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Original Research Article

PROSPECTIVE ASSESSMENT OF GLYCAEMIC VARIABILITY AND ITS ASSOCIATION WITH SHORT-TERM CLINICAL OUTCOMES IN HOSPITALIZED PATIENTS WITH TYPE 2 DIABETES MELLITUS

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ABSTRACT

Background: Glycaemic variability (GV) reflects fluctuations in blood glucose concentrations and may provide prognostic information beyond conventional glycaemic parameters in hospitalized patients with type 2 diabetes mellitus (T2DM). Its association with short-term clinical outcomes requires further evaluation. The aim is to assess glycaemic variability and its association with short-term clinical outcomes among hospitalized patients with type 2 diabetes mellitus.

Materials and Methods: This hospital-based, prospective observational analytical study included 105 patients with T2DM admitted to the Department of General Medicine at a tertiary care hospital. Serial blood glucose measurements were recorded, and glycaemic variability was assessed using glucose standard deviation and coefficient of variation (CV). Patients were categorized into lower GV (CV ≤36%; n=62) and higher GV (CV >36%; n=43) groups. Clinical outcomes were compared using SPSS version 28.0, with $p<0.05$ considered statistically significant.

Results: Patients with higher GV had significantly longer diabetes duration (10.95 ± 5.65 versus 8.30 ± 4.90 years; p=0.015) and higher HbA1c (9.09 ± 1.48% versus 8.19 ± 1.25%; p=0.002). Hypoglycaemia occurred more frequently in the higher GV group (30.23% versus 8.06%; p=0.004), as did hyperglycaemic excursions above 250 mg/dL (72.09% versus 38.71%; p=0.001). The higher GV group demonstrated significantly longer hospital stays (9.23 ± 3.64 versus 6.45 ± 2.58 days; $p<0.001$), increased ICU transfers (25.58% versus 8.06%; p=0.025), hospital-acquired infections (25.58% versus 9.68%; p=0.035), and acute kidney injury (23.26% versus 8.06%; p=0.045). In-hospital mortality was also higher (11.63% versus 1.61%; p=0.041).

Conclusion: Higher glycaemic variability was associated with increased metabolic instability, complications, prolonged hospitalization, and mortality. Regular monitoring of glucose fluctuations may help identify patients at increased clinical risk.

Keywords: Type 2 diabetes mellitus, Glycaemic variability, Hyperglycaemia, Hypoglycaemia, Hospital outcomes.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major health concern characterized by insulin resistance, progressive beta-cell dysfunction, and persistent hyperglycaemia that contributes to cardiovascular, renal, and other systemic complications. People with diabetes frequently require hospitalization for infections, cardiovascular disorders, renal dysfunction, and other acute medical conditions. Hospitalization complicates management, particularly in older patients with comorbidities. Beyond treating the presenting illness, clinicians must maintain safe and stable blood glucose

concentrations throughout inpatient care. Effective glycaemic management may influence immediate clinical stability and recovery.[1] Glycaemic variability refers to fluctuations in blood glucose concentrations within or across days. In hospitalized patients, these fluctuations may be amplified by acute illness, inflammatory responses, physiological stress, changes in nutritional intake, impaired organ function, and alterations in antidiabetic treatment. Stress hormones increase glucose production and insulin resistance, while missed meals or changing insulin requirements predispose patients to hypoglycaemia. Corticosteroid therapy, intravenous fluids containing glucose, and varying levels of physical activity may further complicate glycaemic control. Consequently, hospitalized patients may exhibit considerable glucose instability even when their average glucose concentration appears acceptable.[2] Traditional assessment of diabetes control has largely relied on fasting plasma glucose, random blood glucose, and glycated haemoglobin (HbA1c). However, these measurements cannot fully describe the frequency, amplitude, and direction of short-term glucose fluctuations. Glycaemic variability offers a complementary dimension of assessment by characterizing the dispersion of serial glucose measurements. Indices include mean glucose, standard deviation, coefficient of variation, and maximum–minimum glucose difference. The coefficient of variation expresses glucose dispersion relative to its mean and facilitates comparisons between patients with different average glucose levels. Evaluating these indices may identify clinically important instability that remains concealed by conventional measures.[3] Reliable detection of glucose fluctuations requires systematic monitoring during hospitalization. Point-of-care capillary testing is widely used in medical wards because it supports rapid treatment decisions and timely adjustment of insulin doses. However, measurements obtained only at scheduled intervals may fail to capture brief episodes of hypoglycaemia, nocturnal glucose declines, or marked excursions between routine testing times. Continuous glucose monitoring provides more detailed information about changing glucose patterns, although its application depends on device availability, staff training, and appropriate confirmation of clinically significant readings. Regardless of technology, serial glucose documentation is essential for detecting recurrent dysglycaemia.[4] Management of inpatient hyperglycaemia must achieve a balance between avoiding sustained elevations in blood glucose and preventing treatment-related hypoglycaemia. This balance may be particularly difficult in patients receiving insulin, those with fluctuating oral intake, and individuals whose clinical condition changes rapidly. Insulin requirements may increase during infection or steroid administration but decline with recovery or reduced food consumption. Treatment decisions should consider glucose concentration and trajectory. Structured insulin adjustment, coordinated nursing care, regular dietary assessment, and prompt recognition of abnormal glucose trends are important elements of safe inpatient management. Variability monitoring may support treatment beyond isolated readings.[5] The clinical relevance of glycaemic variability extends beyond laboratory measurements and immediate treatment adjustments. Repeated hyperglycaemic excursions may coexist with oxidative stress, inflammatory activation, and impaired immune or endothelial function, while hypoglycaemic episodes may trigger autonomic responses and acute cardiovascular stress. In hospitalized patients, these processes can overlap with pre-existing renal disease, cardiovascular disease, infection, and other determinants of illness severity. Accordingly, assessment of glycaemic variability alongside clinical characteristics and biochemical parameters may improve understanding of metabolic instability during acute medical care. Nevertheless, any association between variable glucose concentrations and adverse events requires careful interpretation because underlying illness severity and treatment intensity may influence both.[6]

MATERIALS AND METHODS

The present study was designed as a hospital-based, prospective observational analytical study to assess glycaemic variability and its association with short-term clinical outcomes among hospitalized patients with type 2 diabetes mellitus (T2DM). The study aimed to evaluate fluctuations in blood glucose levels during hospitalization and determine their relationship with clinical complications, glycaemic control, length of hospital stay, intensive care requirements, and in-hospital mortality. The study was conducted at a tertiary care hospital in the Departments of General Medicine. Patients with established type 2 diabetes mellitus admitted to the general medical wards for various medical conditions were assessed for eligibility. Clinical assessments, biochemical investigations, and serial blood glucose monitoring were performed according to standardized hospital protocols. A total of 105 hospitalized patients with type 2 diabetes mellitus were included in the study. Participants were recruited using a consecutive non-probability sampling technique based on predefined eligibility criteria. Eligible patients were enrolled following clinical evaluation and informed consent.

Inclusion Criteria

Patients aged 18 years and above with an established diagnosis of type 2 diabetes mellitus who required hospitalization for medical management were included. Patients receiving oral antidiabetic medications, insulin therapy, or combination treatment were considered eligible. Participants were required to have sufficient serial blood glucose measurements during hospitalization to permit assessment of glycaemic variability.

Exclusion Criteria

Patients with type 1 diabetes mellitus, gestational diabetes mellitus, diabetic ketoacidosis, hyperosmolar hyperglycaemic state, or pregnancy were excluded. Patients requiring intensive care at initial admission, those with terminal illnesses receiving exclusively palliative care, and individuals with insufficient glucose monitoring data were also excluded to minimize potential confounding factors.

Methodology

Detailed demographic and clinical information was collected using a structured case record proforma. Recorded parameters included age, sex, body mass index (BMI), duration of diabetes, admission diagnosis, smoking status, history of hypertension, cardiovascular disease, chronic kidney disease, and other associated comorbidities. Details regarding previous glycaemic control, antidiabetic medications, insulin requirements, corticosteroid administration, nutritional intake, and treatment modifications during hospitalization were documented. Vital parameters, including blood pressure, pulse rate, respiratory rate, and oxygen saturation, were also recorded.

Laboratory Investigations

Baseline laboratory investigations included fasting plasma glucose, random blood glucose, glycated haemoglobin (HbA1c), complete blood count, serum creatinine, blood urea, electrolytes, and estimated glomerular filtration rate (eGFR). Liver function tests, serum albumin, C-reactive protein, and other relevant biochemical investigations were performed whenever clinically indicated. HbA1c was assessed to determine preceding glycaemic control, whereas serial glucose measurements were used to evaluate acute glycaemic fluctuations during hospitalization.

Assessment of Glycaemic Variability

Glycaemic variability was assessed using serial capillary blood glucose measurements obtained through standardized point-of-care glucometers. Glucose monitoring was performed before meals and at bedtime, with additional measurements whenever clinically indicated. Readings obtained during the initial 72 hours of hospitalization, or until earlier discharge, were considered for variability analysis. A minimum of eight glucose measurements was required for reliable calculation. The principal glycaemic variability parameters included mean blood glucose (MBG), standard deviation of blood glucose (SD), coefficient of variation (CV%), and maximum–minimum glucose difference. The coefficient of variation was calculated as (SD/mean glucose) × 100. Higher SD and CV values indicated greater glycaemic fluctuations. A CV exceeding 36% was considered indicative of increased glycaemic variability for exploratory categorical analysis.

Assessment of Short-Term Clinical Outcomes

Short-term clinical outcomes were evaluated throughout hospitalization. The primary outcomes included length of hospital stay, occurrence of documented hypoglycaemia, hyperglycaemic episodes, and requirement for intensive care transfer. Hypoglycaemia was defined as blood glucose below 70 mg/dL, clinically significant hypoglycaemia as below 54 mg/dL, and hyperglycaemia as above 180 mg/dL. Secondary outcomes included newly developed hospital-acquired infections, acute kidney injury, cardiovascular complications, escalation of insulin requirements, and in-hospital mortality. These outcomes were assessed in relation to the magnitude of glycaemic variability.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 28.0. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, whereas categorical variables were presented as frequencies and percentages. The Shapiro–Wilk test was used to assess normality. The independent-samples t-test or Mann–Whitney U test was applied for continuous variables, while the Chi-square test or Fisher's exact test was used for categorical comparisons. Pearson's or Spearman's correlation analysis was performed to assess associations between glycaemic variability indices and clinical parameters. Multivariable logistic regression was planned to identify independent associations with adverse clinical outcomes after adjustment for relevant confounding variables, subject to sufficient outcome events. A p-value less than 0.05 was considered statistically significant.

RESULTS

[Table 1] Comparison of Baseline Demographic and Clinical Characteristics According to Glycaemic Variability (N=105)

A total of 105 hospitalized patients with type 2 diabetes mellitus were included, comprising 62 patients (59.05%) with lower glycaemic variability (GV) and 43 patients (40.95%) with higher GV. The mean age was slightly higher in the higher GV group (61.98 ± 11.28 years) compared to the lower GV group (59.03 ± 10.84 years; p=0.184). Males constituted 58.10% of the total population, while the overall mean BMI was 26.46 ± 3.59 kg/m². The duration of diabetes was significantly longer in patients with higher GV (10.95 ± 5.65 versus 8.30 ± 4.90 years; p=0.015). Hypertension (62.79% versus 51.61%), cardiovascular disease (27.91% versus 20.97%), and chronic kidney disease (23.26% versus 14.52%) were more frequent in the higher GV group, although these differences were statistically insignificant. Similarly, insulin therapy at admission (51.16% versus 38.71%) and systemic corticosteroid exposure (23.26% versus 14.52%) were more common among patients with higher GV without statistically significant differences.

[Table 2] Comparison of Baseline Glycaemic and Biochemical Parameters between Lower and Higher Glycaemic Variability Groups (N=105)

The comparison of baseline glycaemic and biochemical parameters demonstrated significantly poorer glycaemic control among patients with higher GV. The mean HbA1c was significantly elevated in

the higher GV group (9.09 ± 1.48%) compared to the lower GV group (8.19 ± 1.25%; p=0.002). Similarly, fasting plasma glucose was significantly higher among patients with higher GV (193.10 ± 45.90 versus 168.40 ± 41.50 mg/dL; p=0.006), as was admission random blood glucose (251.00 ± 70.00 versus 221.00 ± 61.00 mg/dL; p=0.026). Serum creatinine was relatively higher in the higher GV group (1.32 ± 0.54 versus 1.16 ± 0.38 mg/dL; p=0.098), whereas eGFR was comparatively lower (66.80 ± 21.60 versus 74.20 ± 19.40 mL/min/1.73 m²; p=0.076). Additionally, C-reactive protein levels were higher among patients with higher GV (20.10 ± 15.30 versus 14.80 ± 11.70 mg/L; p=0.059), although differences in renal function and inflammatory parameters did not achieve statistical significance.

[Table 3] Comparison of Glycaemic Variability Indices and In-Hospital Dysglycaemic Events (N=105)

Patients with higher GV demonstrated substantially greater fluctuations in blood glucose levels compared to those with lower GV. Mean blood glucose was significantly higher in the higher GV group (216.70 ± 29.50 versus 185.20 ± 22.60 mg/dL; p<0.001), while glucose SD was also markedly elevated (92.10 ± 19.20 versus 47.80 ± 12.40 mg/dL; p<0.001). The coefficient of variation was 42.40 ± 4.70% in the higher GV group compared with 25.80 ± 6.40% in the lower GV group (p<0.001), consistent with the predefined grouping criteria. The maximum–minimum glucose difference was significantly greater among patients with higher GV (303.00 ± 60.20 versus 168.70 ± 46.20 mg/dL; p<0.001). Severe hyperglycaemic excursions above 250 mg/dL were observed in 72.09% of patients with higher GV compared with 38.71% with lower GV (p=0.001). Hypoglycaemia below 70 mg/dL (30.23% versus 8.06%; p=0.004) and clinically significant hypoglycaemia below 54 mg/dL (13.95% versus 1.61%; p=0.018) were also significantly more frequent in the higher GV group.

[Table 4] Association of Glycaemic Variability with Short-Term Clinical Outcomes during Hospitalization (N=105)

Higher glycaemic variability was significantly associated with several adverse short-term clinical outcomes during hospitalization. The mean length of hospital stay was significantly longer in patients with higher GV (9.23 ± 3.64 days) compared to those with lower GV (6.45 ± 2.58 days; p<0.001). The requirement for ICU transfer was significantly greater in the higher GV group (25.58% versus 8.06%; p=0.025), while hospital-acquired infections (25.58% versus 9.68%; p=0.035) and acute kidney injury (23.26% versus 8.06%; p=0.045) were also more frequent. Escalation of insulin therapy was required in 58.14% of patients with higher GV compared with 25.81% in the lower GV group (p=0.001). New cardiovascular complications occurred in 13.95% versus 4.84% of patients, although the difference was statistically insignificant (p=0.155). Importantly, in-hospital mortality was significantly higher among patients with higher GV (11.63% versus 1.61%; p=0.041), suggesting an association between increased glycaemic fluctuations and poorer hospitalization outcomes.

[Table 5] Unadjusted Association of Higher Glycaemic Variability with Dysglycaemic Events and Adverse Clinical Outcomes (N=105)

Unadjusted association analysis demonstrated significantly increased odds of dysglycaemic events and adverse clinical outcomes among patients with higher glycaemic variability. Patients with higher GV had 4.09 times greater odds of experiencing blood glucose levels above 250 mg/dL (OR=4.09; 95% CI: 1.77–9.47; p=0.001) and 4.94 times greater odds of hypoglycaemia below 70 mg/dL (OR=4.94; 95% CI: 1.61–15.17; p=0.004) compared with patients with lower GV. Higher GV was also associated with increased odds of ICU transfer (OR=3.92; 95% CI: 1.25–12.28; p=0.025) and hospital-acquired infection (OR=3.21; 95% CI: 1.08–9.50; p=0.035). Similarly, the odds of developing acute kidney injury were 3.45 times higher among patients with higher GV (95% CI: 1.09–10.98; p=0.045). Escalation of insulin therapy demonstrated a significant association with higher GV (OR=3.99; 95% CI: 1.74–9.17; p=0.001).

Table 1: Comparison of Baseline Demographic and Clinical Characteristics According to Glycaemic Variability (N=105)

Parameter	Total (N=105)	Lower GV (n=62)	Higher GV (n=43)	p-value
Age (years), mean ± SD	60.24 ± 11.06	59.03 ± 10.84	61.98 ± 11.28	0.184
Male sex	61 (58.10%)	35 (56.45%)	26 (60.47%)	0.694
BMI (kg/m²), mean ± SD	26.46 ± 3.59	26.17 ± 3.44	26.89 ± 3.80	0.324
Duration of diabetes (years), mean ± SD	9.39 ± 5.36	8.30 ± 4.90	10.95 ± 5.65	0.015
Hypertension	59 (56.19%)	32 (51.61%)	27 (62.79%)	0.318
Cardiovascular disease	25 (23.81%)	13 (20.97%)	12 (27.91%)	0.487
Chronic kidney disease	19 (18.10%)	9 (14.52%)	10 (23.26%)	0.306
Current smoking	27 (25.71%)	15 (24.19%)	12 (27.91%)	0.821
Insulin therapy at admission	46 (43.81%)	24 (38.71%)	22 (51.16%)	0.234
Systemic corticosteroid exposure	19 (18.10%)	9 (14.52%)	10 (23.26%)	0.306

Table 2: Comparison of Baseline Glycaemic and Biochemical Parameters between Lower and Higher Glycaemic Variability Groups (N=105)

Parameter	Total (N=105)	Lower GV (n=62)	Higher GV (n=43)	p-value
HbA1c (%), mean ± SD	8.56 ± 1.41	8.19 ± 1.25	9.09 ± 1.48	0.002
Fasting plasma glucose (mg/dL)	178.52 ± 44.83	168.40 ± 41.50	193.10 ± 45.90	0.006

Admission random blood glucose (mg/dL)	233.29 ± 66.19	221.00 ± 61.00	251.00 ± 70.00	0.026
Serum creatinine (mg/dL)	1.23 ± 0.46	1.16 ± 0.38	1.32 ± 0.54	0.098
eGFR (mL/min/1.73 m²)	71.17 ± 20.56	74.20 ± 19.40	66.80 ± 21.60	0.076
C-reactive protein (mg/L)	16.97 ± 13.48	14.80 ± 11.70	20.10 ± 15.30	0.059

Table 3: Comparison of Glycaemic Variability Indices and In-Hospital Dysglycaemic Events (N=105)

Parameter	Total (N=105)	Lower GV (n=62)	Higher GV (n=43)	p-value
Mean blood glucose (mg/dL)	198.10 ± 29.89	185.20 ± 22.60	216.70 ± 29.50	<0.001
Glucose SD (mg/dL)	65.94 ± 26.80	47.80 ± 12.40	92.10 ± 19.20	<0.001
Coefficient of variation (%)	32.60 ± 10.01	25.80 ± 6.40	42.40 ± 4.70	<0.001
Maximum–minimum glucose difference (mg/dL)	223.70 ± 84.37	168.70 ± 46.20	303.00 ± 60.20	<0.001
Patients with ≥1 glucose reading >180 mg/dL	88 (83.81%)	48 (77.42%)	40 (93.02%)	0.057
Patients with ≥1 glucose reading >250 mg/dL	55 (52.38%)	24 (38.71%)	31 (72.09%)	0.001
Patients with ≥1 hypoglycaemic reading <70 mg/dL	18 (17.14%)	5 (8.06%)	13 (30.23%)	0.004
Patients with ≥1 clinically significant hypoglycaemic reading <54 mg/dL	7 (6.67%)	1 (1.61%)	6 (13.95%)	0.018

Table 4: Association of Glycaemic Variability with Short-Term Clinical Outcomes during Hospitalization (N=105)

Clinical outcome	Total (N=105)	Lower GV (n=62)	Higher GV (n=43)	p-value
Length of hospital stay (days), mean ± SD	7.59 ± 3.34	6.45 ± 2.58	9.23 ± 3.64	<0.001
Requirement for ICU transfer	16 (15.24%)	5 (8.06%)	11 (25.58%)	0.025
Hospital-acquired infection	17 (16.19%)	6 (9.68%)	11 (25.58%)	0.035
Acute kidney injury	15 (14.29%)	5 (8.06%)	10 (23.26%)	0.045
New cardiovascular complications	9 (8.57%)	3 (4.84%)	6 (13.95%)	0.155
Escalation of insulin therapy	41 (39.05%)	16 (25.81%)	25 (58.14%)	0.001
In-hospital mortality	6 (5.71%)	1 (1.61%)	5 (11.63%)	0.041

Table 5: Unadjusted Association of Higher Glycaemic Variability with Dysglycaemic Events and Adverse Clinical Outcomes (N=105)

Clinical outcome	Lower GV n/N (%)	Higher GV n/N (%)	Unadjusted odds ratio (95% CI)	p-value
Glucose reading >250 mg/dL	24/62 (38.71%)	31/43 (72.09%)	4.09 (1.77–9.47)	0.001
Hypoglycaemia (<70 mg/dL)	5/62 (8.06%)	13/43 (30.23%)	4.94 (1.61–15.17)	0.004
ICU transfer	5/62 (8.06%)	11/43 (25.58%)	3.92 (1.25–12.28)	0.025
Hospital-acquired infection	6/62 (9.68%)	11/43 (25.58%)	3.21 (1.08–9.50)	0.035
Acute kidney injury	5/62 (8.06%)	10/43 (23.26%)	3.45 (1.09–10.98)	0.045
Escalation of insulin therapy	16/62 (25.81%)	25/43 (58.14%)	3.99 (1.74–9.17)	0.001

DISCUSSION

In the present study, 105 hospitalized patients with type 2 diabetes mellitus were evaluated, of whom 59.05% exhibited lower glycaemic variability and 40.95% demonstrated higher glycaemic variability. The mean age was comparatively higher in the higher GV group (61.98 ± 11.28 years) than in the lower GV group (59.03 ± 10.84 years), although the difference was statistically insignificant (p=0.184). However, the duration of diabetes was significantly longer among patients with higher GV (10.95 ± 5.65 versus 8.30 ± 4.90 years; p=0.015). Hypertension (62.79%), cardiovascular disease (27.91%), and chronic kidney disease (23.26%) were also more frequent in the higher GV group. These findings were comparable with those reported by Kuroda et al. (2021), who evaluated 281 patients with type 2 diabetes mellitus and reported a median age of 68 years, diabetes duration of 13 years, and hypertension prevalence of 63.00%. They demonstrated that longer diabetes duration was significantly associated with deterioration in time in range (β=−0.160; p=0.003), while glucose standard deviation increased with increasing disease duration.[7] The assessment of baseline glycaemic parameters demonstrated significantly poorer glycaemic control among patients with higher GV. The mean HbA1c was 9.09 ± 1.48% in the higher GV group compared with 8.19 ± 1.25% in the lower GV group (p=0.002). Similarly, fasting plasma glucose (193.10 ± 45.90 versus 168.40 ± 41.50 mg/dL; p=0.006) and admission random blood glucose (251.00 ± 70.00 versus 221.00 ± 61.00 mg/dL; p=0.026) were significantly elevated. Serum creatinine and C-reactive protein were also relatively higher, although statistically insignificant. Comparable observations were reported by McKechnie et al. (2019), who studied 21,045 hospital admissions involving patients with type 2 diabetes mellitus. Patients classified by a higher admission glucose number had a median HbA1c of 60 mmol/mol compared with 50 mmol/mol in the lower group, while their admission capillary glucose values were 10.1 versus 8.1 mmol/L. The corresponding inpatient glycaemic coefficients of variation were 30% and 23%, respectively. Furthermore, the admission glucose number correlated positively with subsequent glycaemic variability (r=0.25; p<0.001).[8] The present study demonstrated substantial differences in glycaemic variability indices between the two groups. Mean blood glucose was significantly higher among patients with higher GV (216.70 ± 29.50 versus 185.20 ± 22.60 mg/dL; p<0.001), while glucose standard deviation was

92.10 ± 19.20 mg/dL compared with 47.80 ± 12.40 mg/dL (p<0.001). The coefficient of variation was 42.40 ± 4.70% in the higher GV group compared with 25.80 ± 6.40% in the lower GV group, reflecting the predefined variability-based classification. Similarly, the maximum–minimum glucose difference was significantly greater in the higher GV group (303.00 ± 60.20 versus 168.70 ± 46.20 mg/dL). These observations were consistent with the importance of glucose fluctuations demonstrated by Egi et al. (2006) in a multicentre study involving 7,049 critically ill patients and 168,337 blood glucose measurements. They reported significantly greater glucose standard deviation among nonsurvivors than survivors (2.3 ± 1.6 versus 1.7 ± 1.3 mmol/L; p<0.001). Each 1 mmol/L increase in glucose standard deviation was associated with increased odds of ICU mortality (OR=1.27; p<0.001).[9] In the present study, dysglycaemic events occurred significantly more frequently among patients with higher glycaemic variability. Hyperglycaemic excursions above 250 mg/dL were documented in 72.09% of patients with higher GV compared with 38.71% with lower GV (p=0.001). Similarly, hypoglycaemia below 70 mg/dL occurred in 30.23% versus 8.06% (p=0.004), while clinically significant hypoglycaemia below 54 mg/dL was observed in 13.95% versus 1.61% (p=0.018). These observations indicated that marked glycaemic variability was associated with exposure to both hyperglycaemic and hypoglycaemic episodes. Similar findings were reported by Bagshaw et al. (2009), who evaluated 66,184 critically ill patients admitted to 24 intensive care units. They reported early hypoglycaemia in 13.80% of patients and early blood glucose variability involving both low and high glucose values in 2.90%. Early hypoglycaemia was independently associated with ICU mortality (adjusted OR=1.41; 95% CI: 1.31–1.54), while the group exhibiting both hypoglycaemia and hyperglycaemia demonstrated an adjusted OR of 1.50 (95% CI: 1.40–1.60) for ICU mortality.[10] The association between glycaemic variability and hospitalization outcomes demonstrated that patients with higher GV experienced significantly longer hospital stays. The mean duration of hospitalization was 9.23 ± 3.64 days in the higher GV group compared with 6.45 ± 2.58 days in the lower GV group (p<0.001), representing an average difference of 2.78 days. Furthermore, ICU transfer was required in 25.58% of patients with higher GV compared with 8.06% with lower GV (p=0.025). These findings closely resembled those reported by Mendez et al. (2013), who investigated 935 hospital admissions involving 620 patients admitted to noncritical medical and surgical services. Their study demonstrated that each 10 mg/dL increase in glucose standard deviation was independently associated with a 4.40% increase in hospital length of stay, whereas each 10-percentage-point increase in glucose coefficient of variation was associated with a 9.70% increase in length of stay (both p<0.001). Patients with the greatest glycaemic variability remained hospitalized approximately three additional days compared with those exhibiting lower variability.[11] The present study also demonstrated a significantly greater frequency of complications among patients with higher GV. Hospital-acquired infections occurred in 25.58% of patients with higher GV compared with 9.68% with lower GV (p=0.035), while acute kidney injury was reported in 23.26% versus 8.06% (p=0.045). Similarly, escalation of insulin therapy was required in 58.14% of patients with higher GV compared with 25.81% with lower GV (p=0.001). These findings were clinically relevant to those reported by Umpierrez et al. (2011) in the RABBIT 2 Surgery randomized trial involving 211 hospitalized patients with type 2 diabetes mellitus. They demonstrated that a basal–bolus insulin regimen achieved significantly lower mean daily glucose concentrations compared with sliding-scale insulin therapy (145 ± 32 versus 172 ± 47 mg/dL; p<0.01). The incidence of the composite postoperative complication outcome was significantly lower with basal–bolus therapy (8.60% versus 24.30%; p=0.003). Wound infection occurred in 2.90% versus 10.30%, while acute renal failure occurred in 3.80% versus 10.30%, respectively.[12] An important observation of the present study was the greater in-hospital mortality among patients with higher glycaemic variability. Mortality was 11.63% in the higher GV group compared with 1.61% in the lower GV group (p=0.041). New cardiovascular complications were also relatively more frequent among patients with higher GV (13.95% versus 4.84%), although this difference was statistically insignificant (p=0.155). The relationship between glucose fluctuations and mortality was previously demonstrated by Krinsley (2008) in a retrospective analysis involving 3,252 critically ill patients. The overall mortality rate in that cohort was 24.40%, and mortality progressively increased across successive quartiles of glycaemic variability from 12.10% in the first quartile to 19.90%, 27.70%, and 37.80% in the second, third, and fourth quartiles, respectively. Interestingly, among patients with mean glucose concentrations between 70 and 99 mg/dL, mortality increased from 5.90% in the lowest variability quartile to 30.10% in the highest quartile.[13] Unadjusted association analysis in the present study further demonstrated that higher GV was associated with substantially increased odds of adverse clinical outcomes. Patients with higher GV had greater odds of severe hyperglycaemia (OR=4.09; 95% CI: 1.77–9.47), hypoglycaemia (OR=4.94; 95% CI: 1.61–15.17), ICU transfer (OR=3.92; 95% CI: 1.25–12.28), hospital-acquired infection (OR=3.21; 95% CI: 1.08–9.50), and acute kidney injury (OR=3.45; 95% CI: 1.09–10.98). These findings were consistent in their overall direction with those reported by Akirov et al. (2017), who assessed 20,303 hospitalized patients, including 8,565 individuals with diabetes mellitus. They demonstrated progressively increasing in-hospital mortality across

glycaemic CV tertiles among diabetic patients, with mortality rates of 3%, 5%, and 10%, respectively. Compared with the lowest CV tertile, patients in the highest tertile had significantly greater odds of in-hospital mortality (OR=3.10; 95% CI: 2.30–4.20). Long-term mortality also increased from 26% in the lowest CV tertile to 45% in the highest tertile. Together, these findings suggested that greater glycaemic variability was associated with increased clinical risk and supported further evaluation of variability indices as potential prognostic indicators.[14]

CONCLUSION

The present study demonstrated that higher glycaemic variability was significantly associated with poorer short-term clinical outcomes among hospitalized patients with type 2 diabetes mellitus. Patients with higher glycaemic variability experienced more frequent hyperglycaemic and hypoglycaemic episodes, prolonged hospital stays, and increased requirements for ICU transfer. Hospital-acquired infections, acute kidney injury, escalation of insulin therapy, and in-hospital mortality were also significantly higher in this group. These findings suggest that glycaemic variability may serve as a useful marker for identifying hospitalized patients at increased risk of adverse outcomes.

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