

Association of Perioperative Blood Glucose Variability with Postoperative Outcomes in Patients Undergoing Major Surgery

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ABSTRACT

Background: While strict glycemic control is a standard of care in surgical settings, recent evidence suggests that blood glucose variability (BGV)—the fluctuation of glucose levels—may be a more potent predictor of adverse outcomes than absolute hyperglycemia. This study investigates the impact of perioperative BGV on postoperative complications in a rural tertiary care setting.

Methods: A prospective observational study was conducted at SRM MCH, Bhawanipatna, Kalahandi, from March 2024 to March 2025. We enrolled 104 adult patients undergoing major elective and emergency surgeries. BGV was measured using the coefficient of variation (CV%) of perioperative capillary and venous blood glucose readings taken over the first 48 hours. Patients were stratified into two cohorts: Low BGV (CV ≤ 20%) and High BGV (CV > 20%).

Results: Of 104 patients, 42 (40.3%) had high BGV and 62 (59.6%) had low BGV, with comparable baseline characteristics. High BGV was associated with significantly higher surgical site infections (21.4% vs. 6.4%, $p = 0.023$), acute kidney injury (16.6% vs. 3.2%, $p = 0.018$), longer ICU stay (4.2 vs. 2.1 days, $p < 0.001$), and hospital stay (12.4 vs. 8.2 days, $p < 0.001$). A CV >20% independently predicted composite postoperative complications (OR 3.14, 95% CI 1.32–6.88, $p = 0.011$).

Conclusion: High perioperative blood glucose variability is strongly associated with increased postoperative morbidity, longer ICU stays, and higher infection rates in patients undergoing major surgery. Minimizing glucose fluctuations, rather than just treating absolute hyperglycemia, should be a primary clinical focus.

Key-words: Blood Glucose Variability, Perioperative Care, Postoperative Complications, Surgical Site Infection, Glycemic Control, Coefficient of Variation

INTRODUCTION

Surgical trauma induces a marked metabolic and neuroendocrine stress response, which commonly results in perioperative hyperglycemia. Traditionally, perioperative glycemic management has focused on maintaining blood glucose within a predefined target

range, with the aim of reducing postoperative morbidity and mortality. However, increasing evidence indicates that the pattern and magnitude of fluctuations in blood glucose may be clinically important in addition to absolute glucose levels. Blood glucose variability (BGV) refers to the degree of fluctuation in blood glucose concentrations over time and has emerged as an important predictor of adverse outcomes in critically ill and surgical patients [1,2].

Several studies have demonstrated that increased glycemic variability is associated with poor clinical outcomes and mortality, independent of mean blood glucose levels [3,4]. Rapid fluctuations in glucose may

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produce greater metabolic stress than sustained hyperglycemia. Acute glucose excursions have been associated with increased oxidative stress, endothelial dysfunction, and cellular injury, which may contribute to postoperative organ dysfunction and impaired recovery^[5]. These mechanisms provide a physiological basis for considering glucose variability as an important component of perioperative glycemic management rather than focusing only on mean or peak glucose values.

The clinical relevance of BGV has also been demonstrated in patients undergoing major surgical procedures. Increased perioperative glycemic variability has been associated with adverse postoperative outcomes, including complications following major surgery and coronary artery bypass procedures^[6,7]. Furthermore, dynamic changes in blood glucose have been associated with mortality and adverse outcomes among critically ill patients, emphasizing the importance of maintaining stable glucose levels during the perioperative and postoperative periods^[8].

Despite growing evidence regarding the adverse effects of glycemic variability, data from rural and semi-urban tertiary care centers remain limited. Patients undergoing major surgery in such settings may have diverse metabolic and clinical characteristics, making evaluation of perioperative BGV particularly relevant. Therefore, the present prospective observational study was undertaken at SRM Medical College Hospital, Bhawanipatna, Kalahandi, to evaluate the association between perioperative BGV and short-term postoperative outcomes in patients undergoing major elective and emergency surgeries.

MATERIALS AND METHODS

Study Design and Setting- This was a prospective, single-center observational study conducted at the Department of Surgery and Anesthesiology, SRM Medical College Hospital (SRM MCH), Bhawanipatna, Kalahandi, Odisha. The study spanned one year, from March 2024 to March 2025.

Participants- A total of 104 consecutive adult patients (aged ≥ 18 years) undergoing major surgical procedures (defined as requiring general or regional anesthesia with an anticipated recovery time of >48 hours) were enrolled. Both diabetic and non-diabetic patients were

included. Patients with end-stage renal disease, preoperative sepsis, or those who died within 24 hours of surgery were excluded.

Inclusion Criteria

- Adults ≥ 18 years undergoing major surgery.
- Both diabetic and non-diabetic patients.
- Expected postoperative recovery >48 hours.

Exclusion Criteria

- End-stage renal disease.
- Preoperative sepsis.
- Death within 24 hours of surgery.

Data Collection and BGV Calculation- Blood glucose was monitored at standard intervals (every 2-4 hours intraoperatively and postoperatively for the first 48 hours). BGV was quantified using the Coefficient of Variation (CV%), calculated as the standard deviation (SD) of glucose readings divided by the mean glucose reading, multiplied by 100. Based on existing literature, patients were divided into a High BGV group (CV $> 20\%$) and a Low BGV group (CV $\leq 20\%$).

Statistical Analysis- Data were analyzed using SPSS Version 28. Continuous variables were expressed as mean $\pm$ SD and analyzed using Student's t-test. Categorical variables were presented as percentages and compared using the Chi-square test or Fisher's exact test. Multivariate logistic regression was performed to identify independent risk factors for complications. A *p*-value of <0.05 was considered statistically significant.

RESULTS

A total of 104 patients completed the study. Forty-two patients (40.3%) were classified into the High BGV group, and 62 patients (59.6%) into the Low BGV group.

The two groups were well-matched at baseline. While there were slightly more patients with pre-existing diabetes in the High BGV group, the difference was not statistically significant, ensuring that diabetes status alone did not heavily skew the results (Table 1).

Table 1: Baseline Demographics and Clinical Characteristics

Variable	Total (N = 104)	Low BGV (n = 62)	High BGV (n = 42)	p-value
Age (years, Mean $\pm$ SD)	54.2 $\pm$ 12.4	53.8 $\pm$ 11.9	54.8 $\pm$ 13.1	0.690
Male Gender, n (%)	58 (55.7%)	34 (54.8%)	24 (57.1%)	0.817
Pre-existing Diabetes, n (%)	38 (36.5%)	20 (32.2%)	18 (42.8%)	0.274
ASA Grade III/IV, n (%)	41 (39.4%)	22 (35.4%)	19 (45.2%)	0.315
Surgery Duration (mins)	165 $\pm$ 45	160 $\pm$ 42	172 $\pm$ 48	0.188

Table 2 illustrates the distinct glycemic profiles of the two cohorts. Expectedly, the High BGV group had a significantly larger standard deviation and coefficient of variation. Notably, the absolute mean glucose was only

marginally higher in the High BGV group, emphasizing that the groups differed primarily in fluctuation, not just absolute hyperglycemia.

Table 2: Perioperative Glycemic Parameters

Glycemic Parameter	Low BGV (n = 62)	High BGV (n = 42)	p-value
Mean Glucose (mg/dL)	142.4 $\pm$ 18.5	154.2 $\pm$ 22.4	0.004*
Standard Deviation (SD)	18.2 $\pm$ 4.1	42.6 $\pm$ 8.5	<0.001*
Coefficient of Variation (CV%)	12.7% $\pm$ 2.8%	27.6% $\pm$ 4.2%	<0.001*
Incidence of Hypoglycemia (<70 mg/dL)	2 (3.2%)	8 (19.0%)	0.014*

Patients with high glycemic fluctuations experienced significantly higher rates of clinical complications.

Surgical site infections (SSI) and acute kidney injury (AKI) were markedly higher in the High BGV group (Table 3).

Table 3: Primary Postoperative Outcomes

Clinical Outcome	Low BGV (n = 62)	High BGV (n = 42)	p-value
Surgical Site Infection (SSI)	4 (6.4%)	9 (21.4%)	0.023*
Acute Kidney Injury (AKI)	2 (3.2%)	7 (16.6%)	0.018*
Cardiovascular Events (MACE)	3 (4.8%)	5 (11.9%)	0.180
Respiratory Failure (requiring vent)	2 (3.2%)	6 (14.2%)	0.041*

The systemic stress of highly variable blood sugars translated directly into longer hospitalizations and intensive care requirements (Table 4).

Table 4: Resource Utilization and Mortality (Secondary Outcomes)

Outcome Measure	Low BGV (n = 62)	High BGV (n = 42)	p-value
ICU Length of Stay (Days)	2.1 $\pm$ 1.2	4.2 $\pm$ 2.6	<0.001*
Total Hospital Stay (Days)	8.2 $\pm$ 2.4	12.4 $\pm$ 4.5	<0.001*
30-Day Readmission, n (%)	5 (8.0%)	9 (21.4%)	0.052
30-Day Mortality, n (%)	1 (1.6%)	3 (7.1%)	0.155

To ensure our findings weren't just a byproduct of older age or pre-existing diabetes, we ran a multivariate analysis. High BGV (CV > 20%) emerged as a strong,

independent predictor of suffering a postoperative complication, tripling the odds compared to low BGV (Table 5).

Table 5: Multivariate Logistic Regression for Composite Postoperative Complications

Risk Factor	Odds Ratio (OR)	95% Confidence Interval	p-value
Age > 65 Years	1.85	0.88 – 3.92	0.104
Pre-existing Diabetes	2.10	0.95 – 4.65	0.065
Surgery Duration > 3 hrs	2.45	1.15 – 5.20	0.019*
High BGV (CV > 20%)	3.14	1.32 – 6.88	0.011*
ASA Grade III/IV	2.80	1.25 – 6.30	0.013*

DISCUSSION

The present study demonstrates a significant association between increased perioperative blood glucose variability and adverse postoperative outcomes. Among 104 patients, 42 (40.3%) had high BGV (CV >20%), while 62 (59.6%) had low BGV. Although baseline demographic and clinical characteristics were comparable between the groups, patients with high BGV experienced significantly higher rates of surgical site infection and acute kidney injury. High BGV was also associated with significantly longer ICU and overall hospital stays. Importantly, multivariate analysis demonstrated that a CV >20% was an independent predictor of composite postoperative complications, with an odds ratio of 3.14. These findings are consistent with previous evidence showing that increased glucose variability is associated with adverse clinical outcomes in critically ill patients. Glycemic variability has been reported as an important predictor of mortality and short-term outcomes, suggesting that fluctuations in glucose may provide additional prognostic information beyond absolute glucose concentrations [9,10]. The present findings extend these observations to a cohort of patients undergoing major surgery in a rural tertiary-care setting.

A possible explanation for the observed association is the biological effect of rapid glucose fluctuations. Acute glucose excursions can increase oxidative stress and contribute to endothelial dysfunction, thereby affecting vascular and cellular function [11]. Previous experimental and clinical observations have suggested that acute glucose fluctuations may produce greater oxidative stress than sustained hyperglycemia, potentially impairing normal physiological responses during the postoperative period [12]. Such effects may contribute to impaired tissue recovery and increased susceptibility to postoperative complications.

The higher incidence of surgical site infection in the High BGV group may also be related to the adverse effects of glucose instability on immune and endothelial function. In the present study, surgical site infections occurred in 21.4% of patients with high BGV compared with 6.4% in the Low BGV group. Similarly, acute kidney injury was significantly more frequent in the High BGV group. These findings are clinically relevant because glycemic variability has previously been associated with adverse outcomes in patients with systemic illness, including sepsis [13].

Another important observation was the significantly higher incidence of hypoglycemia in the High BGV group. Hypoglycemia may occur alongside marked glucose fluctuations and can itself contribute to adverse clinical outcomes. Previous work has highlighted the difficulty in distinguishing the effects of hypoglycemia from those of the underlying illness or its treatment [14]. Therefore, efforts to control hyperglycemia should avoid excessive glucose lowering and repeated swings between hyperglycemia and hypoglycemia.

The High BGV group also demonstrated significantly prolonged ICU and hospital stays. ICU stay was approximately twice as long in patients with high BGV, while overall hospital stay was also substantially longer. These findings indicate that glycemic instability may have implications not only for individual postoperative complications but also for resource utilization and duration of recovery. Appropriate perioperative glycemic management is therefore important, particularly in patients undergoing major surgical procedures [15].

The present study has several limitations. It was a single-center observational study with a relatively modest sample size of 104 patients. In addition, glucose measurements were obtained intermittently rather than through continuous glucose monitoring, which may have failed to capture some short-term glucose fluctuations.

Nevertheless, the findings provide clinically relevant evidence of an association between perioperative BGV and postoperative morbidity and support the need for further studies evaluating strategies aimed at maintaining stable perioperative glucose levels.

LIMITATIONS

This study is limited by its single-center design and relatively modest sample size of 104 patients. Additionally, we relied on intermittent capillary and venous blood sampling rather than continuous glucose monitoring (CGM), which might have missed subtle micro-fluctuations in glucose levels.

CONCLUSIONS

Perioperative blood glucose variability is a critical, independent determinant of postoperative morbidity. Our study at SRM MCH demonstrates that a glucose coefficient of variation above 20% dramatically increases the risk of infections, organ dysfunction, and prolonged hospital stays. Surgical and critical care teams must shift their focus from merely treating absolute hyperglycemia to ensuring smooth, stable glycemic control, avoiding the dangerous peaks and valleys that compromise patient recovery.

CONTRIBUTION OF AUTHORS

Research concept- Dr Sudeep Jena

Research design- Dr Laxmi Narayan Dash

Supervision- Dr Satyajit Kumar Sahoo

Materials- Dr Satyajit Kumar Sahoo

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