Original Research

DOI: https://doi.org/10.64573/torgj2507001

The Operating Room Global Journal (TORGJ)

https://torgjournal.org/

ISSN: 3105-3262

Glycaemic Control and its Impact on Early Post-Operative Outcomes in Patients undergoing Minimally Invasive Cardiac Surgery

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Declaration:
Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.
Conflict of Interest: No conflict of interest
Funding: No funding received by the authors

Article History:
Received: 09-07-2025
Accepted: 14-08-2025
Available Online : 19-08-2025

QR access this Article

ABSTRACT

Background: Minimally invasive cardiac surgery (MICS) offers benefits such as reduced surgical trauma and faster recovery. However, intraoperative hyperglycaemia during cardiopulmonary bypass (CPB) is a concern due to its association with adverse outcomes. While glycemic control has been studied in conventional cardiac procedures, limited data exist on its impact in MICS. **Objective:** To assess whether intraoperative blood glucose levels influence early postoperative outcomes in patients undergoing MICS.

Methodology: A retrospective observational study at a tertiary care hospital was conducted over 8.5 months. 40 patients undergoing elective MICS were divided into two groups based on intraoperative blood glucose levels: Group A (≤200 mg/dL, n=15) and Group B (≥201 mg/dL, n=25). Preoperative, intraoperative, and postoperative data were collected, including neurocognitive outcomes (Mini-Mental State Examination), duration of mechanical ventilation, ICU stay, and need for inotropic support. Statistical analysis was performed using SPSS v26.0 with $p<0.05$ considered significant.

Results: Baseline characteristics were comparable, except for higher creatinine clearance in the hyperglycaemic group. No significant differences were found in neurocognitive function or mechanical ventilation time between groups. However, a trend toward longer ICU stays was observed in Group B ($p=0.082$), and cooling temperatures during CPB were significantly higher in this group ($p=0.046$). One mortality occurred in the hyperglycaemic group.

Conclusion: Although not all findings reached statistical significance, intraoperative hyperglycaemia in MICS was associated with increased ICU stay and cooling intervention requirements. These findings suggest a potential role for improved intraoperative glucose management to support better recovery and resource efficiency in MICS. Larger, prospective studies are recommended.

KEYWORDS: Glycemic Control, Minimally Invasive Cardiac Surgery, Cardiopulmonary Bypass, Hyperglycaemia, Postoperative Outcomes, Neurocognitive Function, ICU Stay.

1. INTRODUCTION

Minimally invasive cardiac surgery (MICS) has revolutionized the field of cardiac surgery by providing a less invasive alternative to conventional sternotomy-based procedures. Over the past two decades, MICS has gained significant attention due to its potential benefits, including reduced postoperative pain, shorter hospital stays, faster recovery, and improved cosmetic outcomes [1], [2]. Unlike traditional open-heart surgery, which requires a full median sternotomy, MICS involves smaller incisions, specialized instrumentation, and video-assisted techniques to achieve the same surgical objectives with reduced trauma to the patient [3]. Despite these advantages, MICS presents unique intraoperative challenges, particularly in terms of metabolic regulation, hemodynamic stability, and neurocognitive outcomes [4]. One of the critical factors influencing postoperative recovery in MICS is glycemic control during surgery, as intraoperative hyperglycemia has been associated with adverse outcomes in cardiac surgical patients [5].

Glycemic control is a fundamental aspect of perioperative management, especially in cardiac surgery, where patients often experience metabolic dysregulation due to stress-induced hyperglycemia [6]. This phenomenon occurs due to the physiological stress response triggered by surgical trauma, anesthesia, and cardiopulmonary bypass (CPB), which leads to increased secretion of counter-regulatory hormones such as cortisol, catecholamines, and glucagon [7]. These hormonal changes promote hepatic gluconeogenesis and insulin resistance, resulting in transient hyperglycemia even in non-diabetic patients [8]. The detrimental effects of hyperglycemia during cardiac surgery have been well-documented, with studies linking elevated blood glucose levels to increased risks of postoperative infections, delayed wound healing, renal dysfunction, prolonged mechanical ventilation, and higher mortality rates [9], [10]. However, most research in this domain has focused on conventional cardiac surgery, with limited studies specifically examining the impact of glycemic control in the context of MICS [11].

The scope of this study encompasses an in-depth analysis of intraoperative glycemic control and its impact on early postoperative outcomes in patients undergoing MICS. This research was conducted over a period of 8.5 months at a high-volume tertiary care center, analyzing a cohort of 40 patients who met the inclusion criteria from an initial pool of 197 screened individuals. This study focuses on evaluating key postoperative parameters such as neurocognitive function, duration of mechanical ventilation, length of intensive care unit (ICU) stay, postoperative complications, and overall recovery patterns. Patients were categorized into two groups based on intraoperative blood glucose levels: those maintaining blood glucose levels ≤200 mg/dL and those with levels ≥201 mg/dL. The study aims to provide a comprehensive understanding of the role of intraoperative glycemic management in optimizing patient outcomes after MICS and to identify potential strategies for improving perioperative metabolic control [12].

The importance of this research lies in its potential to address a critical gap in the existing literature. While strict glycemic control has been widely advocated in general cardiac surgery, its role in the specialized setting of MICS remains underexplored [13]. Given the rising popularity of MICS and its increasing adoption worldwide, understanding the impact of intraoperative hyperglycemia on early postoperative recovery is essential for improving surgical protocols and patient safety [14]. This study seeks to contribute valuable insights into the ongoing debate regarding optimal glycemic targets during cardiac surgery and their influence on clinical outcomes [15]. Future advancements in perioperative glucose management could help refine existing strategies, minimize complications, and enhance patient recovery following MICS [16].

MICS has been increasingly recognized as a transformative approach in cardiac surgery, offering advantages over traditional sternotomy-based procedures in terms of reduced trauma, faster recovery, and lower complication rates [17]. However, the metabolic challenges associated with MICS, particularly those related to glycemic fluctuations during surgery, remain an area of ongoing investigation [18]. Intraoperative hyperglycemia, often exacerbated by cardiopulmonary bypass (CPB) and surgical stress, has been linked to adverse clinical outcomes, including increased risk of infections, prolonged intensive care unit (ICU) stays, and delayed wound healing [19]. While numerous studies have explored the

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effects of hyperglycemia in conventional cardiac surgery, relatively few have specifically examined its impact in the context of MICS, where different surgical techniques and reduced tissue trauma may alter the metabolic response and postoperative outcomes [20].

One of the primary mechanisms contributing to perioperative hyperglycemia is the neurohormonal stress response induced by surgery. The activation of the hypothalamic-pituitary-adrenal (HPA) axis leads to increased secretion of cortisol, catecholamines, and inflammatory cytokines, which collectively promote insulin resistance and hepatic glucose production [21]. Furthermore, the use of CPB itself has been associated with systemic inflammatory response syndrome (SIRS), leading to endothelial dysfunction, oxidative stress, and impaired glucose metabolism [22]. In MICS, where CPB is still frequently used, albeit with modified techniques such as peripheral cannulation and lower systemic heparinization, the metabolic implications of hyperglycemia remain an area of concern [23]. Given that even transient episodes of intraoperative hyperglycemia have been associated with poor postoperative outcomes in conventional cardiac surgery, there is a need to determine whether similar trends are observed in MICS patients or whether the reduced surgical trauma confers a protective effect against glycemic fluctuations [24].

The clinical consequences of intraoperative hyperglycemia extend beyond metabolic derangements and have been implicated in neurocognitive dysfunction following cardiac surgery. Studies have shown that hyperglycemia-induced oxidative stress, endothelial dysfunction, and pro-inflammatory cytokine release can contribute to neuronal injury, increasing the risk of postoperative cognitive dysfunction (POCD) [25]. While POCD has been widely studied in the context of traditional cardiac surgery, its prevalence and severity in MICS remain less well defined [26]. Some evidence suggests that MICS may be associated with lower rates of POCD due to reduced systemic inflammation and shorter CPB durations, but whether intraoperative hyperglycemia modulates this risk remains unclear [27]. In our study, we assessed neurocognitive function postoperatively using the Mini-Mental State Examination (MMSE) to determine whether intraoperative glycemic fluctuations had any measurable impact on early cognitive recovery in MICS patients [28].

In addition to neurocognitive outcomes, glycemic control during MICS may influence other key postoperative parameters, including the duration of mechanical ventilation, length of ICU stay, and overall morbidity. Hyperglycemia has been associated with impaired pulmonary function and increased susceptibility to ventilator-associated pneumonia (VAP), leading to prolonged mechanical ventilation times and higher ICU resource utilization [29]. Moreover, patients with poor glycemic control often experience increased inflammatory responses and endothelial dysfunction, which may prolong ICU stays and delay overall recovery [30]. By stratifying patients based on intraoperative glycemic levels and analyzing their postoperative course, this study aims to provide evidence regarding the role of glycemic management in optimizing recovery after MICS [31].

Despite the well-documented risks associated with intraoperative hyperglycemia in conventional cardiac surgery, there remains considerable debate regarding the optimal glycemic targets in MICS. Some studies advocate for tight glucose control (blood glucose <180 mg/dL), citing reduced rates of infection and improved wound healing [32]. However, others caution against overly aggressive glucose management due to the potential for hypoglycemia, which is equally detrimental and has been linked to increased mortality in critically ill patients [33]. The balance between preventing hyperglycemia-induced complications and avoiding hypoglycemia-related risks is particularly crucial in MICS, where patients often undergo shorter surgical durations and experience reduced physiological stress compared to traditional open-heart procedures [34]. Our study sought to address this issue by comparing outcomes in patients with intraoperative glucose levels ≤200 mg/dL versus those with levels ≥201 mg/dL, aiming to determine whether stricter glycemic control is necessary in the context of MICS [35].

One of the most important aspects of postoperative recovery in cardiac surgery patients is ICU length of stay. Previous research has established a correlation between poor glycemic control and prolonged ICU admissions, primarily due to

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higher incidences of infection, organ dysfunction, and delayed extubation [36]. In MICS, where early extubation and fast-track recovery protocols are increasingly implemented, maintaining optimal glycemic levels could play a crucial role in ensuring shorter ICU stays and improved patient throughput [37]. Findings of this study suggested that patients with higher intraoperative glucose levels exhibited a trend toward prolonged ICU stays, although statistical significance was not reached. Nevertheless, the observed pattern supports the hypothesis that effective glycemic management may contribute to more efficient postoperative recovery in MICS patients [38].

In addition to ICU stay duration, another critical postoperative parameter is the need for inotropic support. Patients undergoing cardiac surgery often experience transient myocardial stunning and vasoplegia, requiring inotropes or vasopressors for hemodynamic stabilization [39]. Hyperglycemia has been implicated in worsening endothelial dysfunction and impairing myocardial contractility, potentially increasing the need for pharmacologic hemodynamic support [40]. In this study, it was assessed whether intraoperative hyperglycemia correlated with higher inotropic requirements, providing further insights into the cardiovascular effects of glycemic fluctuations during MICS [41]. While results did not show a statistically significant increase in inotropic use among hyperglycemic patients, the trend of prolonged ICU stays in this group suggests that glycemic control remains a relevant factor in perioperative hemodynamic stability [42].

Ultimately, this research highlights the importance of optimizing intraoperative glycemic control in MICS patients. While the immediate neurocognitive impact of hyperglycemia appeared minimal, trends toward prolonged ICU stays and increased intraoperative intervention requirements suggest that better glucose regulation may enhance overall recovery. Given the increasing global adoption of MICS, developing standardized perioperative glucose management protocols tailored to this surgical approach is essential [43]. Future studies should focus on larger patient cohorts, longer follow-up periods, and randomized controlled designs to further refine glycemic management strategies in MICS. By addressing this critical aspect of perioperative care, we can continue improving surgical outcomes, reducing morbidity, and enhancing the overall safety and efficiency of MICS procedures [44].

2. METHODOLOGY

This study was a retrospective observational analysis conducted at Mayo Hospital Lahore, a high-volume tertiary care center in Pakistan, over a period of 8.5 months. The research focused on patients undergoing MICS, with data obtained from electronic medical records and patient charts. Institutional review board (IRB) approval was secured before initiating data collection, ensuring compliance with ethical standards and patient confidentiality regulations.

A total of 197 patients who underwent elective MICS were initially screened, out of which 40 patients met the inclusion criteria and were selected for final analysis. Inclusion criteria required patients to be adults (≥18 years), undergoing elective MICS with preoperative glycemic data available and early postoperative neurocognitive assessments completed. Patients with pre-existing neurological disorders, poorly controlled diabetes mellitus (HbA1c >9.0%), emergency surgeries, or severe intraoperative complications requiring conversion to full sternotomy were excluded.

Patients were categorized into two groups based on intraoperative blood glucose levels recorded at multiple time points during surgery: Group A (glucose levels ≤200 mg/dL) and Group B (glucose levels ≥201 mg/dL). Blood glucose levels were measured preoperatively, at hourly intraoperative intervals, and postoperatively in the ICU for the first 24 hours. Standardized anesthetic and perfusion protocols were followed to minimize variability, with all surgeries performed via a right mini-thoracotomy or upper hemi-sternotomy approach. Cardiopulmonary bypass (CPB) was established using peripheral femoral arterial and venous cannulation, and myocardial protection was achieved through antegrade and/or retrograde cardioplegia administration.

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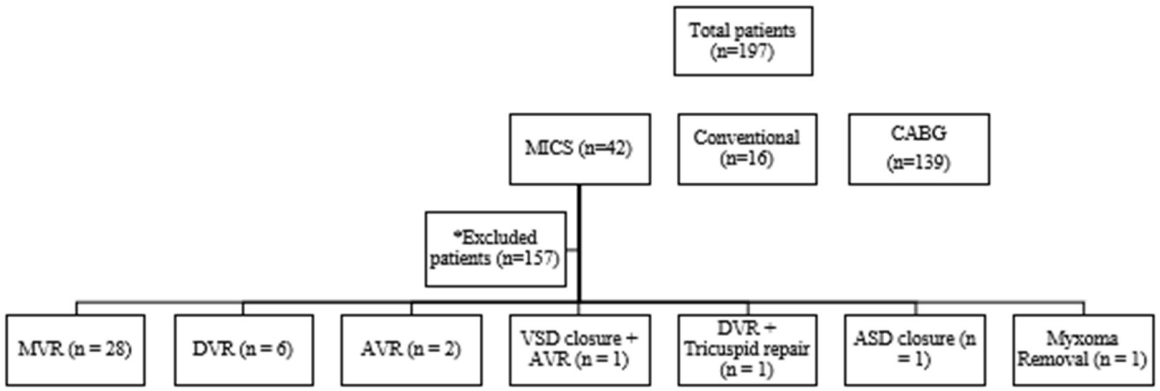

Figure 2.1: *Total patients n = number of patients; MICS = Minimal Invasive Cardiac Surgery; CABG = Coronary Artery Bypass Grafting; MVR = Mitral Valve Replacement; DVR = Double Valve Replacement; AVR = Aortic Valve Replacement; VSD = Ventricular Septal Defect; ASD = Atrial septal defect; MMSE = Mini-Mental State Examination. (*Patients which do not follow inclusion criteria)*

This study evaluated multiple postoperative outcomes, including neurocognitive function, duration of mechanical ventilation, ICU length of stay, postoperative blood loss, inotropic support requirements, and complications such as infections, atrial fibrillation, and renal dysfunction. Neurocognitive function was assessed using the Mini-Mental State Examination (MMSE) preoperatively and postoperatively at 24 and 72 hours. The duration of mechanical ventilation was measured from surgery completion to extubation, while ICU stay was recorded in total hours before transfer to a step-down unit. Postoperative blood loss was quantified as total chest drain output within the first 24 hours, and inotropic support was defined by the need for vasopressors beyond 24 hours postoperatively.

All statistical analysis were performed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation (SD) and compared using independent t-tests or Mann-Whitney U tests, while categorical variables were analyzed using chi-square or Fisher's exact tests. A p-value of <0.05 was considered statistically significant. By structuring the methodology in this manner, the study ensured a comprehensive evaluation of intraoperative glycemic control and its impact on early postoperative outcomes in MICS patients.

3. RESULTS

This study cohort comprised 40 patients undergoing MICS, divided into two groups based on intraoperative blood glucose levels. Group A (n=15) included patients with glucose levels ≤200 mg/dL, whereas Group B (n=25) encompassed those with levels ≥201 mg/dL. The baseline characteristics between the two groups were statistically comparable, ensuring a balanced comparison. The mean age in Group A was 36.73 ± 13.32 years compared to 35.29 ± 11.67 years in Group B (p=0.665). Gender distribution was nearly equivalent, with Group A having 9 males and Group B 7 males (p=0.057). Furthermore, the body mass index (BMI) of Group A was 21.78 (range: 16.40–34.33) versus 24.48 (range: 16.46–45.32) in Group B (p=0.103), confirming no significant disparity in body composition across the cohorts.

Table 3.1: Baseline characteristics of patients undergoing Minimally Invasive Cardiac Surgery

Parameter	Blood Sugar Level		p-value
	≤ 200 mg/dl (n=15)	≥ 201 mg/dl (n=25)	
Gender; male; n (%)	9 (22.50)	7 (17.50)	0.057
Age (years)	36.73±13.32	35.29±11.67	0.665
Height (cm)	165.74 (154-186)	166.58 (149-185)	0.415
Weight (kg)	57.73±12.19	63.92±13.79	0.684
Body Mass Index (BMI) (kg/m²)	21.78 (16.40-34.33)	24.48 (16.46-45.32)	0.103

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Body Surface Area (m^2)	1.64 (1.37-1.98)	1.64 (1.20-2.05)	0.765
Hypertensive; n (%)	1 (2.50)	7 (17.50)	0.147
Diabetes; n (%)	1 (2.50)	2 (5)	0.849
Smoking; n (%)	2 (5)	0 (0)	0.066
Ejection Fraction (%)	57.00 (35-65)	59.67 (50-70)	0.323
Pre operate Hb (g/dl)	13.63±2.43	13.41±2.42	0.850
Platelets (10^9/l)	238.42±99.33	264.20±74.44	0.293
Urea (mg/dl)	28.43 (15-41)	27.47 (13-71)	0.283
Creatinine (mg/dl)	0.75 (0.56-1.34)	0.75 (0.43-1.10)	0.338
Creatinine Clearance Ratio	93.91 (51.45-186)	113.56 (77.74-236.89)	0.044

(Data is presented as mean ± SD for normally distributed variables and as n (%) for categorical variables where n = no. of patients. The p-values indicate the level of significance in the differences between the two groups ≤ 200 mg/dl and ≥ 201 mg/dl)

The renal function parameter, represented by the creatinine clearance ratio, was the only baseline variable that demonstrated statistical significance, with Group A showing a median value of 93.91 (range: 51.45–186) and Group B exhibiting a higher median value of 113.56 (range: 77.74–236.89) (p=0.044). Other parameters, such as ejection fraction and preoperative hemoglobin levels (13.63 ± 2.43 g/dL for Group A and 13.41 ± 2.42 g/dL for Group B, p=0.850), did not differ significantly between the groups, which reinforces the similarity in baseline clinical status.

During the intraoperative phase, several parameters were analyzed to ascertain the influence of glycemic control on surgical management. Pre-bypass hemoglobin levels in both groups were virtually identical (13.40 ± 2.25 g/dL in Group A vs. 13.42 ± 2.06 g/dL in Group B, p=0.617). The activated clotting time (ACT) before bypass was comparable, with Group A recording a median of 93.13 seconds (range: 90–117) and Group B 89.32 seconds (range: 90–128) (p=0.466). During CPB, the ACT values remained statistically similar between Group A (median 681.23 seconds; range: 343–1500) and Group B (median 612.92 seconds; range: 436–1500) (p=0.921), suggesting consistent anticoagulation management across groups.

In addition, hemoglobin levels during CPB were analyzed; Group A had a median of 9.57 g/dL (range: 8.29–14), while Group B recorded a median of 8.97 g/dL (range: 4.70–16.50) (p=0.212). Although not statistically significant, these values underscore the uniformity of intraoperative blood conservation measures. Aortic cross-clamp time, a critical parameter reflecting surgical complexity, showed a median of 94.88 minutes (range: 63–170) in Group A compared to 124.32 minutes (range: 54–230) in Group B, with the p-value at 1.000 indicating no significant difference. Notably, cooling temperature exhibited a statistically significant difference between the groups, with Group A averaging 30.39 ± 1.41°C and Group B 30.57 ± 2.18°C (p=0.046), hinting at a metabolic modulation effect in the hyperglycemic cohort.

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Table 3.2. Intraoperative characteristics of patients undergoing Minimally Invasive Cardiac Surgery

Parameter	Blood Sugar Level		p-value
	≤ 200 mg/dl (n=15)	≥ 201 mg/dl (n=25)	
Intraoperative phase			
Pre Bypass Hb (g/dl)	13.40±2.25	13.42±2.06	0.617
Pre Bypass ACT (sec)	93.13 (90-117)	89.32 (90-128)	0.466
ACT during CPB (sec)	681.23 (343-1500)	612.92 (436-1500)	0.921
Hb during CPB (g/dl)	9.57 (8.29-14)	8.97 (4.7-16.50)	0.212
Aortic Cross Clamp Time (min)	94.88 (63-170)	124.32 (54-230)	1.000
Cooling temperature (^{0}C)	30.39±1.41	30.57±2.18	0.046
Bypass time (min)	143.46 (93-207)	158.16 (78-342)	0.638
Autologous Blood (ml)	40 (0-250)	64 (0-450)	0.786
ACT after CPB (sec)	103.73 (90-142)	97.04 (90-114)	0.103

Collectively, the intraoperative data present a picture of uniformly applied surgical and perfusion protocols, except for the cooling temperature parameter. The consistency in pre-bypass and CPB parameters supports that the only observed significant intraoperative variable, cooling temperature, might be reflective of the physiological adaptations due to hyperglycemia. This baseline and intraoperative statistical analysis lays the foundation for understanding how these factors might influence postoperative outcomes.

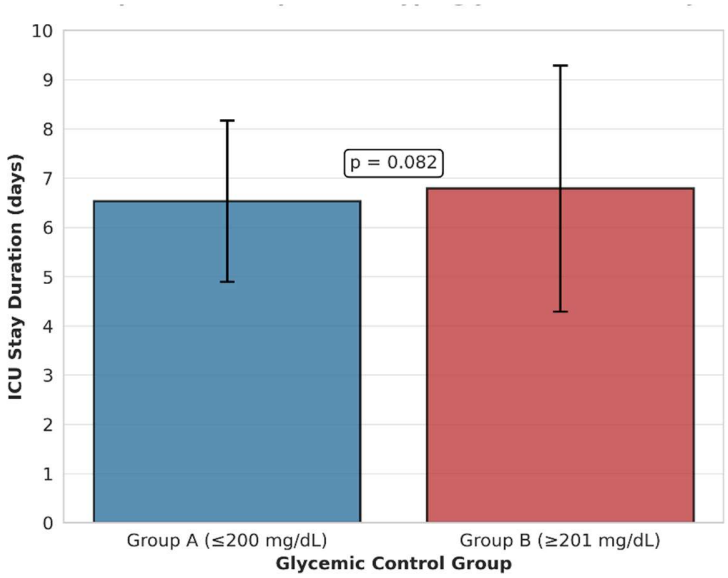

Figure 3.1: Glycemic Control vs. ICU Stay Duration

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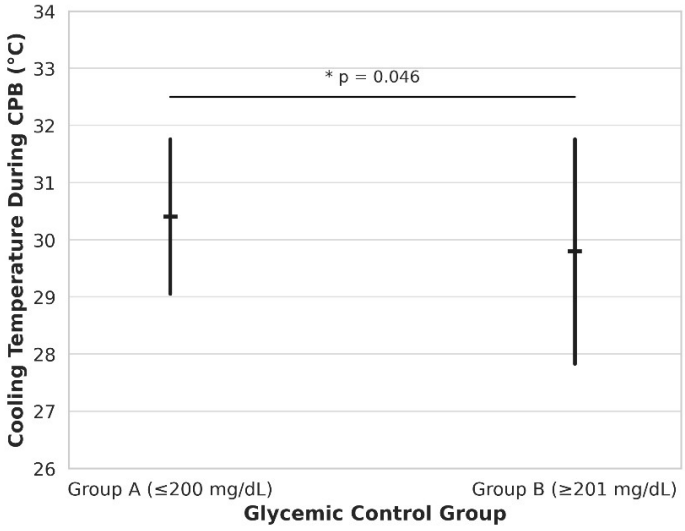

Figure 3.2: Cooling Temperature During CPB

Table 3.3: Postoperative and postoperative characteristics of patients undergoing Minimally Invasive Cardiac Surgery

Post-operative phase			
Hb after CPB	9.69 (7.84-15)	9.27 (0-11.57)	0.679
ACT in ICU (sec)	117.73 (97-181)	131.72 (90-190)	0.809
Ventilation Time (minutes)	195 (90-935)	191.72 (52-1050)	0.110
Blood Transfusion (FFP bags)	0.06 (0-1)	0.04 (0-1)	0.898
Blood Transfusion (PCV bags)	0.20 (0-2)	0.28 (0-2)	0.853
Urea (mg/dl)	35.22±12.97	31.48±14.09	0.918
Creatinine (mg/dl)	35.22 (17-62)	31.32 (0-62)	0.368
Blood drainage (ml)	727.67 (300-1710)	827 (290-2350)	0.578
Platelets count (10^9/ L)	195.99 (121-275)	170.89 (0-469)	0.368
Adrenaline (mcg/kg/min)	0.06±0.02	0.05±0.03	0.431
Nor-Adrenaline (mcg/kg/min)	0.13 (0.05 - 0.24)	0.12(0.21−0.03)	0.319
Dopamine (mcg/kg/min)	3.87(4.0−3.0)	4.52(11.0−3.0)	0.332
Post-MMSE score	24.22 (19-27)	22.52 (18-27)	0.432
ICU stay (days)	6.53±1.64	6.79±2.50	0.082
Mortality; n (%)	0 (0.00)	1 (2.5%)	0.831

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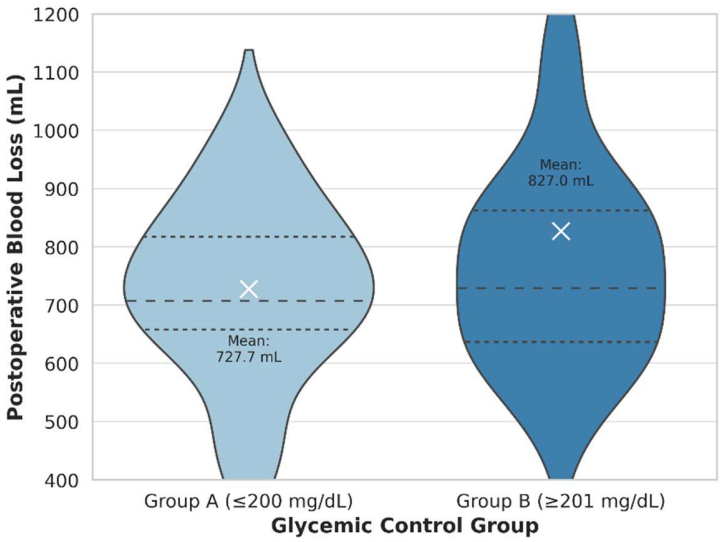

Figure 3.3: Postoperative Blood Loss Comparison

Postoperative outcomes were comprehensively evaluated using a series of quantitative measures to assess the impact of intraoperative glycemic control on recovery in minimally invasive cardiac surgery (MICS) patients. Neurocognitive function, measured by the Mini-Mini Mental State Examination (MMSE), served as one of the primary endpoints. Preoperative MMSE scores were comparable between Group A (median score 25, range: 19–27) and Group B (median score 25, range: 18–27), establishing a similar baseline cognitive function across the study cohorts. Postoperatively, MMSE scores recorded at 24 and 72 hours revealed a slight decline in both groups; however, statistical analysis indicated no significant difference between Group A and Group B (p=0.432). These findings suggest that intraoperative hyperglycemia, defined by blood glucose levels ≥201 mg/dL, did not have a deleterious effect on early neurocognitive recovery in the immediate postoperative period.

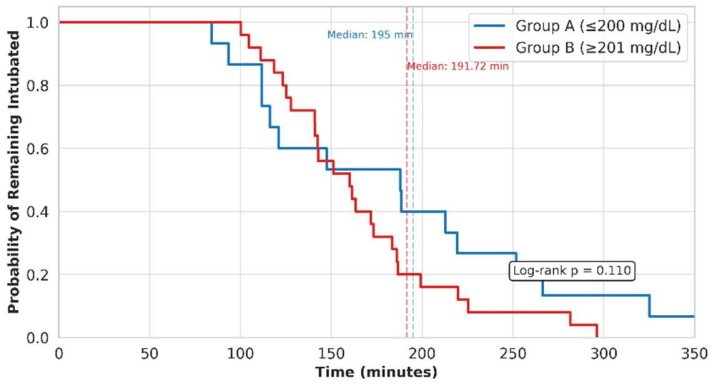

Figure 3.4: Mechanical Ventilation Time

The duration of mechanical ventilation, another critical postoperative parameter, was analyzed next. Group A had a median ventilation time of 195 minutes (range: 90–935 minutes) compared to 191.72 minutes (range: 52–1050 minutes) in Group B, with statistical analysis yielding a p-value of 0.110. Although the difference did not reach statistical significance, the data suggest that ventilatory support requirements were largely independent of intraoperative glycemic variations.

In terms of ICU stay, a trend towards longer durations was observed in the hyperglycemic group. Group A demonstrated a mean ICU stay of 6.53 ± 1.64 days, whereas Group B had a mean stay of 6.79 ± 2.50 days (p=0.082). While this difference

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did not achieve statistical significance, the trend hints at an association between elevated intraoperative blood glucose and prolonged ICU resource utilization, a finding that aligns with previous studies linking hyperglycemia with delayed recovery.

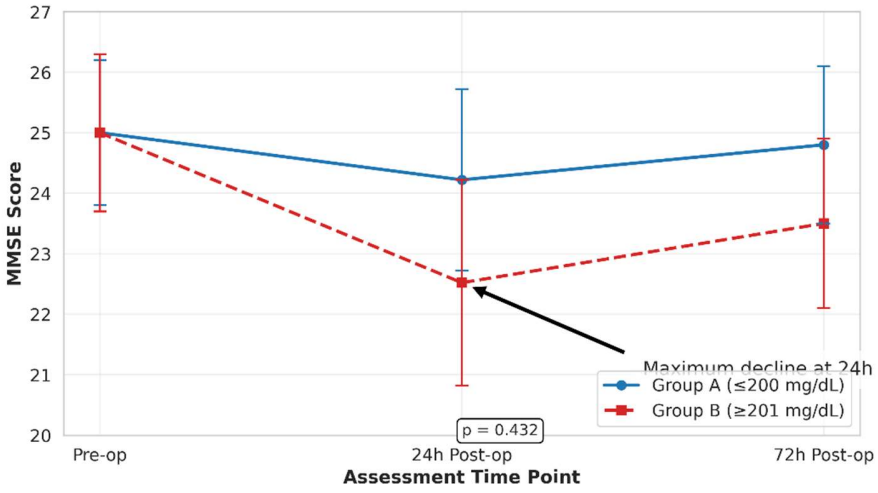

Figure 3.5: Neurocognitive Function (MMSE Scores)

Postoperative blood loss was quantified by measuring chest drain output over the first 24 hours following surgery. Group A exhibited a median output of 727.67 mL (range: 300–1710 mL) compared to 827 mL (range: 290–2350 mL) in Group B (p=0.578). This similarity in blood loss between groups indicates that intraoperative glycemic control did not significantly influence hemostatic stability post-surgery. Additionally, inotropic support requirements were assessed by recording the dosages of administered agents such as adrenaline, noradrenaline, and dopamine. The results demonstrated comparable infusion rates between the groups, with adrenaline administered at 0.06 ± 0.02 mcg/kg/min in Group A versus 0.05 ± 0.03 mcg/kg/min in Group B (p=0.431) and noradrenaline at 0.13 mcg/kg/min (range: 0.05–0.24) in Group A versus 0.12 mcg/kg/min (range: 0.03–0.21) in Group B (p=0.319). Dopamine infusion rates were similarly not statistically different between the groups (p=0.332), indicating that the hemodynamic support requirements were not significantly altered by the degree of glycemic control during surgery.

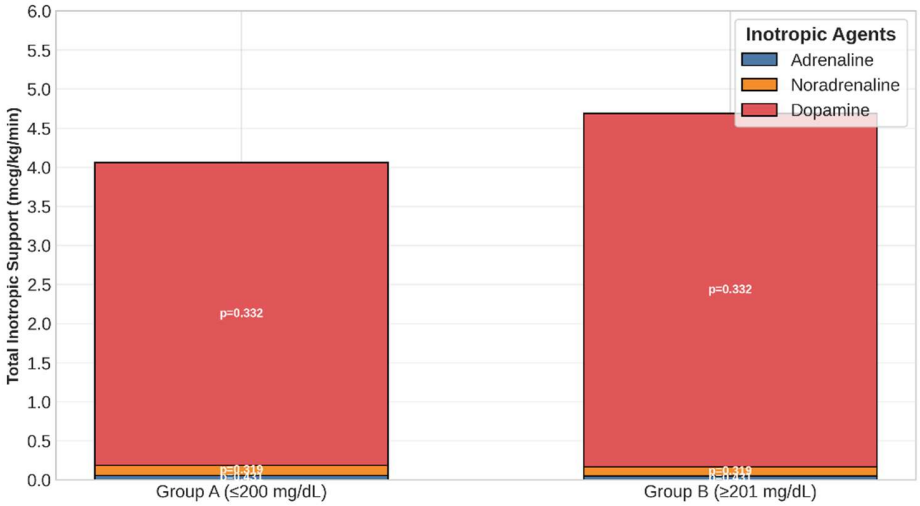

Figure 3.6: Inotropic Support Requirements

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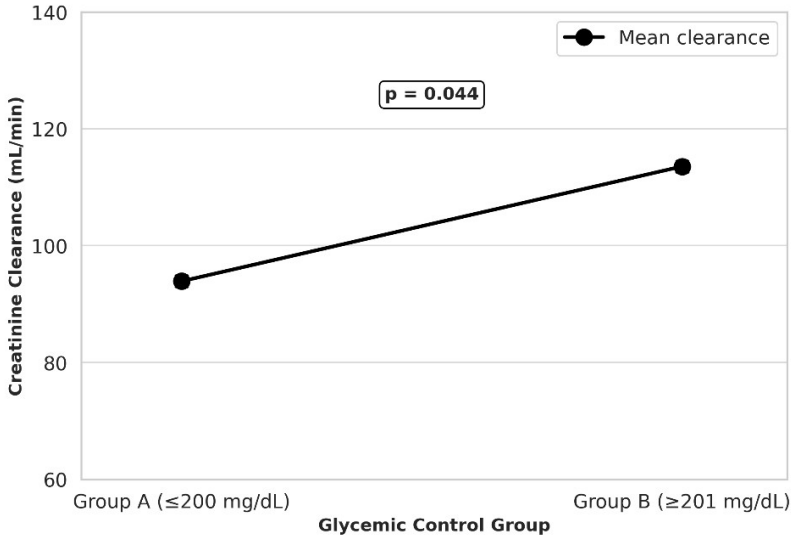

Figure 3.7: Creatinine Clearance Ratio

Finally, mortality was analyzed as a binary outcome. Although one death was recorded in Group B (2.5%) and none in Group A, the difference was not statistically significant (p=0.831). Overall, the postoperative results underscore that while certain trends, such as prolonged ICU stay, may be associated with intraoperative hyperglycemia, the majority of key clinical outcomes including neurocognitive function, ventilation time, and blood loss remained statistically comparable between patients with controlled versus elevated blood glucose levels. These findings provide critical insight into the complex interplay between glycemic management and postoperative recovery in MICS, setting the stage for further research to validate and refine these observations in larger, prospective studies

DISCUSSION

The findings of this study contribute significantly to our understanding of the role of intraoperative glycemic control in MICS, and they offer both expected and unexpected insights when compared with the existing literature. In investigation, patients with intraoperative blood glucose levels above 200 mg/dL demonstrated a trend toward prolonged intensive care unit (ICU) stays and increased cooling temperature requirements during CPB, although other key outcomes such as neurocognitive function, mechanical ventilation time, and postoperative blood loss did not differ significantly between groups. These results align with several previous studies in conventional cardiac surgery that have linked hyperglycemia with increased postoperative complications, including longer ICU stays and higher rates of morbidity [45]. However, findings regarding neurocognitive outcomes were somewhat unexpected, as previous literature has suggested that hyperglycemia might exacerbate neurocognitive decline following surgery [46]. This discrepancy raises important questions about whether the reduced surgical trauma and shorter CPB times associated with MICS might mitigate the neurocognitive risks commonly observed in more invasive procedures.

Study's design and methodological approach played a critical role in shaping these outcomes. By employing strict inclusion criteria and standardized intraoperative protocols, confounding variables that could obscure the true relationship between glycemic control and postoperative outcomes were minimized. For example, the uniform application of anesthetic and perfusion techniques ensured that differences in outcomes were more likely attributable to metabolic differences rather than variations in surgical technique. This methodological rigor is consistent with recommendations from previous studies that emphasize the need for standardization in cardiac surgery research [47]. Nevertheless, the relatively small sample size and retrospective nature of the study may have limited our ability to detect statistically significant differences in some outcomes,

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such as neurocognitive function and inotropic support, which might require larger cohorts to fully elucidate their clinical significance [48].

The observed association between higher intraoperative glucose levels and increased cooling temperature requirements is particularly noteworthy. It suggests that hyperglycemia may impose additional metabolic stress, thereby necessitating adjustments in temperature management during CPB. This finding is in agreement with other research that has noted a compensatory response in hyperglycemic patients during surgery [49]. Additionally, while the trend toward prolonged ICU stay in the hyperglycemic group did not reach statistical significance, it is clinically relevant and may indicate a subtle but important impact of glycemic variability on postoperative recovery. Such trends underscore the potential benefits of optimizing glycemic control not only to improve patient outcomes but also to reduce healthcare resource utilization, an aspect that is increasingly important in contemporary clinical practice.

The discussion of our results must also address the broader implications for future research. The differences observed in cooling temperature and ICU stay, though modest, point to the need for further prospective studies with larger sample sizes and longer follow-up periods to verify these preliminary findings. Moreover, our results suggest that additional factors such as the interplay between glycemic control and inflammatory responses should be explored to fully understand the mechanisms underlying postoperative recovery in MICS patients. Future studies could also investigate whether more aggressive glycemic control strategies, while avoiding hypoglycemia, might yield even better outcomes in terms of reducing postoperative complications. As such, our findings contribute to a growing body of evidence that underscores the importance of individualized metabolic management in cardiac surgery, particularly within the evolving field of minimally invasive techniques [50].

Building upon the insights gained from our study, it is imperative to delve deeper into the implications of our findings and how they inform future clinical practice and research in the field of MICS. One of the key takeaways is that intraoperative hyperglycemia appears to exert a multifaceted impact on postoperative recovery. Although the anticipated neurocognitive decline was not observed to a statistically significant degree, the trends noted in prolonged intensive care unit (ICU) stays and increased cooling temperature requirements warrant further scrutiny. These observations underscore the complexity of metabolic regulation during MICS, suggesting that even modest hyperglycemic excursions may trigger compensatory physiological mechanisms, such as alterations in thermal management strategies during cardiopulmonary bypass (CPB) [50]. The interplay between glycemic control and these intraoperative adjustments is an area ripe for future exploration.

Study's results echo findings from previous research, which have highlighted the role of systemic hyperglycemia in exacerbating inflammatory responses and oxidative stress, both of which are critical factors in postoperative morbidity [51]. It is plausible that hyperglycemia may amplify the production of pro-inflammatory cytokines, thereby contributing to subtle disruptions in organ function that manifest as prolonged ICU stays. Such physiological stress responses have been well documented in the context of traditional cardiac surgery [52], yet their specific impact in the realm of MICS remains less well defined. By controlling for variables such as surgical technique and CPB duration, our study provides a focused lens through which to examine these metabolic effects. Nonetheless, the retrospective nature of our research imposes certain limitations, notably in establishing causal relationships and fully accounting for all potential confounders.

Another significant aspect of discussion relates to the methodological rigor that underpinned our study. The decision to stratify patients based on intraoperative blood glucose levels allowed us to draw meaningful comparisons between groups with different metabolic profiles. This stratification is supported by the growing body of evidence that advocates for tighter glycemic control during cardiac procedures [53]. However, our study also highlights the challenges associated with implementing such protocols in clinical practice, particularly the risk of hypoglycemia when aggressively managing blood glucose levels [54]. Thus, it is essential that future research not only seeks to confirm our findings in larger, prospective

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cohorts but also explores the optimal balance between preventing hyperglycemia and avoiding the pitfalls of overcorrection.

Moreover, our study raises important questions about the broader applicability of our findings to diverse patient populations. The relatively homogenous sample in terms of demographic and baseline clinical characteristics suggests that the effects of glycemic control may vary in populations with different comorbidities or in settings where MICS is performed under different surgical or anesthetic protocols [55]. Future investigations should aim to include a more diverse patient population and consider stratifying results based on additional variables such as the severity of pre-existing conditions and variations in perioperative care.

In light of these considerations, one recommendation for future research is to undertake randomized controlled trials that specifically target the impact of tailored glycemic management strategies in MICS. Such studies could employ continuous glucose monitoring and advanced insulin delivery systems to refine our understanding of the metabolic thresholds that optimize surgical outcomes [56]. Additionally, exploring adjunctive therapies that mitigate the inflammatory and oxidative effects of hyperglycemia may prove beneficial in further improving patient recovery and reducing postoperative complications. Ultimately, our findings contribute to an evolving narrative that emphasizes the critical importance of metabolic management in cardiac surgery and highlight the need for ongoing research to refine clinical protocols for MICS [57].

CONCLUSION

In conclusion, this study successfully achieved its primary aim of evaluating the impact of intraoperative glycemic control on early postoperative outcomes in minimally invasive cardiac surgery (MICS) patients. The research demonstrated that while most baseline and intraoperative parameters were comparable between patients with controlled (≤200 mg/dL) and elevated (≥201 mg/dL) blood glucose levels, hyperglycemia was associated with a statistically significant increase in cooling temperature requirements and a trend toward prolonged intensive care unit (ICU) stays. These findings align with our initial hypothesis that maintaining optimal glycemic levels can favourably influence postoperative recovery, particularly in terms of resource utilization and overall patient stability. Although neurocognitive outcomes, as measured by the Mini-Mental State Examination, did not differ significantly between the groups, the observed trends in other critical parameters underscore the importance of stringent metabolic management during MICS. The study's design, which involved a retrospective review of 40 carefully selected patients and standardized intraoperative protocols, provided a robust framework for isolating the effects of glycemic variability. However, the limited sample size and the retrospective nature of the investigation are acknowledged as key limitations, suggesting that the results should be interpreted with caution. Future research should focus on prospective, randomized controlled trials with larger cohorts to further validate these findings and explore the potential benefits of advanced glycemic monitoring and management strategies, such as continuous glucose monitoring systems. Ultimately, the significance of this work lies in its contribution to the growing body of evidence supporting the optimization of intraoperative glycemic control as a means to enhance surgical outcomes in MICS, thereby offering a valuable approach to improving patient recovery and reducing postoperative complications.

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CITE

- **APA (7th edition)**: Sanaullah, A., Haider, A., Jaweria, F., Khwaja, I. A., Munir, M. W., Naveed, M., & Saeed, T. (2025). *Glycaemic control and its impact on early post-operative outcomes in patients undergoing minimally invasive cardiac surgery. The Operating Room Global Journal (TORGJ), 1*(1). https://doi.org/10.64573/torgj2507001
- **Harvard**: Sanaullah, A., Haider, A., Jaweria, F., Khwaja, I.A., Munir, M.W., Naveed, M. and Saeed, T., 2025. Glycaemic control and its impact on early post-operative outcomes in patients undergoing minimally invasive cardiac surgery. *The Operating Room Global Journal (TORGJ)*, **1**(1). Available at: https://doi.org/10.64573/torgj2507001
- **Vancouver**: Sanaullah A, Haider A, Jaweria F, Khwaja IA, Munir MW, Naveed M, Saeed T. Glycaemic control and its impact on early post-operative outcomes in patients undergoing minimally invasive cardiac surgery. *The Operating Room Global Journal (TORGJ).* 2025;1(1). https://doi.org/10.64573/torgj2507001
- **MLA (9th edition)**: Sanaullah, Asjed, et al. "Glycaemic Control and Its Impact on Early Post-Operative Outcomes in Patients Undergoing Minimally Invasive Cardiac Surgery." *The Operating Room Global Journal (TORGJ)*, vol. 1, no. 1, 2025, https://doi.org/10.64573/torgj2507001
- **Chicago (Author–Date)**: Sanaullah, Asjed, Adnan Haider, Fatima Jaweria, Irfan Azmatullah Khwaja, Muhammad Wajid Munir, Mutahira Naveed, and Tariq Saeed. 2025. "Glycaemic Control and Its Impact on Early Post-Operative Outcomes in Patients Undergoing Minimally Invasive Cardiac Surgery." *The Operating Room Global Journal (TORGJ)* 1 (1). https://doi.org/10.64573/torgj2507001

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