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Exploring the Efficacy of Minimally Invasive Cardiac Surgery in a Single-Center Cohort of 100 Coronary Artery Bypass Grafting Cases

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ABSTRACT

Background: Our study emerges against the backdrop of ongoing advancements in cardiac surgery, specifically within the realm of minimally invasive approaches for coronary artery bypass grafting (CABG). As medical practices continually refine their techniques for improved patient outcomes, a critical examination of the efficacy of these procedures becomes imperative.

Aim and Objectives: To investigate the evolving landscape of cardiac surgical methodologies, focusing on the intricacies and ramifications of minimally invasive cardiac surgery.

Materials and Methods: This retrospective study analyzes outcomes in the initial 100 patients undergoing Minimally Invasive Coronary Artery Bypass Grafting (MICS CABG) at our institution from January 2021 to December 2022. Conducted by a single experienced surgeon, the study documents early MICS CABG experiences and compares them with conventional CABG via sternotomy. Inclusion criteria encompassed MICS suitability, while exclusion criteria considered factors like valvular pathology and previous cardiac surgery.

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Results: Patients, averaging 45.3 years old, showed a male predominance (2.45:1) and common cardiovascular risk factors, including 44% with diabetes, 65% with hypertension, and 28% with chronic obstructive pulmonary disease. Coronary artery disease distribution was 37% single vessel disease, 41% double vessel disease, 22% triple vessel disease, and 26% left main coronary artery disease. The pre-op ejection fraction was 37±7.8%, and 9% experienced cardiogenic shock. Intra-operatively, 97% of surgeries were off-pump, with a mean incision size of 7.2±0.5 cm. Postoperatively patient's demonstrated quick recovery with no significant complications. Our study affirms that MICS CABG demonstrates comparable comfort for the operator when addressing multivessel disease, akin to single- or double-vessel cases.

Conclusion: Our findings parallel the observation that, in certain instances, there may be a temporary increase in operating time for MICS CABG compared to sternotomy. However, consistent with the cited example, our study reveals no significant difference in postoperative adverse events between MICS and sternotomy. Importantly, our investigation supports the advantages of MICS over sternotomy in immediate postoperative aspects, including reduced ventilation time, mean drainage, postoperative discomfort, and shorter intensive care unit and hospital stays.

Keywords: minimally invasive cardiac surgery, coronary artery bypass grafting (CABG), postoperative outcomes

INTRODUCTION

Minimally Invasive Coronary Artery Bypass Grafting (MICS CABG) represents a paradigm shift in cardiac surgery, introducing a less invasive approach associated with compelling benefits, including reduced morbidity, expedited recovery, and heightened patient satisfaction.[1,2] Among the various applications of MICS, coronary artery bypass grafting (CABG) represents a critical frontier, offering the potential for reduced postoperative morbidity and quicker recovery.[3] However, despite the growing interest in MICS-CABG, comprehensive data on the initial experiences with this approach still need to be available.

Traditional CABG has long been associated with significant morbidity, prompting the exploration of alternative approaches, such as MICS, to mitigate complications and enhance overall patient outcomes.[4,5] The decision to adopt MICS-CABG is often influenced by the desire to minimize surgical trauma, decrease hospitalization duration, and facilitate a faster return to normal daily activities.[6]The adoption of MICS-CABG is often driven by the aspiration to minimize surgical trauma, reduce hospitalization duration, and expedite the resumption of normal daily activities.[7]

This study addresses this gap by presenting insights from the early experiences involving the first 100 patients who underwent minimally invasive cardiac surgery for coronary artery bypass grafting. By analyzing patient demographics, procedures, and immediate outcomes, we aim to offer insights for refining and adopting minimally invasive techniques in coronary revascularization. The overview of our institution's experience provides a straightforward look at the feasibility, safety, and efficacy of MICS-CABG in coronary artery bypass grafting.

MATERIAL AND METHODS

This retrospective observational study systematically explores the outcomes of the initial 100 patients undergoing MICS CABG at our institution from January 2021 to December 2022. The study, conducted by a single experienced surgeon, aims to document the early experiences of MICS CABG comprehensively and includes an unpaired comparison with patients undergoing conventional CABG via median sternotomy during the same period.

Inclusion and Exclusion Criteria:

Inclusion criteria encompassed patients willing to undergo MICS CABG, with target coronary arteries deemed suitable for left thoracotomy. Preoperative assessments included coronary angiography, ECG, chest radiograph, 2D echocardiogram, and relevant blood tests. Exclusion criteria comprised patients with valvular pathology, congenital abnormalities, diffuse coronary artery disease with poor distal runoff, ejection fraction below 24%, history of previous cardiac surgery, acute/recent MI within the last seven days, peripheral vascular disease, smokers, history of tuberculosis or interstitial lung diseases, spine deformities like scoliosis or kyphosis, and recent history of stroke. Relative contraindications for MICS, such as obesity and large breasts in females, were considered on a case-by-case basis.

Procedural Details:

In our study of 100 patients undergoing Minimally Invasive Coronary Artery Bypass Grafting (MICS CABG) with a comprehensive 2-year follow-up, stringent inclusion criteria were applied. The preoperative assessment involved arterial blood gas (ABG) analysis, confirming values of $PaCO_2$ <50 mmHg and PaO_2 >65 mmHg for room air, crucial for determining eligibility for one-lung ventilation.[8] Patients unable to meet these criteria on ABG were excluded from the trial.

The patient's positioning played a pivotal role in preventing visual-related procedural complications. The standard posture included both upper limbs in adduction and the left chest elevated by 30 degrees. Midline and intercostal spaces (ICS), particularly the third through fifth, were delineated after draping, with the fifth ICS often used for thoracic entry based on cardiac apex level on chest radiograph. Incisions for males were made below the left nipple, and for females, half an inch below the left sub-mammary crease.

Utilizing MICS tools like the chest spreader and internal mammary artery arc retractor, the procedure involved early harvesting of the left internal mammary artery using monopolar cautery. Distinct conduits such as the left radial artery (78%) and great saphenous vein (8%) were employed, with the radial artery being the preferred second channel. Three myocardial stabilizers, including the traditional Octopus® Evolution AS, were chosen based on visibility and target vessel positioning. Sequential grafting included the prior descending artery, diagonal, ramus, obtuse marginal, and left anterior descending artery (LAD). Distal anastomoses were completed using 7-0 polypropylene sutures.

The procedure, conducted off-pump in our standard protocol, only involved cardiopulmonary bypass in one patient out of 100 due to intraoperative hemodynamic instability. Post-surgery,

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patients underwent follow-up management, including intravenous (IV) diltiazem infusion for those with radial artery grafts. Pain management procedures included IV fentanyl infusion and intravenous paracetamol administration, followed by oral paracetamol. Pain severity was monitored using the Wong-Baker Facial pain rating scale during the first three days post-surgery. Patients were prescribed dual antiplatelet drugs (aspirin 150 mg and clopidogrel 75 mg) upon discharge, along with a lipid-lowering prescription. Patients receiving radial artery conduits were advised to take 90 mg/day of oral diltiazem for 12 months post-surgery. Outpatient follow-ups involving 2D echocardiography, electrocardiography (ECG), and chest radiography were scheduled at one week, three months, and then every six months for 2 years. For 12 months, they have recommended chest radiography, 2D echocardiography, ECG, and computed tomography coronary angiography.

The statistical analysis was performed using the software SPSS ver. 25, including descriptive statistics, mean, standard deviation, median, interquartile range, and summarized continuous variables. In contrast, categorical variables were presented as frequencies and percentages. The Mann-Whitney U and chi-square tests were used for nonparametric and categorical variables. Primary endpoints, such as operating time and early postoperative parameters, underwent detailed statistical analysis to discern significant differences between MICS CABG and sternotomy cases.

RESULTS

Between 2021 and 2023, our facility performed 300 cardiac operations, with 100 of them (33.3%) being MICS CABG through left anterior thoracotomy, and the remaining 200 conducted sternotomy. The average age of the patients was 45.3 years, spanning from 24 to 69 years. The male-to-female ratio was 2.45, indicating the cohort's predominance of male patients. Diabetes was observed in 44% of the cases with hypertension, a common cardiovascular risk factor, was present in 65% of the patients. Additionally, 28% of the patients had Chronic Obstructive Pulmonary Disease (COPD), emphasizing the impact of respiratory health on cardiovascular conditions.The prevalence of single vessel disease was 37%, double vessel disease was 41%, triple vessel disease was 22%, and left main coronary artery disease was observed in 26% of the cases. The preoperative health status of the patients, as indicated by the mean pre-op ejection fraction of 37±7.8%, provides insight into the cardiac function before intervention. Additionally, 9% of the patients experienced cardiogenic shock, underscoring the critical condition of a subset of individuals requiring immediate and intensive cardiac care. (Table 1) The Canadian Cardiovascular Society grading distribution is Grade I (1%), Grade II (6%), Grade III (75%), and Grade IV (18%). (Fig 1)

In our study (n=100), intra-operative characteristics of patients undergoing cardiac procedures revealed that 97% of surgeries were performed off-pump, with an average incision size of 7.2+0.5 cm. Left internal mammary artery conduits were used in 100% of cases, while radial conduits were utilized in 63% and saphenous vein conduits in 11%. Left Anterior Descending grafts were performed in all cases, along with other graft types such as diagonal (26%), ramus

(34%), obtuse marginal (39%), and posterior descending artery (69%). The average number of grafts was 2.61±0.9, and the ratio of intended grafts to perform was 149/122. The majority of cases involved the use of double grafts (64%), followed by single (25%) and triple grafts (11%). There was minimal conversion to sternotomy (1%) and re-exploration (1%), with no graft revisions reported. The mean procedure time was 135.41+30.79 minutes, and operative times varied for single, double, and triple grafts. (Table 2)

In our study (n=100), patients' postoperative characteristics revealed a mean ventilation duration of 6.25±1.45 hours, with a mean total drainage of 221±1.2 ml and an average of 2.56±0.7 blood transfusions. Patients demonstrated early mobilization, with a mean day out of bed at 1.57±0.7 days. There were no cases of acute renal failure, cardiac arrhythmias, stroke, readmission within 30 days, postoperative myocardial infarction, or deaths reported. The mean duration of ICU stay was 3.24±1.05 days, and the overall hospital stay averaged 5.1±0.84 days. The postoperative ejection fraction was 44.34±4.56%. Wound infections occurred in 3% of cases, with pain scores on the Wong–Baker Faces pain rating scale averaging 4.18±0.79 on postoperative day 1, 3.43±0.38 on postoperative day 2, and data missing for postoperative day 3. (Table 2)

Significant differences emerged in comparing MICS CABG (minimally invasive coronary artery bypass grafting) with sternotomy groups. MICS CABG patients, comprising 50 cases, demonstrated a younger mean age (45.3 vs. 61.68 years) and a higher sex ratio (2.45 vs. 2.15). Notably, the MICS CABG group had lower rates of diabetes (44% vs. 71.5%), hypertension (65% vs. 65.5%), COPD (28% vs. 50%), and chronic renal failure (4% vs. 4.5%). While the pre-op ejection fraction was slightly lower in the MICS CABG group, the post-op ejection fraction was comparable. Cardiogenic shock rates were similar (9% vs. 8.5%), with no occurrences of acute renal failure, arrhythmias, or stroke in the MICS CABG group.Regarding postoperative outcomes, MICS CABG patients experienced shorter ICU stays (3.24+1.05 days vs. 4.05±1.52 days) and hospital stays (5.1+0.84 days vs. 7.28±1.43 days). Rates of wound infections and postoperative myocardial infarction were lower in the MICS CABG group (3% vs. 3.5% and 0% vs. 1.5%, respectively). The MICS CABG group had fewer cases on the pump (3 vs. 22) and lower re-exploration rates (1 vs. 9), with comparable graft revision rates.

Regarding procedural aspects shown in Table 4, MICS CABG procedures exhibited less mean total drainage (221+1.2 ml vs. 249.76±44.25 ml) and fewer blood transfusions (2.56+0.7 vs. 4.05±0.57). Graft distribution differed, with more single grafts (25 vs. 23), comparable double grafts, and fewer triple grafts in the MICS CABG group. Operative times varied, with MICS CABG generally taking longer for two and three grafts but shorter for single grafts than sternotomy.

DISCUSSION

In our study, we investigated the intra-operative and postoperative characteristics of 100 patients undergoing cardiac procedures, with a specific focus on MICS CABG, in comparison to 200 patients undergoing sternotomy approaches. The analysis of our study revealed distinct

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differences between the two groups, shedding light on various parameters such as age, comorbidities, operative times, and postoperative outcomes.Our study examined the intra-operative and postoperative characteristics of patients undergoing cardiac procedures, specifically focusing on two distinct surgical approaches: MICS CABG and sternotomy.

In our comprehensive investigation of 100 patients undergoing cardiac procedures, with a specific focus on MICS CABG and sternotomy, we compared our findings with those from studies conducted by Ruel et al.[9], Guo et al.[10], and Solanki et al.[11] Commencing with the age of patients, our study revealed a median age range of 57.0 to 71.0 years, illustrating a diverse demographic seeking cardiac interventions. In comparison, Ruel et al.[9] reported a mean age of 64 ± 8 years, Guo et al.[10] included patients with a median age of 64.0 years, and Solanki et al.[11] reported a median age of 49.5 years. This showcases a spectrum of age distributions across the studies.[9,11,12]

Operatively, our focus on MICS CABG performed by a single surgeon in 91.8% of cases aligns with Guo et al.'s[10] extensive experience with this technique. In contrast, Ruel et al.[9] significantly emphasized off-pump surgeries, constituting 76% of their cases, highlighting a notable preference for this approach in their cohort. Solanki et al.[11] specifically examined the learning curve and results of the first 50 instances of MICS CABG at their facility, observing a significant decrease in operating time after the first 20 cases.Our study reported a median of 5.0 days concerning the duration of hospital stay, suggesting a reasonable recovery period post-MICS CABG. This aligns with Ruel et al.[9], where the median length of hospital stay was 4 days, indicating a consistent trend toward shorter hospitalization in both studies.[9,11]

Postoperatively, our investigation observed a low perioperative mortality rate of 0.2% and a 1.4% occurrence of major adverse cardiac or cerebrovascular events (MACCE) within 30 days. In contrast, Ruel et al.[9] reported no perioperative mortality, no conversions to sternotomy, and a 26% transfusion rate. Guo et al.'s[12] MIST trial primarily focus on quality of life assessment at 1 month postoperatively, introducing a unique perspective on early postoperative recovery. Solanki et al.[11] reported no conversions and no deaths, with notable advantages of MICS over sternotomy in immediate postoperative parameters such as ventilation time, mean drainage, postoperative discomfort, length of stay in ICU, and hospital.

Long-term outcomes from our study revealed favorable Kaplan-Meier estimates, with 80.0% freedom from MACCE and all-cause mortality at 10 years, showcasing the durability of MICS CABG in experienced hands. Guo et al.'s[12] extensive follow-up of 510 consecutive patients over a mean of 6.1 years demonstrated comparable long-term outcomes, affirming the sustained efficacy of MICS CABG. While providing short-term outcomes, Ruel et al.'s study9 presented an ongoing MIST trial that aims to contribute valuable insights into both early recovery and long-term outcomes. Solanki et al.'s [11] conclusion highlighted the feasibility of MICS CABG for multivessel disease once the learning curve is overcome, emphasizing its advantages over sternotomy in immediate postoperative parameters.

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Moreover, our commitment to minimizing invasiveness resonates with McGinn et al.'s [13] focus on a 4- to 6-cm left fifth intercostal thoracotomy. Their emphasis on excellent procedural and short-term outcomes, with only 7.6% of cases using cardiopulmonary bypass, supports our findings that MICS CABG is a safe and effective option. We observed comparable outcomes regarding operative times, suggesting that MICS CABG can make multivessel minimally invasive coronary surgery more widely available.

Davierwala et al.'s [14] extensive 20-year outcomes study with 2667 patients undergoing minimally invasive direct coronary artery bypass (MIDCAB) provides additional data. Our study's focus on postoperative outcomes aligns with their findings of excellent early and long-term outcomes, emphasizing the sustained safety and efficacy of MIDCAB. The constant in-hospital mortality reported by Davierwala et al.[14] over the 22 years despite worsening patient demographics complements our focus on long-term survival. Once the learning curve is overcome, we found that MICS CABG exhibits comparable advantages, demonstrating that MICS CABG can be performed for multivessel disease with the same comfort for the operator as for a single- or double-vessel disease. Marin-Cuartas et al.'s [15] overview of minimally invasive coronary artery surgery, including robotic and nonrobotic techniques, contributes a broader perspective on the evolution of these procedures. While our study specifically examines MICS CABG and sternotomy, it aligns with the shared goal of reducing invasiveness and enhancing patient outcomes. The consistent themes of safety, efficacy, and excellent outcomes across these studies[11,14,15] reinforce the importance of ongoing research to refine and expand the applications of minimally invasive approaches in cardiac procedures.

Our study aligns with Guo et al.'s [16] investigations involving 566 patients over 17 years, emphasizing the safety and durability of MICS CABG. Both studies[16] highlight the importance of thorough long-term assessments, with Guo et al. identifying correlates of mortality, including age and comorbidities. Guo et al.'s[16] 82.2% ± 2.6% 12-year survival echoes our findings, reinforcing that MICS CABG is a viable alternative to sternotomy with excellent short- and long-term outcomes, particularly for multivessel coronary disease. The minimal incidence of significant symptoms and incisional pain in both studies[16] underscores the favorable patient experiences associated with MICS CABG.

The evolution of MICS CABG over the past 25 years has witnessed substantial advancements, with refined techniques and reduced surgical trauma.[17] The review by Bonatti et al.[18] underscores the extensive progress, incorporating mini-incisions, beating heart surgery, sophisticated technology, and robotic assistance, resulting in an average of 1.3 grafts per patient and an operative time of approximately 3 hours and 42 minutes. The cumulative outcomes reveal a low hospital mortality rate of 1.0%, a stroke rate of 0.6%, and an overall favorable safety profile in 11,135 patients. Furthermore, Demirsoy et al.[19] contribute valuable insights into the feasibility and outcomes of multivessel MICS CABG in 230 patients. Their clinical experience, encompassing elective surgeries formultivessel coronary disease, demonstrates a mortality rate of 0.9%, no observed myocardial infarctions in the early postoperative period, and minimal

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complications, such as a low reoperation rate of 2.2% for postoperative bleeding. These findings affirm the safety and reproducibility of minimally invasive techniques, encouraging their routine application.

While our study provides crucial insights into intra-operative and postoperative characteristics of cardiac procedures, it has inherent limitations. The retrospective design may introduce biases, the sample size of 100 patients might limit generalizability, the focus on specific approaches may not represent all cardiac procedures, and the follow-up duration could restrict capturing long-term outcomes.

CONCLUSION

Our study into the comparison of MICS CABG procedures with traditional sternotomy approaches reveals a consistently low percentage, affirming the efficacy and feasibility of the MICS technique. The successful completion of multivessel bypass surgeries using MICS, following a brief learning curve, highlights its adaptability and competence. Notably, MICS CABG emerges as a more advantageous option for expeditious recovery and reduced hospital stay, maintaining comparable surgical times and postoperative outcomes to sternotomy. While our study focused on a two-year duration, the absence of long-term follow-up highlights an avenue for future research to enrich further our understanding of the sustained benefits of MICS CABG.

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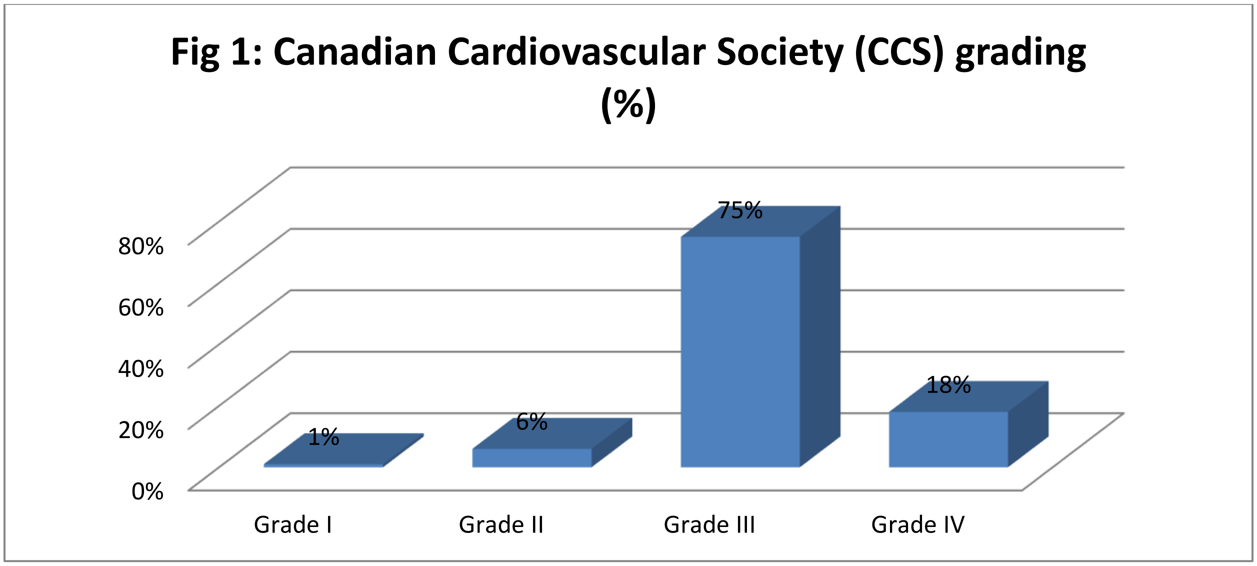

Table 1: Preoperative Characteristics of Patients

Characteristics	
Mean age (years)	45.3 (24-69)
Sex ratio	2.45
Diabetic (%)	44 (44%)
Hypertensive (%)	65 (65%)
Chronic Obstructive Pulmonary Disease	28 (28%)
Chronic Renal Failure	4 (4%)
Thyroid abnormality	12 (12%)
Smoking history	27 (27%)
Previous Percutaneous Transluminal Coronary Angioplasty	14 14%)
Previous Myocardial Infarction	22 (22%)
Unstable Angina	7 (7%)
Single vessel disease	37 (37%)
Double Vessel Disease	41 (41%)
Triple Vessel Disease	22 (22%)
Left Main Coronary Artery Disease	26 (26%)
Mean Pre-Op Ejection Fraction (%)	37 ± 7.8
Cardiogenic Shock	9 (9%)

Table 2: Intra-Operative Characteristics of Patients

Intra-operative patients Characteristics	(n=100)
On Pump	3 (3%)
Off Pump	97 (97%)
Average Incision Size (cm)	7.2±0.5
Left Internal Mammary Artery Conduits	100 (100%)
Radial Conduits	63 (63%)
Saphenous Vein Conduits	11 (11%)
Left Anterior Descending Graft	100 (100%)
Diagonal Graft	26 (26%)
Ramus Graft	34 (34%)
Obtuse Marginal Graft	39 (39%)
Posterior Descending Artery Graft	69 (69%)
Average No of Grafts	2.61±0.9
Ratio of intended grafts to performed	149/122
Single graft used	25 (25%)
Double graft used	64 (64%)
Triple graft used	11 (11%)
Left Internal Mammary Artery used as a sequence to diagonal and LAD	0
Conversion to Sternotomy	1 (1%)
Re-exploration	1 (1%)
Graft Revision	0
Mean Procedure time (min)	135.41±30.79
Mean operative time for single grafts (min)	125.55±23.12
Mean operative time for two grafts (min)	135.34±41.24
Mean operative time for three grafts (min)	145.45±23.56

Table 3: Postoperative Patient Characteristics

Postoperative characteristics (n=100)	
Mean Duration of Ventilation (hours)	6.25±1.45
Mean Total Drainage (ml)	221±1.2
Mean Blood Transfusion (n)	2.56±0.7
Mean Day of Mobilization out of Bed	1.57±0.7
Acute Renal Failure	0
Cardiac Arrhythmias	0
Stroke	0
The mean duration of ICU stay (day)	3.24±1.05

The mean duration of Hospital stay	5.1±0.84
Post of Ejection Fraction (%)	44.34±4.56
Readmission in 30 days	0
Postoperative MI	0
Deaths	0
Wound Infections	3 (3%)
Pain score: Wong–Baker Faces pain rating (0 to 10) (mean)	
Post-op day 1	4.18±0.79
Post-op day 2	3.43±0.38
Post-op day 3	Post-op day 3

Table 4: Parameter Comparisons between the MICS CABG and Sternotomy Groups at Baseline, During Surgery, and During Recovery

Parameter	MICS CABG (n=100)	Sternotomy (n=200)
Mean age (years)	45.3 (24-69)	61.68±9.67 (range 35-86)
Sex ratio	2.45	2.15
Diabetic (%)	44 (44%)	143 (71.5%)
Hypertensive (%)	65 (65%)	131 (65.5%)
Chronic Obstructive Pulmonary Disease	28 (28%)	50 (50%)
Chronic Renal Failure	4 (4%)	9 (4.5%)
Thyroid abnormality	12 (12%)	19 (9.5%)
Mean Pre-op Ejection Fraction (%)	37±7.8	43.13±10.66
Mean Post-op Ejection Fraction (%)	44.34±4.56	47.56±7.22
Cardiogenic Shock	9 (9%)	17 (8.5%)
Acute Renal Failure	0	3 (1.5%)
Cardiac Arrhythmias	0	23 (11.5%)
Stroke	0	1 (0.5%)
The mean duration of ICU stay (day)	3.24±1.05	4.05±1.52
The mean duration of Hospital stay	5.1±0.84	7.28±1.43
Wound Infection	3	7 (3.5%)
Postoperative MI	0	3 (1.5%)
Deaths	0	3 (1.5%)
On Pump	3	22 (11%)

Off Pump	97	178 (89%)
Re-exploration	1	9 (4.5%)
Graft Revision	0	7 (3.5%)
Mean Total Drainage (ml)	221±1.2	249.76±44.25
Mean Blood Transfusion (n)	2.56±0.7	4.05±0.57
One graft	25	23 (11.5%)
Two graft	64	53 (26.5%)
Three graft	11	124 (62%)
Mean operative time for single grafts (min)	125.55±23.12	104.55±16.77
Mean operative time for two grafts (min)	135.34±41.24	116.66±30.2
Mean operative time for three grafts (min)	145.45±23.56	127.88±20.53