research is to demonstrate the benefits of MICS-CABG, a procedure for minimally invasive coronary artery bypass grafting. In addition, the article delves into the technical details, patient selection, resource use, and early short-term outcomes of minimally invasive coronary artery bypass grafting.

Patients and methods
Study Design
Type and Setting of the Study

This retrospective-prospective (ambispective) analysis was performed in compliance with human-studies guidelines during the period between February 2023 and February 2024. Thirty patients of various ages and genders underwent MICS-CABG at Kasr-Alainy Hospitals.

Patient selection, technical considerations, perioperative and postoperative results, and the benefits of MICS-CABG were among the topics covered in this study, which sought to address the adoption and initial results of minimally invasive multivessel revascularization.

Ethical Aspects

Good guidelines for clinical practice, relevant local regulatory requirements, and the Declaration of Helsinki's ethical principles were all adhered to throughout the course of this study. The local Ethical Committee of the Institute of Postgraduate Studies, Cairo University, approved the study protocol. Written informed consent was obtained from all participants, including the following points:

- The aim, procedures, and duration of the study were explained in a simple manner.
- Patients' ability to receive medical treatment was unaffected by their decision to decline participation.
- There was no penalty or requirement for a justification for patients to withdraw from the research.
- Confidentiality of all patient data and results was strictly preserved.

Subjects and Sampling

Thirty patients undergoing MICS-CABG represented the target population. Patients were selected according to the following criteria:

Inclusion Criteria:

- Diagnosed with coronary artery multivessel disease planned for MICS-CABG
- Good left ventricular (LV) function
- No comorbidities such as previous stroke, severe carotid stenosis, or femoral vessel disease
- Adequate pulmonary function
- No significant ascending aortic calcification

Exclusion Criteria:

- Concomitant valvular heart disease requiring surgical intervention
- Single-vessel disease requiring single bypass graft
- Re-do operations (e.g., previous left thoracotomy)
- Poor LV contractility (ejection fraction <35%)
- Urgent surgery with ongoing ischemia or hemodynamic compromise
- Inability to tolerate single-lung ventilation

Methodology

A. Preoperative Data

Every patient was evaluated thoroughly, which included:

History & Clinical Examination:

- Information about the individual, including their name, age, sex, place of residence, and profession
- Medical history: claudication, lower limb discomfort, renal dialysis, A-V fistula creation, prior limb fracture and fixation, caesarean section, valve replacement, myocardial infarction (MI), percutaneous coronary intervention (PCI) history, blood disorders, smoking, chronic obstructive pulmonary disease (COPD)
- Medical history: previous illnesses, chest pain, comorbidities
- Medication history: prior cardiac medications
- PCI history: initially successful then failed or initially failed

Radiological Investigations:

- Electrocardiogram (ECG): identifying ischemic or myocardial infarction (both new and old), cardiac enlargement or contraction, and arrhythmias
- An echocardiogram can detect valve abnormalities, segmental wall movements, and cardiac contractility.
- Angiogram: a tool for planning coronary artery bypass grafting
- Carotid and lower limb arterial duplex
- Pulmonary function test (PFT)
- Chest CT: assessment of aortic calcification

Laboratory Investigations:

- Complete blood count (CBC)
- Coagulation profile and INR
- Bleeding profile
- Evaluations of renal and liver function
- Hypersensitive troponin (Hs-Tn), cardiac enzymes CK and CK-MB
- HbA1c, fasting, and postprandial blood sugar levels

B. Operative Data

- Surgical approach: left anterior thoracotomy (4th or 5th intercostal space)
- Peripheral cannulation (femoro-femoral) if on-pump
- Number and site of grafts
- Proximal anastomosis site (LIMA-LAD, SVG-Aorta, Radial-Y LIMA)
- Harvesting technique (direct vision or tunnel technique for SVG)
- Total operative time
- Cardiopulmonary bypass (CPB) time
- Cross-clamp time
- Need for inotropic support

C. Postoperative Data

- Vital stability
- ECG changes
- Echocardiography follow-up
- Low cardiac output syndrome

- Need for intra-aortic balloon pump (IABP)
- Weaning of inotropes
- Mechanical ventilation duration (time of intubation)
- Consciousness assessment (GCS)
- Re-exploration (for bleeding or graft revision)
- ICU and hospital stay
- Pain score
- Mortality

Patient Selection & Preparation

While choosing a patient, we took their coronary anatomy, surgical exposure, and clinical stability into account.

Routine preoperative preparations included a detailed history of previous chest surgeries and diseases. Preoperative CT angiography or Doppler ultrasonography ensured peripheral vessels were safe for cannulation.

- Incorporating the preoperative CT scan into the sterile field, the left or right femoral area was prepared.
- The left lung was isolated using double-lumen endotracheal intubation.
- Hemodynamic monitoring and the exclusion of cardiac anomalies were both accomplished with the use of transesophageal echocardiography (TEE).
- The patient was lying semi-supine with their right leg bent at the waist, with a range of 25° to 35°.
- The left arm was raised as a flannel roll was inserted from the left shoulder to the hip.
- Skin was marked pre-incision for possible emergency enlargement **(Figure 1).**

Figure 1. Before staining the subject, markings for the intercostal gaps and the position of the incisions can be seen, and there is a double-lumen endotracheal tube. (own photoshoot taken in OR)

Surgical Procedure

A left anterior thoracotomy incision, 5 to 7 cm in length, was made through the fourth intercostal space along the left midclavicular line. In women, a sub-mammary crease incision was preferred for better cosmetic outcomes.

Care was taken during rib exposure to avoid injury to the internal mammary vessels while opening the intercostal space. The incision allowed entry into the pleural space one intercostal space cephalad to the apex of the heart.

The Thoragate™ rib-up retractor (GEISTER®, Tuttlingen, Germany) was then placed in the intercostal space **(Figure 2A)** to facilitate exposure and access for the procedure.

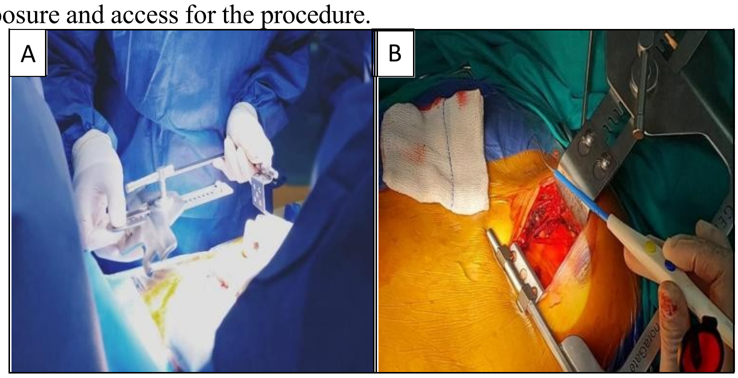

Figure 2. The set up for LIMA harvesting (A) shows the LIMA bed exposure with the Thoragate retractor being positioned in the left side of the patient. (B) LIMA, left internal mammary artery harvested skeletonized through a small thoracotomy. (own photoshoot taken in OR)

The left internal mammary artery (LIMA) was harvested skeletonized from a lateral approach under direct vision using electrocautery diathermy **(Figure 2B).**

After administering heparin to obtain an ACT of 280 or above, the next step was to do distal control and cut the LIMA. At this point, the assisting physician starts harvesting the saphenous vein or radial graft utilizing the bridging procedure under direct vision. **(Figure 3).**

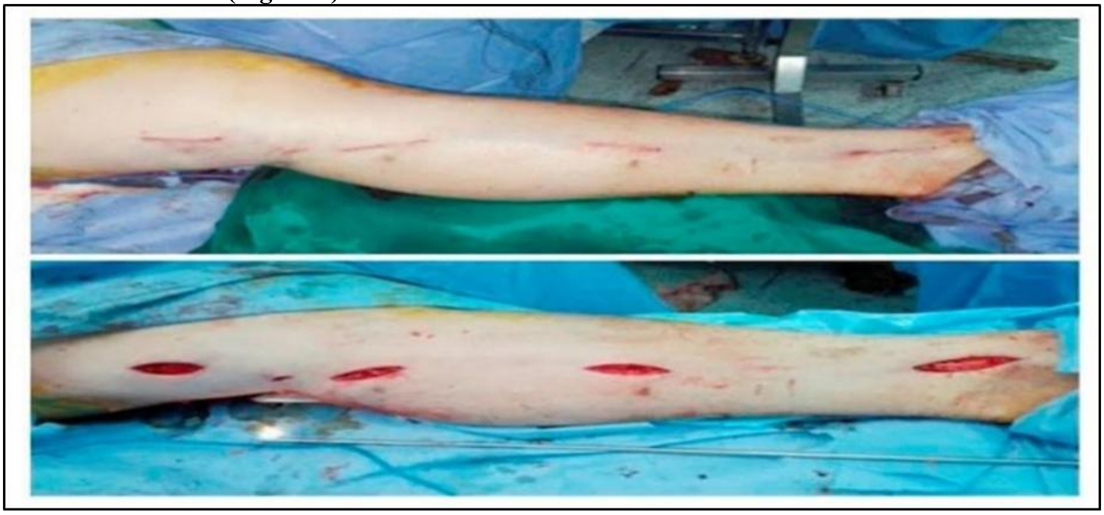

Figure 3. Bridging technique for saphenous vein harvesting (own photoshoot in OR)

In circumstances when the patient was on the pump, a 2.5 cm oblique groin incision was made to access the femoral artery and vein. At the conclusion of graft harvesting, patients were maintained normothermic after heparin administration and CPB was started. At a level two or three centimeters above the phrenic nerve, with an inverted "T" extension toward the apex, the pericardium was opened in a parallel fashion to the LAD. The aorta was pushed closer using traction stitches, and then 6 mm Dacron tape was used to wrap it, allowing for the insertion of the cardioplegia cannula, which was fastened using purse-string sutures. Isothermic blood cardioplegia was provided after each distal anastomosis or every 30 minutes, and a Chitwood-type DeBakey cross-clamp was introduced through the left second intercostal gap. **(Figure 4).**

Figure 4. Isothermal blood cardioplegia, administered via the ascending aorta following Chitwood cross-clamping, causes the heart to halt in diastole. (exclusive photo session conducted in the operating room)

The ascending aorta and inferior vena cava can be encircled with Dacron tapes to help suspend the heart and expose target lesions for anastomosis.

Distal anastomoses were then done using conventional equipment and a 7-0 or 8-0 Prolene suture. The aortic side clamp is applied after the ascending aorta is pulled downward using Dacron tape to close it to the incision site for proximal anastomosis. During aortic cross clamping or, as is typically done with a 6-0 Prolene suture, a side biting clamp was put through the incision under direct view to complete the proximal anastomosis. **(Figure 5).**

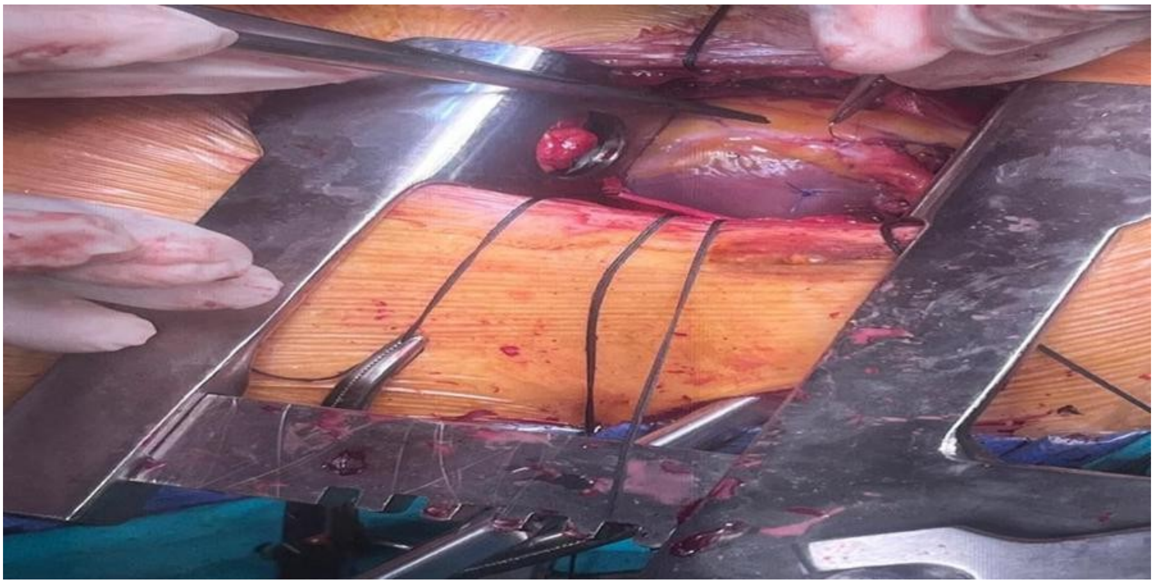

Figure 5. The proximal anastomosis may be observed directly (own photoshoot taken in OR)

The clamp was then removed followed by placing the temporary pacing wires on the right ventricle and then weaning off CPB gets started.

An injection of protamine is given. Following that, decannulation was initiated. While inflating the left lung, specialists made sure the grafts and chest tubes were properly positioned in the left pleural space via the sixth or seventh intercostal gap, and they monitored the process closely.

Reapproximation of the intercostal gap and closure of the subcutaneous tissue and skin are the final goals of the treatment. For the best possible pain management right after surgery, intercostal nerve blocking was a possibility.

The anastomoses were performed using the Octopus (Medtronic, Inc.) in circumstances when the pump was not present. It is recommended to raise the blood pressure. Systolic blood pressure between 140 and 150 mm Hg was our target. In the event that the patient has stable hemodynamics and sufficient coronary exposure, we proceeded to the distal anastomosis. For coronary bleeding control, a temporary silastic suture was placed around the coronary artery to be grafted or an intracoronary shunt can be placed and the suture around the coronary may be taken out, proximally to the planned arteriotomy. This occludes the coronary for a short period and allows better visualization. A blower was also used to improve visibility of the coronary. Then, the Distal anastomosis was performed with a 7-0 or 8-0 Prolene suture with standard instruments.

Using a 6-0 Prolene suture, the proximal anastomosis was performed under direct view, following the conventional procedure. The equipment used for the ascending aorta exposure is removed when the hemostasis of the proximal and distal anastomosis has been verified.

Study outcome:

1. The primary end-point of this study is the assessment of early outcomes MICS-CABG, including the adverse effects such as mortality and morbidity in the form of neurological impairment during follow-up, complications such as renal insufficiency, tracheostomy, failure of weaning from ventilator and re-exploration due to bleeding or revision of grafts, need for IABP, wound complication.
2. Hemodynamic stability
3. ICU & hospital stay
4. Incidence of early diagnosed MI in first 30 days postoperative
5. Incidence of early cerebrovascular accidents in first 30 days postoperative

Statistical Analysis

In the present study, 30 patients with ischemic heart disease of both genders who were candidates for MSCS-CABG operated upon at Kasr Alainy Hospitals, were included.

A. Preoperative data: -

1. Demographic and anthropometric data of studied patients:

Mean age in studied patients was 57.67±7.42 years ranging between 44 and 68 years. Among our studied patients, 28 (93.3%) patients were males and 2 (6.7%) patients were females. Mean BMI was 23.30±4.09 kg/m2 ranging between 18 and 33 kg/m2

Table 1: Demographic and anthropometric data in studied patients

Age (years)	**Mean±SD**	57.67±7.42
	(Range)	(44.00 - 68.00)
Gender Count (%)	**Male**	28 (93.3%)
	Female	2 (6.7%)
Body mass index (kg/m^2)	**Mean±SD**	23.30±4.09
	(Range)	(18.00 - 33.00)

2. Distribution of risk factors in studied patients

Diabetes mellitus was reported in 16 (53.3%) patients, hypertension was reported in 20 (66.7%) patients, smoking was reported in 16 (53.3%) patients, grade 1 nephropathy was reported in 3 (10.0%) patients, hepatic diseases was reported in 3 (10.0%) patients, and hypothyroidism in 1 patient (3.3%).

Table 2: Distribution of risk factors in studied patients

Risk Factors	Count (%)
Diabetes mellitus	16 (53.3%)
Hypertension	20 (66.7%)
Smoking	16 (53.3%)
Renal diseases	3 (10.0%)
Hypothyroidism	1 (3.3%)
Hepatic diseases	3 (10.0%)

B. Operative data: -

Surgical details in studied patients

All studied patients underwent left anterior thoracotomy on double lumen anesthesia. 22 (73.3%) patients were done on pump with aortic cross clamp and 6 (20.2%) patients were done on pump assisted beating heart with femoro-femoral cannulation while 2 (6.5%) patients were done off-pump.

Proximal anastomosis site was the aorta in 26 (86.6%) patients and LIMA in 4 (13.4%) patients.

LIMA was anastomosed to LAD in all cases. In 12 (40%) patients, radial artery was anastomosed distally to the diagonal or oblique marginal branches and then was anastomosed proximally either to LIMA as Y / T graft or directly over the aorta.

SVG was used in the remaining 18 (60%) patients and was anastomosed distally to the D1, OM, Ramus or PDA branches then proximally to the ascending aorta. (Table), (Figures)

There was no need for conversion to median sternotomy in our patients.

Table 3: Surgical approach, cannulation, proximal anastomosis site in studied patients

		Count (%)
Approach	**Left anterior thoracotomy**	30 (100.0%)
Cannulation	**Off-pump**	2 (6.5%)
	Femoro-femoral	28 (93.5%)
Proximal anastomosis site	**Aorta**	26 (86.6%)
	LIMA	4 (13.4%)

Intraoperative time parameters in studied patients

Mean total operative time in studied patients was 4.87±0.76 hours ranging between 4 and 6 hours. Mean cross clamp time was 68.12±18.67 minutes ranging between 50 and 90 minutes. Mean bypass time was 85.23±16.84 minutes ranging between 75 and 180 minutes.

Table 4: Intraoperative time parameters in studied patients

	Mean±SD	(Range)
Total operative time (hours)	4.87±0.76	(4.00 - 6.00)
Bypass time (min)	85.23±16.84	(75.00 - 180.00)
Cross clamp time (min)	68.12±18.67	(50.00 - 90.00)

C. Postoperative data: -

Postoperative details

Early postoperative vitals data in studied patients

All studied patients were vitally stable and transferred to the ICU with good hemodynamics. Regarding the use of inotropes among studied patients, 6 (20.0%) patients were off inotropic support, Noradrenaline was needed in 13 (43.4%) patients, Adrenaline was needed in 11 (36.6%). Vasodilators (e.g., Nitroglycerin) were needed in 4 patients.

Table 4: Early postoperative vitals data in studied patients

Postoperative		**Count (%)**
Inotropes	**Noradrenaline**	13 (43.4%)
	Adrenaline	11 (36.6%)
	Off inotropes	6 (20.0%)

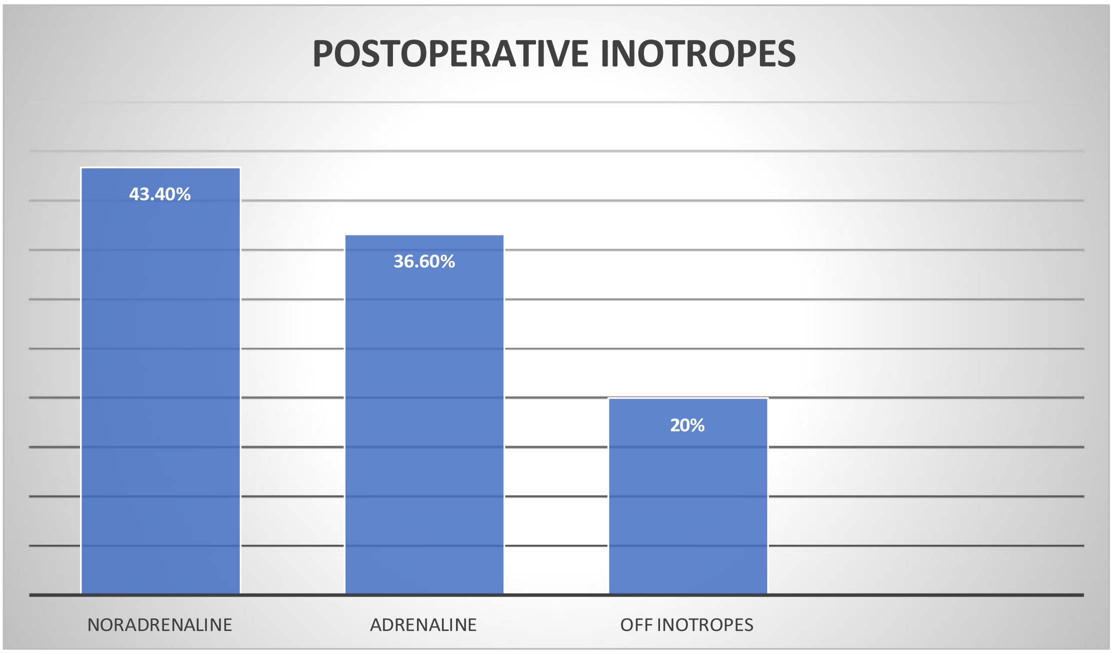

Figure 6: Postoperative inotropes in studied patients

Postoperative outcome in studied patients

Postoperative superficial wound infection was reported in 2 (6.7%) patients. There was no postoperative need for IABP, re-exploration, or postoperative mortality was reported in the present study. In 22 patients, blood transfusion was needed.

Table 5: Postoperative outcome in studied patients

	Count (%)
Superficial wound infection	2 (6.7%)
Need for blood transfusion	22 (73.3%)

DISCUSSION

Since it allows for optimal exposure of all cardiac tissues, median complete sternotomy (MS) continues to be the conventional surgical method for coronary artery bypass grafting (CABG). It makes it possible to palpate and visually inspect coronary arteries to find good distal targets, which improves transplant placement and surgical results. [4].

Despite advances in percutaneous coronary interventions (PCI), CABG continues to be the gold standard for myocardial revascularization, offering superior long-term results and clinical durability. However, conventional MS is associated with significant complications, including superficial and deep sternal wound infections, mediastinitis, and sternal instability. These complications not only increase morbidity and hospital stay but also negatively impact patients' quality of life. Consequently, minimally invasive CABG

(MICS-CABG) has emerged as a less invasive alternative, aiming to achieve the benefits of complete revascularization while minimizing surgical trauma and associated complications [5,6].

The technically demanding procedure of MICS-CABG has been around since the 1960s. Despite the fact that technology has made the treatment easier, only few facilities throughout the globe regularly conduct MICS-CABG or minimally invasive direct coronary artery bypass (MIDCAB). [5,7].

The growing demand for minimally invasive procedures has stimulated research on their feasibility and outcomes in patients with coronary artery disease (CAD). MICS-CABG is performed via a small intercostal incision, reducing invasiveness while allowing patients to achieve earlier return to physical function. Nevertheless, its use in multi-vessel disease is limited due to inherent surgical challenges, including difficult visualization, restricted operative space, and the need for specialized instruments [8].

Although previous studies have evaluated graft patency and long-term outcomes of MICS-CABG, there is comparatively less literature detailing technical challenges, intraoperative management strategies, and practical modifications required to optimize outcomes. MICS-CABG, also referred to as total coronary revascularization via left anterior thoracotomy (TC RAT), has demonstrated safety, efficacy, and reproducibility, allowing complete anatomical revascularization with excellent clinical outcomes and promising angiographic graft patency rates [9].

The current study included 30 patients with ischemic heart disease of both genders who underwent multi-vessel MICS-CABG at Kasr Al-Ainy Hospitals. Under general anesthesia, all patients had a left anterior thoracotomy. A double-lumen endotracheal tube was inserted to allow for selective single-lung breathing during LIMA harvesting. Patients with pre-existing pulmonary illness may not be able to tolerate single-lung ventilation. In such circumstances, intermittent full-lung ventilation with a reduced tidal volume, an increased respiratory rate, and the use of wet gauze to maximize exposure and keep oxygen saturation over 90% may be necessary. [10,11].

Techniques such as the straining pericardium method have been reported to maintain continuous lung ventilation during surgery but require additional incisions to externalize pericardial sutures [10].

Cannulation was predominantly femoro-femoral in 28 (93.5%) patients, with 2 (6.5%) undergoing off-pump surgery. On-pump approaches facilitated heart manipulation and exposure of the ascending aorta for proximal anastomoses, while on-pump arrested heart cases utilized cardioplegia and aortic cross-clamping. Off-pump MICS-CABG is advantageous for patients with severely atherosclerotic or calcified ascending aortas, reducing risks of embolism, neurological complications, and aortic injury [12]. Proximal anastomosis is technically challenging due to the depth and angle, requiring long instruments, such as needle holders, ring tissue forceps, and knot pushers, to facilitate secure suturing [12].

Vein-to-aorta anastomosis is critical in achieving complete grafting, replicating the success of conventional OPCABG [11]. In this cohort, proximal anastomoses were performed on the aorta in 26 (86.6%) patients and on LIMA in 4 (13.4%) patients. Techniques to improve exposure included pericardial retraction, placement of gauze, and left postero-inferior displacement of the right ventricular outflow tract using an epicardial stabilizer, although this may transiently elevate pulmonary pressures [11].

The number of grafts per patient ranged from 2 to 3, with grafts including SVG, LIMA, and radial artery targeting the LAD, OM, RCA, and PDA. Comparable studies reported mean graft numbers of 3.19 ± 0.75 in Liu et al., 2021 [11] and 2.6 ± 0.5 in Snegirev et al., 2020 [9]. Mean total operative time was 4.87 ± 0.76 hours, mean cross-clamp time 68.12 ± 18.67 minutes, and mean bypass time 85.23 ± 16.84 minutes, slightly shorter than previous reports of CPB times (101 ± 18 minutes) [9].

MICS-CABG avoids sternotomy-related complications, with postoperative superficial wound infections occurring in only 2 (6.7%) patients in this study. There were no cases of deep wound infection or need for re-exploration, consistent with other studies reporting minimal surgical site complications. No postoperative IABP support was required, and there was no mortality, aligning with previous reports of 0–1% in-hospital or 30-day mortality [13].

Postoperative outcomes demonstrated advantages of MICS-CABG in terms of early recovery. Mean mechanical ventilation time was 5.60 ± 0.77 hours, shorter than reported in other studies (e.g., Bakthavachalam and Yusuf, 2024: 7.87 ± 3.22 hours) [14].

ICU stay averaged 2.63 ± 0.49 days, consistent with other reports (Bakthavachalam and Yusuf, 2.29 ± 1.18 days; Ling et al., 2016: 24.27 ± 17.85 hours). Mean hospital stay was 5.90 ± 0.92 days, similar to Snegirev et al., 6.7 ± 1.3 days, and shorter than conventional OPCABG, reflecting earlier ambulation, reduced pain, preserved sternal integrity, and fewer ventilator-associated complications [15,16].

MICS-CABG demonstrates safety even in high-risk patients, including those with severe LV dysfunction (EF <30%), high EuroSCORE, or reduced eGFR, with outcomes comparable to conventional OPCABG [72]. Multiple studies report low perioperative mortality, high graft patency, and superior long-term survival compared to sternotomy CABG [17]. Hospital stay, ICU stay, and ventilation times are consistently shorter with MICS-CABG, underscoring its patient-centered advantages.

Advances in surgical instruments, visualization techniques, and minimally invasive platforms continue to enhance reproducibility, safety, and outcomes in MICS-CABG. Future improvements are required to make it a standard practice worldwide [18–19].

The present study reinforces that MICS-CABG is a feasible, safe, and effective approach for multi-vessel revascularization with minimal morbidity and mortality while promoting faster recovery and reduced hospital resource utilization.

Conclusion

Based on our findings, patients who underwent MICS-CABG in Kasr Alainy Hospitals had favorable outcome without postoperative need for IABP or re-exploration. In addition, MICS- CABG had early recovery times (Mechanical ventilation, ICU and hospital stay) with low pain scoring giving the opportunity for early return to work and normal daily activities. The wound appeared cosmetically better with low incidence of infection been reported. Therefore, MICS-CABG is safe in properly selected patients with low risk profile and more studies with large cohort are needed.

Recommendations

More prospective studies on larger scales are required to evaluate the uptake and early outcomes of minimally invasive multi-vessel revascularization.

More long-term follow-up studies (≥5 years) are needed to assess outcomes such as MACCE incidence and the need for repeat revascularization.

More comparative studies are required to evaluate outcomes of minimally invasive multi-vessel revascularization across different hospitals.
More comparative studies are needed to compare outcomes between minimally invasive and open multi-vessel revascularization.

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