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Perioperative Glycaemic Dynamics in Type 2 Diabetes Mellitus: Comparison of Minimally Invasive and Conventional Coronary Artery Bypass

Abstract

Aim. To compare perioperative glycaemic dynamics and the need for inotropic support in patients with type 2 diabetes undergoing minimally invasive versus conventional coronary artery bypass grafting.

Materials and Methods. The study included 60 patients with multivessel coronary artery disease and type 2 diabetes mellitus not treated with insulin. All underwent coronary artery bypass grafting (CABG) with cardiopulmonary bypass. Group 1 (prospective, n=30) underwent minimally invasive CABG (MICS CABG) via left anterior thoracotomy; Group 2 (retrospective, n=30) underwent conventional CABG via sternotomy. Glycaemic levels were assessed perioperatively at six time points, and integral indices (mean AUC, AUC>10) were calculated. Statistical analyses included the Friedman test with post-hoc Wilcoxon comparisons and Spearman correlation for associations with clinical parameters.

Results. Completeness of revascularisation was comparable between groups: the completeness index was 0.95±0.138 in Group 1 and 0.94±0.127 in Group 2 (p=0.811). Operative (Group 1: 341.9±31.6 min; Group 2: 258.4±27.9 min) and perfusion times were longer in the minimally invasive group (p<0.001), reflecting greater technical complexity. However, the sternotomy group showed significantly higher postoperative glucose levels and a greater overall glycaemic load. Mean AUC was 8.3 (7.4-8.9) in Group 1 and 9.7 (8.4-11.1) in Group 2 (p<0.001), along with a longer time in clinically significant hyperglycaemia (AUC>10, p=0.01). These patients also required more frequent (p=0.021) inotropic support with dobutamine, with significantly higher dosing (p=0.018) and longer infusion duration (p=0.037). AUC>10 correlated positively with the mean dobutamine dose (p=0.42, p=0.01).

Conclusions. Minimally invasive CABG, while technically more demanding, provided equivalent revascularisation with reduced metabolic and haemodynamic stress compared with sternotomy. Integral glycaemic indices, particularly AUC>10, emerged as sensitive markers of metabolic stress and potential predictors of inotropic dependence, supporting their role in personalised perioperative management

Keywords: *coronary artery disease, cardiac surgery, minimally invasive CABG or CABG, T2DM, CPB або cardiopulmonary bypass, perioperative management, inotropic support, metabolic stress, glucose, integral glycaemic indices.*

Introduction. Type 2 diabetes mellitus is a major risk factor for coronary artery disease and is associated with diffuse, severe atherosclerosis [1-3]. Such patients often present with multivessel disease requiring surgical revascularisation, most commonly coronary artery bypass grafting (CABG) [4]. Conventional CABG via full median sternotomy provides wide exposure but entails greater invasiveness, a higher risk of infection, prolonged recovery, and reduced quality of life, particularly in those with metabolic imbalance. Even in the long term, some patients report persistent exercise limitations or chest pain one year postoperatively [5].

Minimally invasive coronary artery bypass (MICS CABG), performed through a small left anterior thoracotomy without sternotomy, has therefore gained attention. Current evidence suggests that MICS CABG decreases operative trauma, lowers complication rates, shortens hospital stay, and improves patient satisfaction [6]. Patients with type 2 diabetes represent a particularly vulnerable group due to increased sensitivity to surgical stress, impaired wound healing, and susceptibility to infection, emphasising the importance of se-

lecting the most appropriate surgical technique for this cohort [7,8].

Aim. To compare perioperative glycaemic control and the requirement for inotropic support in patients with type 2 diabetes undergoing minimally invasive versus conventional CABG.

Materials and methods. The study included 60 patients with coronary artery disease and multivessel involvement combined with moderate-severity type 2 diabetes mellitus managed without insulin. All underwent coronary artery bypass grafting with cardiopulmonary bypass (CPB); in every case, a mammary-to-left anterior descending artery anastomosis was performed.

A combined design was used: Group 1 (prospective) comprised 30 patients who underwent minimally invasive CABG, and Group 2 (retrospective) included 30 patients treated via sternotomy. In both groups, the operations were carried out in an elective setting. Patient selection for group 1 was consecutive. The level of glycated haemoglobin before surgery was 7.5 (6.4-8.5) mmol/l in group 1 and 7.3 (6.2-8.0) mmol/l in group 2 (p=0.659).

Prior to CABG, computed tomography was performed in all patients to assess vascular anatomy and evaluate the feasibility of femoral cannulation. For the preparation of autovenous grafts, the great saphenous vein was harvested with preservation of the intimal layer, minimisation of wall trauma, and avoidance of excessive dilatation. The conduit was inspected for tributaries; side branches were ligated, and an adequate length was ensured for the planned anastomoses. The vein was flushed with a heparinised solution to assess patency and prepared for use as a distal or sequential graft. All harvesting steps were performed in adherence to atraumatic principles.

In minimally invasive coronary artery bypass grafting, the femoral vein and artery were exposed in the right groin for cardiopulmonary bypass (CPB) cannulation. A left fourth-intercostal thoracotomy was performed, followed by mobilisation of the left internal thoracic artery. During CPB, ventricular fibrillation was induced. Distal anastomoses were constructed under aortic cross-clamping with registration of ischaemic time, followed by reperfusion. The aorta was cross-clamped using a Chitwood clamp. The left internal thoracic artery was anastomosed to the left anterior descending artery, and autovenous grafts were attached to the target distal coronary vessels. After completion of the distal anastomoses, the proximal ends of the venous grafts were sutured to the ascending aorta using a side-biting clamp. Cardiac activity returned spontaneously or with defibrillation if required.

In conventional CABG, following sternotomy, CPB was established by cannulating the ascending aorta and the right atrium or inferior vena cava (two-stage cannula). The technique for constructing anastomoses was similar to that used in the minimally invasive approach.

CPB was conducted under moderate hypothermia (32-33 °C). The priming solution was identical in both groups (Gelofusine, 4.2 % sodium bicarbonate, 15 % mannitol, Sterofundin) with a total volume of 1200-1300 ml. Perfusion pressure was maintained at 60-80 mmHg.

At all stages of the study, blood glucose control was performed using venous samples analysed as point-of-care testing with a Roche Cobas b 212 biochemical analyser. The target blood glucose level we aimed to achieve during hyperglycaemia correction was 6.5-7.5 mmol/L, which corresponds to the typical preoperative range observed in stable patients with type 2 diabetes and is considered clinically safe in the perioperative period. During cardiopulmonary bypass, glycaemic control was maintained using a glucose–insulin mixture (8-10 units of short-acting insulin diluted in 100 mL of 5 % glucose) administered at a rate of 1 mL/kg/hour. Blood glucose levels were monitored every 20-30 minutes. In the postoperative period, during the first 24 hours, patients received a glucose–insulin–potassium (GIK) infusion consisting of 5 % glucose, short-acting insulin, and potassium chloride. The required potassium volume was calculated using the formula: Potassium deficit (mmol) = (4.0-plasma [K^+]) × body weight (kg) × 0.4. Blood glucose was monitored at 2-4 hour intervals. Provided that glucose levels remained stable, monitoring frequency was reduced to once every 6 hours over the subsequent 48 hours; in cases of glucose variability or signs of insulin resistance, monitoring was intensified as clinically indicated.

On the second postoperative day, once enteral nutrition and haemodynamic stability were restored, patients gradually resumed the oral antihyperglycaemic medications taken preoperatively, in combination with the ongoing GIK infusion. Where clinically indicated, additional subcutaneous intermediate-acting insulin was administered.

Groups were comparable in age, sex, disease severity, and comorbidities (Table 1).

Coronary angiography was performed preoperatively in all patients to determine the extent of coronary artery bypass grafting. For all patients, the revascularisation index was calculated as the ratio between the number of distal anastomoses actually performed and the number of target coronary lesions identified for surgical revascularisation on preoperative coronary angiography.

Table 2 presents the distribution of coronary artery disease patterns in the study groups.

Statistical analyses were performed with EZR v.1.68, MedStat, and IBM SPSS Statistics 27; all variables were entered into Microsoft Excel 2021.

Normality was assessed by the Shapiro–Wilk test. Student's t-test was applied for normally distributed independent samples, and the Mann–Whitney U test otherwise. Results were reported as mean±SD or median (Q1–Q3), with additional P10–P90 and 95 % CI for non-normal data. Categorical variables were expressed as % and SE; χ^2 test was used for group comparisons, when expected cell counts were ≤5, Fisher's exact test was applied.

Table 1

Baseline clinical and demographic characteristics of the study groups

Characteristics	Study groups of patients		p
	Group 1 (n=30)	Group 2 (n=30)	
Age, years	62.62±1.36	63.05±1.41	0.827
Sex: Male, %	83.3 ± 6.8 % (95 % CI: 65.3-94.4)	80±7.3 % (95 % CI: 61.4-92.3)	1.0
Female, %	16.7±6.6 % (95 % CI: 5.6-34.7)	20±7.3 % (95 % CI: 7.7-38.6)	1.0
Body Surface Area, m^2	2.19±0.04	2.01±0.02	0.692
Body Mass Index, kg/m^2	33.6±2.2	31.8±2.6	0.459
Duration of coronary artery disease, years	4.92±3.31	5.17±3.54	0.451
Duration of type 2 diabetes, years	9.46±4.18	8.99±5.67	0.718
Newly diagnosed diabetes, %	6.7±4.56 % (95 % CI: 8.0-22.1)	10±5.47 % (95 % CI 2.1-26.5)	1.0
Comorbidities: Arterial hypertension, % Grade II	63.3±8.79 % (95 % CI: 43.9-80.1)	56.7±9.04 % (95 % CI: 37.4-74.5)	0.792
Grade III	26.7±8.07 % (95 % CI: 12.3-45.9)	33.3±8.6 % (95 % CI: 17.3-52.8)	0.779
Chronic kidney disease, %	40±8.91 % (95 % CI: 22.7-59.4)	33.3±8.62 % (95 % CI: 17.3-52.8)	0.803
Other, %	23.3±7.71 % (95 % CI: 9.9-42.3)	16.7±6.6 % (95% CI: 5.6-34.7)	0.747
NYHA* functional class: Class III, %	86.7±6.23 % (95 % CI: 69.3-96.2)	80±7.34 % (95 % CI: 61.4-92.3)	0.731
Class IV, %	13.3±6.22 % (95 % CI: 3.8-30.7)	20±7.31 % (95 % CI: 7.7-38.6)	0.729
Post-infarction cardiosclerosis, %	26,6±8.07 % (95 % CI: 12.3- 45.9)	33.3±9.14 % (95 % CI: 17.3-52.8)	0.778

Note: NYHA* – New York Heart Association Classification

Table 2

Extent of coronary artery involvement in the study groups

Coronary artery involvement	Study groups of patients				p
	Group 1 (n=30)		Group 2 (n=30)		
	n	m%±%	n	m%±%	
Two-vessel disease, n	11	36.7±8.79 % (95 % CI 19.9-56.1)	12	40±8.94 % (95 % CI 22.7-59.4)	1.0
Three-vessel or more, n	19	63.3±8.79 % (95 % CI 43.9-80.1)	18	60±8.94 (95 % CI 40.6-77.3)	1.0
LMCA, n	5	16.7±6.6 % (95 % CI: 5.6- 34.7)	7	23.3±7.72 (95 % CI: 9.9-42.3)	0.747

Note: LMCA – Left main coronary artery

For integrated assessment of postoperative glycaemia, the area under the glucose–time curve (AUC) was calculated using the trapezoidal method at baseline, end of surgery, and at 2, 6, 24, and 48 hours. AUC>10 (above 10 mmol/L) reflected the duration of marked hyperglycaemia and episodes of metabolic stress.

Repeated-measures dynamics were analysed with the Friedman test; post-hoc pairwise Wilcoxon tests identified differences between time points. Correlations between glycaemic indices and clinical outcomes were assessed with Spearman's coefficient. A 95 % CI was adopted, with statistical significance at $p < 0.05$.

The study complied with the Declaration of Helsinki and was approved by the Institutional Ethics Committee. All patients volunteered to participate in the study and provided written informed consent describing its purpose, methods, risks, and benefits.

Results. The analysis encompassed the completeness of revascularisation, perioperative glycaemic indices, and the intraoperative and postoperative course. As a first step, completeness of revascularisation was compared between groups. The completeness index was 0.95±0.138 in Group 1 and 0.94±0.127 in Group 2 (p=0.811). Clinically, these findings indicate an equivalent achievement of complete revascularisation in both groups, supporting the technical effectiveness of both minimally invasive and conventional approaches to coronary artery bypass grafting.

Table 3 presents a comparison of the main intraoperative parameters reflecting the technical aspects of coronary artery bypass grafting in both groups.

The analysis revealed significant between-group differences in operative duration: patients undergoing minimally invasive CABG had longer procedures. A similar pattern was observed for cardiopulmonary bypass time, with differences persisting irrespective of the number of grafts (two, three, or more than three). In addition, distal anastomosis time was longer in the minimally invasive group. Taken together, these findings reflect greater technical complexity and longer execution time for minimally invasive procedures compared with conventional operations via median sternotomy.

Table 4 demonstrates the comparison of glycaemic levels over the perioperative course, along with

Table 3

Main intraoperative parameters in minimally invasive versus conventional approaches to coronary artery bypass grafting

	Study groups of patients		
Parameter	**Group 1 (n=30)**	**Group 2 (n=30)**	**p**
Operative time, min	341.9±31.6	258.4±27.9	<0.001
CPB time, min 2 grafts	92.2±8.7	55.6±10.8	<0.001
3 grafts	114.1±12.6	73.4±9.2	<0.001
> 3 grafts	122.9±11.1	85.6±12.3	<0.001
Time for distal anastomosis	11′25″±4′32″	6′38″±3′57″	0.002

Notes: ′ – minute; ″ – second.

Table 4

Glycaemic dynamics and integral indices in patients after coronary artery bypass grafting

Stage/ parametr	**Group**	**Me (Q1 – Q3)**	**P10 – P90**	**95 % CI for the median**	**p**
I	Group 1	7.7 (6.7-8.4)	6.1-10.6	7.1-8.4	0.510
	Group 2	7.4 (6.5-8.1)	6.1-9.8	6.6-8	
II	Group 1	10.3 (8.7-12.0)	7.1-13.4	9.2-11.3	0.009
	Group 2	11.9 (10.4-13.8)	8.4-15.7	10.7-13.5	
III	Group 1	9.1 (7.6-10.4)	7.0-12.1	8.4-10.3	<0.001
	Group 2	10.9 (9.9-12.2)	8.3-13.7	10.5-11.9	
IV	Group 1	8.5 (7.4-9.5)	7.0-11.6	7.5-9.3	0.004
	Group 2	9.8 (8.5-11.0)	7.4-12.5	9.0-10.8	
V	Group 1	7.2 (6.9-8.1)	6.5-9.3	6.9-8.1	<0.001
	Group 2	9.1(7.7-10.3)	7.0-12.3	8.1-9.7	
VI	Group 1	6.9 (6.6-7.6)	6.2-8.6	6.6-7.3	<0.001
	Group 2	8.1 (7.2-9.2)	6.8-10.5	7.5-8.6	
Mean AUC	Group 1	8.3 (7.4-8.9)	7.0-10.5	7.5-8.6	<0.001
	Group 2	9.7 (8.4-1.1)	7.4-12.4	9.2-10.7	
AUC>10	Group 1	0.4 (0.0-2.8)	0-27.4	0-2.5	0.01
	Group 2	3.9 (0.3-22.2)	0-57.3	1.8-17.9	

Notes: I – before surgery; II – after surgery; III – 2 hours postoperatively; IV – 6 hours postoperatively; V – 24 hours postoperatively; VI – 48 hours postoperatively. Glucose measurements are presented in mmol/L; Mean AUC are expressed in mmol·h/L, AUC>10 represents the duration (in hours) with blood glucose levels exceeded 10 mmol/L. Me – median, Q1–Q3 – interquartile range (25th–75th percentile), P10–P90 – 10th–90th percentile range, 95 % CI for the median – 95% confidence interval for the median, p – level of statistical significance.

integral indices (AUC, AUC↑10), in patients in both groups.

The baseline glucose level prior to the initiation of cardiopulmonary bypass did not differ significantly between the groups (p=0.510). The postoperative glucose level in Group 2 was significantly higher compared with Group 1 (p=0.009). Subsequent monitoring in the intensive care unit at 2 and 6 hours confirmed the persistence of this difference, which remained despite pharmacological correction (p<0.001 and p=0.006, respectively). At 24 hours after surgery, as well as at 48 hours, glucose levels in Group 2 remained significantly higher than in Group 1 (p<0.001 and p=0.01, respectively), indicating the stability of this trend.

In Group 1, the Friedman test revealed statistically significant temporal changes in glycaemia (χ^2=84.29; df=5; p<0.001), indicating substantial postoperative fluctuations in glucose levels. Pairwise Wilcoxon signed-rank tests showed a significant increase immediately after surgery compared with baseline (p<0.001), followed by reductions at 24 and 48 hours (both p<0.001). No significant difference was observed between the 24- and 48-hour time points (p>0.05).

In Group 2, the Friedman test demonstrated pronounced temporal differences in glycaemia (χ^2=122.55; df=5; p <0.001). Pairwise Wilcoxon signed-rank tests showed a significant increase in glucose immediately after surgery compared with baseline (p <0.001), with a higher peak than in Group 1. Subsequently, values declined significantly at 6, 24, and 48 hours (all p<0.001), with no difference between 24 and 48 hours (p>0.05). Thus, both groups exhibited a similar pattern of a postoperative peak followed by decline; however, the rise was more pronounced in Group 2, suggesting a higher level of metabolic stress.

Pairwise comparisons of glucose dynamics based on mean ranks for Groups 1 and 2 are shown in Table 5.

To assess the dynamics of the glycaemic response throughout the perioperative period, a within-group comparison of glucose levels across individual time points was performed. In both groups, a characteristic postoperative hyperglycaemic peak was observed immediately after surgery, followed by a gradual decline; however, the magnitude and duration of these changes differed substantially.

In Group 1, the postoperative increase in glucose was moderate and short-lived. Statistically significant differences were detected primarily at early time points, after which glucose levels steadily decreased and returned to preoperative values within 24 hours. By 48 hours, glucose levels approached the lower margin of the baseline range, indicating a rapid restoration of metabolic control. The Δ HL values demonstrated a small negative shift, consistent with a clinically favourable trend towards re-establishing glycaemic homeostasis.

In Group 2, the glycaemic response was markedly more intense and prolonged. The amplitude of the postoperative rise was considerably greater, and statistically significant differences persisted at both early (2-6 h) and later (24-48 h) intervals. Even at 48 hours, glucose levels remained elevated compared with baseline, suggesting a delayed recovery of carbohydrate metabolism. Positive ΔHL values confirmed the persistence of hyperglycaemia not only statistically but also in terms of clinical relevance.

Table 5

Pairwise within-group comparisons of glucose levels across perioperative stages using the Wilcoxon signed-rank test

Perioperative stage comparison	Group 1		Group 2	
	Δ HL (95 % CI)	p	Δ HL (95 % CI)	p
Stage I – Stage II	2.6 (1.85 – 3.2)	<0.0001	4.55 (3.85 – 5.35)	<0.0001
Stage I – Stage III	1.45 (0.85 – 2.0)	0.0001	3.45 (2.95 – 4.0)	<0.0001
Stage I – Stage IV	0.7 (0.2 – 1.3)	0.009	2.3 (1.9 – 2.85)	<0.0001
Stage I – Stage V	-0.35 (-0.9 – 0.25)	0.169	1.45 (0.9 – 2.05)	<0.0001
Stage I – Stage VI	-0.7 (-1.15 – -0.2)	0.007	0.5 (0.15 – 1.05)	0.0131
Stage II – Stage III	-1.1 (-1.55 – -0.5)	0.0032	-1.0 (-1.45 – -0.5)	0.0003
Stage II – Stage IV	-1.8 (-2.45 – -1.1)	0.0002	-2.05 (-2.6 – -1.45)	<0.0001
Stage II – Stage V	-2.85 (-3.55 – -2.05)	<0.0001	-1.75 (-2.1 – -1.4)	<0.0001
Stage II – Stage VI	-3.25 (-3.9 – -2.5)	<0.0001	-3.85 (-4.6 – -3.1)	<0.0001
Stage III – Stage IV	-0.7 (-1.1 – -0.40)	0.0008	-1.1 (-1.3 – -0.8)	<0.0001
Stage III – Stage V	-1.7 (-2.2 – -1.25)	<0.0001	-1.75 (-2.1 – -1.4)	<0.0001
Stage III – Stage VI	-2.1 (-2.65 – -1.65)	<0.0001	-2.8 (-3.25 – 2.35)	<0.0001
Stage IV – Stage V	-1.0 (-1.4 – -0.7)	<0.0001	-0.75 (-1.1 – -0.45)	0.0004
Stage IV – Stage VI	-1.5 (-1.85 – -1.05)	<0.0001	-1.75 (-2.1 – -1.3)	<0.0001
Stage V – Stage VI	-0.35 (-0.7 – -0.1)	0.0076	-0.85 (-1.2 – -0.55)	<0.0001

Note: Stage I – before surgery; Stage II – after surgery; Stage III – 2 hours postoperatively; Stage IV – 6 hours postoperatively; Stage V – 24 hours postoperatively; Stage VI – 48 hours postoperatively. Δ HL (95 % CI) – Hodges–Lehmann median difference with its 95 % confidence interval, p – level of statistical significance.

Although both groups exhibited a broadly similar temporal pattern, Group 2 demonstrated a higher degree of metabolic stress, a more pronounced and sustained elevation in glucose, and a wider range of statistically significant between-time-point differences. In contrast, the faster stabilisation of glucose levels in Group 1 indicates superior adaptive capacity and more effective compensation of stress-induced insulin resistance.

The use of the Hodges–Lehmann estimator allowed not only confirmation of differences between time points but also a quantitative characterisation of their magnitude and clinical significance, clearly demonstrating a more intense and prolonged hyperglycaemic response in Group 2 compared with Group 1.

In the analysis of integral postoperative glycaemic indices, statistically significant between-group differences were observed. The mean AUC was significantly higher in Group 2 than in Group 1 ($p<0.001$), indicating a greater overall glycaemic burden in this cohort. The AUC>10 – representing the area under the curve above the threshold of 10 mmol/L and thus the duration of clinically relevant hyperglycaemia – also differed substantially between groups. In Group 2, the area above 10 mmol/L was markedly greater than in Group 1 ($p=0.01$), consistent with a more pronounced metabolic stress response and a higher risk of adverse outcomes.

After discontinuation of cardiopulmonary bypass, dobutamine was administered as indicated. In Group 1, initiation of dobutamine after perfusion occurred in 30.0±8.36 % of cases (95 % CI: 14.7-49.4), and in Group 2 in 40.0±8.9 % (95 % CI: 22.7-59.4); the between-group difference was not significant ($p=0.588$). However, at 2 hours postoperatively, dobutamine was used in 10.0±5.47 % of cases in Group 1 (95 % CI: 2.1-26.5) and in 36.7±8.79 % in Group 2 (95 % CI: 19.1-56.1), with a significant between-group difference ($p=0.03$). These findings indicate a higher frequency of inotropic support among patients undergoing sternotomy. The dynamics of dobutamine dosing at different time points are presented in Table 5.

Table 5 presents the indices of dobutamine use in both groups. The mean dobutamine dose was significantly higher in Group 2 than in Group 1 both at CPB weaning and at 2 hours after surgery ($p=0.021$ and $p=0.018$, respectively). In addition, the duration of dobutamine infusion was longer in Group 2 ($p=0.037$). These findings indicate a greater need for inotropic support after sternotomy, consistent with a more pronounced degree of metabolic and haemodynamic stress in this cohort.

In the overall cohort, a moderate positive correlation was observed between AUC>10 and the mean dobutamine dose ($\rho=0.42$; $p=0.01$). Moreover, patients who required inotropic support had significantly higher AUC>10 values than those who did not receive dobutamine ($\rho=0.36$; $p=0.02$).

Discussion. Completeness of revascularisation was equivalent between minimally invasive and conventional CABG, confirming comparable effectiveness in restoring coronary blood flow. This supports minimally invasive access as a safe alternative to sternotomy. Intraoperative analysis, however, showed longer operative and perfusion times with the minimally invasive approach, reflecting greater technical complexity that demands surgical expertise and careful patient selection, yet without compromising revascularisation [9,10].

Despite these longer times in Group 1, Group 2 exhibited higher early postoperative glucose levels and greater dobutamine dose use. These differences indicate a greater degree of metabolic stress following sternotomy. Sustained hyperglycaemia despite correction suggests persistent insulin resistance, which is clinically relevant given its association with infection, impaired wound healing, and delayed recovery. Thus, more traumatic access provokes a stronger stress response, requiring stricter glycaemic control [11-13].

In Group 1, glucose rose immediately after surgery and declined by 24-48 hours, reflecting a moderate, correctable stress response. In Group 2, the peak was higher, the decline delayed, and differences persisted at 6 and 24 hours, consistent with more intense stress and insulin resistance. Overall, both groups showed a phasic pattern; however, patients undergoing sternotomy experienced a more prolonged and severe course, underscoring the need for closer glycaemic control (Table 4, Figure 1).

Integral indices confirmed these findings: mean AUC reflected the overall glycaemic burden, while AUC>10 captured the duration and intensity of hyperglycaemia. Both were higher in Group 2, highlighting the cumulative hyperglycaemic load and their potential as prognostic markers. Patients undergoing sternotomy also required higher dobutamine doses and longer infusions, with sig-

Table 5

Use of dobutamine at different stages of postoperative period

Group	Dose of dobutamine, μg/kg/min		Duration of dobutamine infusion, min
	At weaning from CPB	2 hours after surgery	
Group 1	3.77±2.38	2.16±1.92	148.3±124.1
Group 2	6.27±1.89	5.36±2.17	307.3±179.3
p	0.021	0.018	0.037

Note: Data are presented as mean ± standard deviation (m±SD).

nificant differences at 2 hours, indicating greater metabolic and haemodynamic stress.

This likely relates to the physiological impact of sternotomy – respiratory compromise, pain, hypoxia, and raised intrathoracic pressure – leading to increased myocardial oxygen demand and impaired perfusion. In contrast, minimally invasive surgery, despite longer perfusion, caused less trauma, ventilatory impairment, and inflammation, favouring stable haemodynamics and reduced stress.

Correlation analysis further confirmed the link between AUC>10 and inotropic need: higher AUC>10 values and a positive association with dobutamine dose identify hyperglycaemia as a marker of stress and a predictor of complex recovery. Clinically, glycaemic control has haemodynamic as well as metabolic implications, and AUC>10 emerges as a promising integral marker for early identification of patients at risk of inotropic dependence after CABG.

Conclusions. Minimally invasive coronary artery bypass grafting, despite greater technical complexity and longer procedural stages, achieved completeness of revascularisation comparable to the conventional approach, supporting its use as a safe and effective alternative to sternotomy. The postoperative glycaemic course showed a typical phasic rise in both groups, but sternotomy patients exhibited a higher and more prolonged hyperglycaemic peak, indicating stronger metabolic stress. In this group, hyperglycaemia persisted longer despite pharmacological correction, suggesting more sustained early postoperative insulin resistance. Integral indices (AUC and AUC>10) were significantly higher after sternotomy, reflecting greater cumulative hyperglycaemic exposure and longer time in clinically significant hyperglycaemia, making them more sensitive markers of metabolic stress than single measurements. Sternotomy patients also required more frequent and prolonged inotropic support with higher dobutamine doses, reflecting not only greater metabolic but also haemodynamic stress. The correlation between AUC>10 and mean dobutamine dose, as well as higher AUC>10 in patients receiving dobutamine, highlights this metric as a potential predictor of inotropic dependence and underscores its value for personalising postoperative monitoring and therapeutic strategies.

Prospects for Further Research. The work was performed within the framework of the research project "Optimization of approaches to providing specialized medical care for surgical patients using personalized anesthetic support" (2025–2029), state registration number 0125U000315. Performer State Institution of Science «Center of innovative healthcare technologies» State Administrative Department, Kyiv, Ukraine. Within this project, it is planned to continue studying the relationship between perioperative glycaemic regulation, metabolic adaptation, and stress-related hormonal responses, as potential integrated indicators of metabolic resilience and recovery in surgical patients. These investigations aim to refine personalized strategies for predicting and mitigating metabolic stress during cardiac surgery.

Conflict of Interest. The Authors declare no conflict of interest.

Compliance with Ethical Standards. The authors of the manuscript hereby confirm that this prospective study was conducted using data from primary medical records and included clinical observation of patients. The study was carried out in accordance with the ethical standards of the Declaration of Helsinki of the World Medical Association on the ethical principles for medical research involving human subjects, Directive 86/609/EC of the European Community on the participation of humans in biomedical research, and Order No. 690 of the Ministry of Health of Ukraine dated September 23, 2009. Informed consent to participate in the study was obtained from all participants after providing them with clear, complete, and accessible information regarding the study's purpose, design, and methodology, as well as potential risks, expected benefits, and possible alternatives. All participants confirmed their voluntary participation by signing the informed consent document.

Use of Artificial Intelligence. Artificial intelligence tools were used exclusively for language editing under the full control and verification of the authors.

Primary Data and Materials. All collected data were recorded in Microsoft Excel 2021 and documented in individual research protocols for each patient as part of the study's primary dataset.

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Періопераційна динаміка глікемії при цукровому діабеті 2 типу: порівняння малоінвазивного та традиційного коронарного шунтування

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Резюме

Мета. Порівняти періопераційну динаміку глікемії та потребу в інотропній підтримці у пацієнтів із цукровим діабетом 2 типу, яким виконувалося малоінвазивне або традиційне коронарне шунтування.

Матеріали та методи. У дослідження було включено 60 пацієнтів із багатосудинним ураженням коронарних артерій та цукровим діабетом 2 типу, які не отримували інсулінотерапію. Усім хворим виконано коронарне шунтування із застосуванням штучного кровообігу. У проспективній групі 1 (n=30) операцію виконано малоінвазивним методом через ліву передню торакотомію, у ретроспективній групі 2 (n=30) – традиційним методом через стернотомію. Рівень глікемії оцінювали періопераційно у шести часових точках контролю, після чого обчислювали інтегральні індекси (середнє AUC – площа під кривою, AUC>10). Статистичний аналіз включав критерій Фрідмана з post-hoc порівняннями за Вілкоксоном та кореляційний аналіз Спірмена для оцінки зв'язку з клінічними параметрами.

Результати. Повнота реваскуляризації не відрізнялася статистично значущо між групами: індекс реваскулярицації у групі 1 був 0,95±0,138 і 0,94±0,127 у групі 2 (p=0,811). Тривалість операції (група 1 – 341,9±31,6 хв; група 2 – 258,4±27,9 хв) та штучного кровообігу виявилася більшою у групі малоінвазивного шунтування (p<0,001), що відображає підвищену технічну складність методу. Водночас у групі стернотомії спостерігалися достовірно вищі післяопераційні рівні глюкози, більше загальне глікемічне навантаження. Середнє AUC: група 1 – 8,3 (7,4 – 8,9); група 2 – 9,7 (8,4 – 11,1), p<0,001 та триваліший період клінічно значущої гіперглікемії (AUC>10, p=0,01). Ці пацієнти також потребували частішої інотропної підтримки добутаміном із достовірно вищими дозами (p=0,021 і p=0,018 відповідно) й більшої тривалості інфузії (p=0,037). Виявлено позитивну кореляцію між AUC>10 та середньою дозою добутаміну (ρ=0,42; p=0,01).

Висновки. Малоінвазивне коронарне шунтування, попри більшу технічну складність, забезпечує рівноцінну реваскуляризацію зі зниженим метаболічним і гемодинамічним стресом порівняно зі стернотомією. Інтегральні глікемічні індекси, особливо AUC>10, виявилися чутливими маркерами метаболічного стресу та потенційними предикторами інотропної залежності, що підтверджує їхню цінність у персоналізованому періопераційному менеджменті.

Ключові слова: *кардіохірургія, малоінвазивне коронарне шунтування, цукровий діабет 2 типу або ЦД2 типу, штучний кровообіг, періопераційний менеджмент, інотропна підтримка, метаболічний стрес, глюкоза, інтегральні глікемічні індекси.*

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