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Research Article

Association of Glycemic Status with Stroke Severity and In-Hospital Neurological Outcome in Patients with Acute Ischemic Stroke: A Hospital-Based Observational Study

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Abstract

Background: Hyperglycemia is frequently observed in the setting of an acute ischemic stroke and may reflect both pre-existing diabetes and an acute stress response. Increased glucose levels have been associated with more severe neurological damage and worse outcomes, but the association between specific glycemic parameters and early neurological improvement is still clinically relevant.

Objective: To evaluate the association of random blood glucose (RBS), fasting blood glucose (FBS), glycated hemoglobin (HbA1c) and glycemic status with stroke severity and short-term neurological outcome in acute ischemic stroke patients.

Methods: This prospective observational study conducted in a hospital setting involved 100 adult patients diagnosed with CT-confirmed acute cerebral infarction and admitted to the Department of General Medicine, Navodaya Medical College Hospital and Research Center, Raichur between 1st January 2021 and 31st July 2022. RBS, FBS and HbA1c were measured during the hospitalization. Neurological severity was graded by use of the National Institutes of Health Stroke Scale (NIHSS) on admission and at discharge. Glycemic parameters were classified based on the categories applied in the original study analysis. Comparative statistical tests were used to evaluate associations between glycemic parameters and NIHSS.

Results: The mean age of the participants was 64.57 ± 10.06 years, and 60% were males. In 60% of participants random blood sugar was >200 mg/dL, in 65% fasting blood sugar was >126 mg/dL and in 58% HbA1c was >8%. According to the glycemic-status classification recorded in the study, 41% were classified as diabetes mellitus, 26% as stress hyperglycemia and 33% as euglycemia. Mean NIHSS significantly dropped from 15.49 ± 7.83 at admission to 11.77 ± 7.93 at discharge ($p=0.001$). Higher categories of RBS, FBS and HbA1c were associated with significantly higher NIHSS scores. Mean NIHSS was 10.98 among patients with RBS <200 mg/dL vs 20.00 among patients with RBS >200 mg/dL ($p<0.0001$). Mean NIHSS increased from 10.63 in those with FBS <110 mg/dL to 18.45 in those with FBS >126 mg/dL ($p<0.00001$). NIHSS increased from 13.06 in participants with HbA1c <6.5% to 20.40 in those with HbA1c >8% ($p=0.00046$). NIHSS scores were significantly higher in patients with diabetes mellitus or

stress hyperglycemia than in those with euglycemia.

Conclusion: Glycemic disturbances were common in patients with acute ischemic stroke and were significantly associated with higher neurological severity. NIHSS scores were significantly lower at discharge than at admission and higher NIHSS scores were associated with higher RBS, FBS and HbA1c. These findings support the clinical relevance of early assessment of glycemic status in acute ischemic stroke, although the observational design does not prove causality or independent prognostic prediction.

Keywords: acute ischemic stroke; hyperglycemia; diabetes mellitus; stress hyperglycemia; HbA1c; blood glucose; NIHSS; neurological outcome.

Introduction.

Stroke continues to be a leading cause of death and disability worldwide. The Global Burden of Disease Study 2019 reported that in 2019, 12.2 million incident strokes and 6.55 million stroke-related deaths occurred globally, with ischemic stroke comprising about 62% of incident strokes. High plasma glucose at fasting is a major modifiable contributor to global stroke burden. [1] () Hyperglycemia is common in acute ischemic stroke and may be due to pre-existing diabetes mellitus, impaired glucose regulation, or an acute neuroendocrine stress response. Diabetes is a well-known risk factor for ischemic stroke and has also been associated with poorer outcomes after stroke. A meta-analysis of acute stroke hospitalized patients showed that approximately one third of patients had diabetes. Many studies have reported associations between diabetes or acute hyperglycemia and mortality, neurological impairment and functional outcomes. [2] ().

Admission hyperglycemia may be more than chronic glycemic exposure. Acute physiological stress activates sympathetic and hypothalamic-pituitary-adrenal pathways, leading to increased hepatic glucose production and decreased insulin sensitivity. Thus, the glucose concentration measured in acute stroke reflects both the chronic metabolic status and the acute stress. Pooled incidence of approximately 24% across available studies is reported in recent systematic reviews, indicating that stress hyperglycemia is relatively common in acute ischemic stroke. [3] () It is clinically important to distinguish between chronic and acute dysglycemia. HbA1c gives an idea about the longer term glycemic exposure while RBS and FBS reflect the immediate metabolic state. Studies using the stress hyperglycemia ratio, which combines glucose and HbA1c, have reported an association between higher levels of acute glycemic stress and poorer neurological or functional outcomes after ischemic stroke. [4,5] ().

The National Institutes of Health Stroke Scale (NIHSS) is a validated, widely-used, standardized assessment of neurological impairment in acute stroke. Higher NIHSS scores indicate more severe neurological impairment and correlate with clinical outcomes. [6] () However, the observational data linking hyperglycemia with stroke outcomes should not be interpreted as suggesting that aggressive glucose lowering will necessarily improve neurologic recovery. The randomized clinical trial SHINE found no benefit in 90-day functional outcome with intensive glucose control versus standard treatment, and contemporary stroke guidelines do not recommend intensive glucose lowering to 80–130 mg/dL simply to improve functional outcomes. () [7,8]

The present study assessed the correlation of routinely available glycemic parameters RBS, FBS and HbA1c, with neurological severity and short-term neurological outcome in patients with acute ischemic stroke.

Objective

To evaluate the relationship between glycemic status, RBS, FBS and HbA1c with stroke severity and short-term neurological outcome as measured by NIHSS in patients with acute ischemic stroke.

Materials and Methods

Study design and setting

This was a **hospital-based prospective observational study** conducted in the Department of General Medicine, Navodaya Medical College Hospital and Research Centre, Raichur, Karnataka.

The study was a hospital-based prospective cross-sectional observational study.

Study period

Participants were recruited between **January 1, 2021 and July 31, 2022**, corresponding to an 18-month study period.

Sample size

The calculated minimum sample size was 66 based on a cross-sectional sample-size formula using a prevalence estimate of 21.9%, 95% confidence level and an absolute allowable error of 10 percentage points. The final study recruited **100 participants**.

Sampling and recruitment

Eligible patients were recruited until the planned sample size was attained during the study period, as described in the source thesis data-collection procedure.

Eligibility criteria

Inclusion criteria

1. Age >18 years.
2. CT scan demonstrating acute cerebral infarction.

Exclusion criteria

Patients were excluded if they had:

- age <18 years;
- traumatic stroke;
- transient ischemic attack;
- cerebral venous thrombosis;
- intracerebral hemorrhage;
- space-occupying lesion;
- cerebellar/brainstem infarction;
- cardioembolic stroke; or
- coagulation disorders.

Clinical and laboratory assessment

After obtaining informed written consent, demographic and clinical information was recorded. The assessment included history of diabetes mellitus, hypertension, smoking and alcohol consumption.

Laboratory investigations included:

- complete blood count;
- RBS;
- FBS;
- HbA1c;
- fasting lipid profile;
- serum creatinine.

CT brain imaging was performed for confirmation of acute cerebral infarction.

Assessment of neurological severity

Neurological severity was assessed using the NIHSS at admission and again at discharge. The NIHSS is a standardized neurological examination scale ranging from 0 to 42, with higher scores indicating greater neurological impairment. [6]PubMed

The primary neurological outcome for this manuscript was the NIHSS score at admission

and discharge and the difference between these measurements.

Definition and categorization of glycemic variables

The manuscript retains the categories used in the original thesis analysis:

- RBS: <200 versus >200 mg/dL;
- FBS: <110, 111–125 and >126 mg/dL;
- HbA1c: <6.5%, 6.5–8% and >8%.

The glycemic-status analysis categorized participants as:

- diabetes mellitus;
- stress hyperglycemia; or
- euglycemia.

Because the thesis does not provide sufficient information to reconstruct an independent diagnostic algorithm for these categories, these classifications are reported as **study-defined categories** rather than retrospectively applying new diagnostic criteria.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Comparisons of NIHSS between two groups were performed using the t-test, while comparisons across more than two categories were performed using analysis of variance. Admission and discharge NIHSS values were compared using a paired analysis as reported in the original thesis. A p value <0.05 was considered statistically significant.

Ethical considerations

Institutional Ethics Committee approval was obtained from Navodaya Medical College Hospital and Research Centre, Raichur, on **December 22, 2020**. Written informed consent was obtained from participants or their attendants before enrollment.

Results

Baseline characteristics

A total of **100 patients** with acute ischemic stroke were included.

The mean age was **64.57 ± 10.06 years**. Seven percent of participants were younger than 50 years, while 63% were aged 51–70 years. Males constituted 60% of the study population.

Table 1. Baseline demographic characteristics

Characteristic	n (%)
Total participants	**100 (100)**
Age <40 years	1 (1)
Age 41–50 years	6 (6)
Age 51–60 years	24 (24)
Age 61–70 years	39 (39)
Age 71–80 years	20 (20)
Age >81 years	10 (10)
Mean age, years	**64.57 ± 10.06**

Male	60 (60)
Female	40 (40)

Glycemic profile

RBS exceeded 200 mg/dL in 60% of participants. FBS was >126 mg/dL in 65%, while HbA1c was >8% in 58%. The mean RBS was 226.42 ± 84.72 mg/dL, mean FBS was 146.10 ± 42.54 mg/dL and mean HbA1c was 8.51 ± 2.13%.

Table 2. Glycemic profile of study participants

Glycemic parameter	Category	n (%)
RBS	<200 mg/dL	40 (40)
	>200 mg/dL	60 (60)
	Mean ± SD	**226.42 ± 84.72 mg/dL**
FBS	<110 mg/dL	23 (23)
	111–125 mg/dL	12 (12)
	>126 mg/dL	65 (65)
	Mean ± SD	**146.10 ± 42.54 mg/dL**
HbA1c	<6.5%	24 (24)
	6.5–8%	18 (18)
	>8%	58 (58)
	Mean ± SD	**8.51 ± 2.13%**

Study-defined glycemic status

The thesis classified 41% of participants as having diabetes mellitus, 26% as having stress hyperglycemia and 33% as euglycemic.

Table 3. Study-defined glycemic status

Glycemic status	n (%)
Diabetes mellitus	41 (41)
Stress hyperglycemia	26 (26)
Euglycemia	33 (33)

Total	**100 (100)**

Data-integrity note: The clinical-history table separately reports diabetes in 42% of participants. Because the source thesis contains this internal discrepancy, the present manuscript does not attempt to reconcile the two values. The 41% figure is used only when reporting the thesis's specific **glycemic-status outcome classification**. The separate clinical-history diabetes variable is not used as the primary exposure in this manuscript.

Neurological severity at admission and discharge

Mean NIHSS was **15.49 ± 7.83 at admission** and decreased to **11.77 ± 7.93 at discharge**. The difference was statistically significant (p=0.001).

Table 4. NIHSS at admission and discharge

Assessment	Mean NIHSS	SD
Admission	15.49	7.83
Discharge	11.77	7.93
Difference	3.72	—
Statistical test	t = −3.338	**p=0.001**

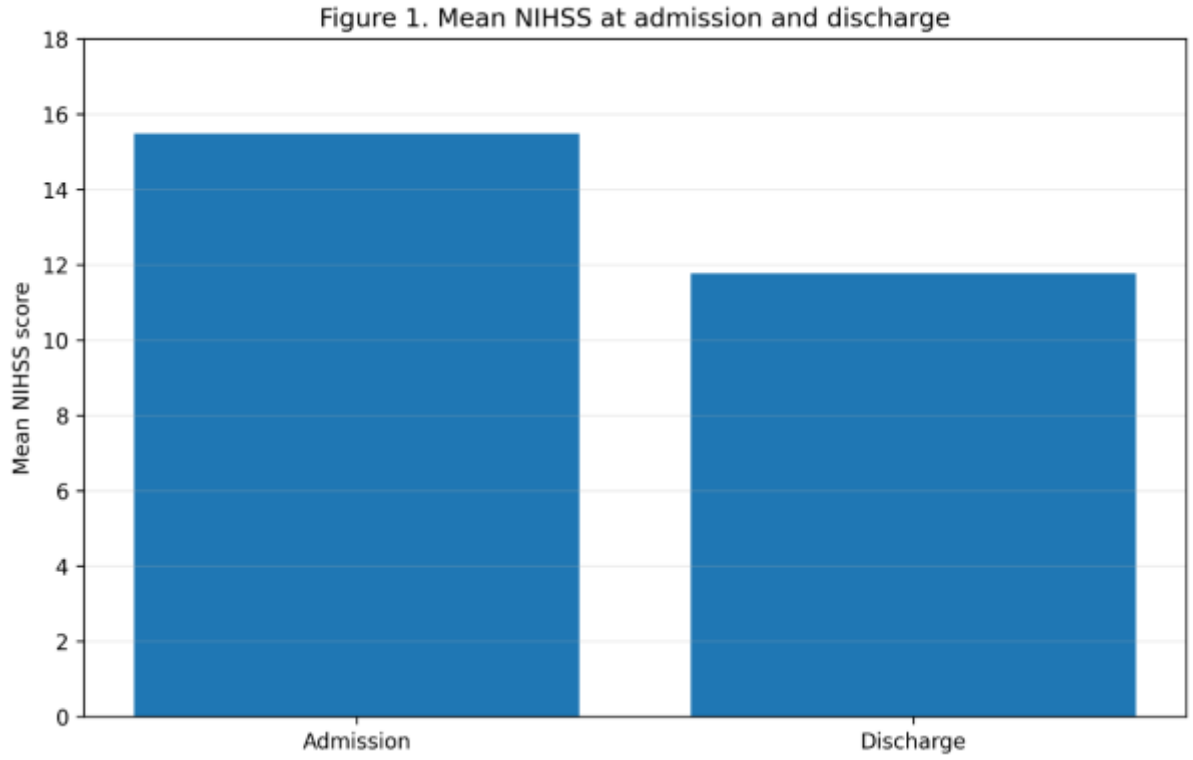

Figure 1. Mean NIHSS score at admission and discharge.
A paired bar chart showing mean NIHSS declining from 15.49 at admission to 11.77 at discharge.

Association Between Glycemic Parameters and NIHSS

Random blood glucose

Participants with RBS >200 mg/dL had a substantially higher mean NIHSS than those with RBS <200 mg/dL:

- <200 mg/dL: **10.98**
- 200 mg/dL: **20.00**

The difference was statistically significant (**p<0.0001**).

Fasting blood glucose

Mean NIHSS increased progressively across FBS categories:

- <110 mg/dL: **10.63**
- 111–125 mg/dL: **16.58**
- 126 mg/dL: **18.45**

The overall difference was statistically significant (**F=13.1539, p<0.00001**).

HbA1c

Mean NIHSS also increased across HbA1c categories:

- <6.5%: **13.06**
- 6.5–8%: **15.44**
- 8%: **20.40**

The association was statistically significant (**F=8.3324, p=0.00046**).

Table 5. Association between glycemic parameters and NIHSS

Parameter	Category	n	Mean NIHSS	p value
RBS	<200 mg/dL	40	10.98	<0.0001
	>200 mg/dL	60	20.00	
FBS	<110 mg/dL	23	10.63	<0.00001
	111–125 mg/dL	12	16.58	
	>126 mg/dL	65	18.45	
HbA1c	<6.5%	24	13.06	0.00046
	6.5–8%	18	15.44	
	>8%	58	20.40	

The p values represent the overall comparison across the respective categories.

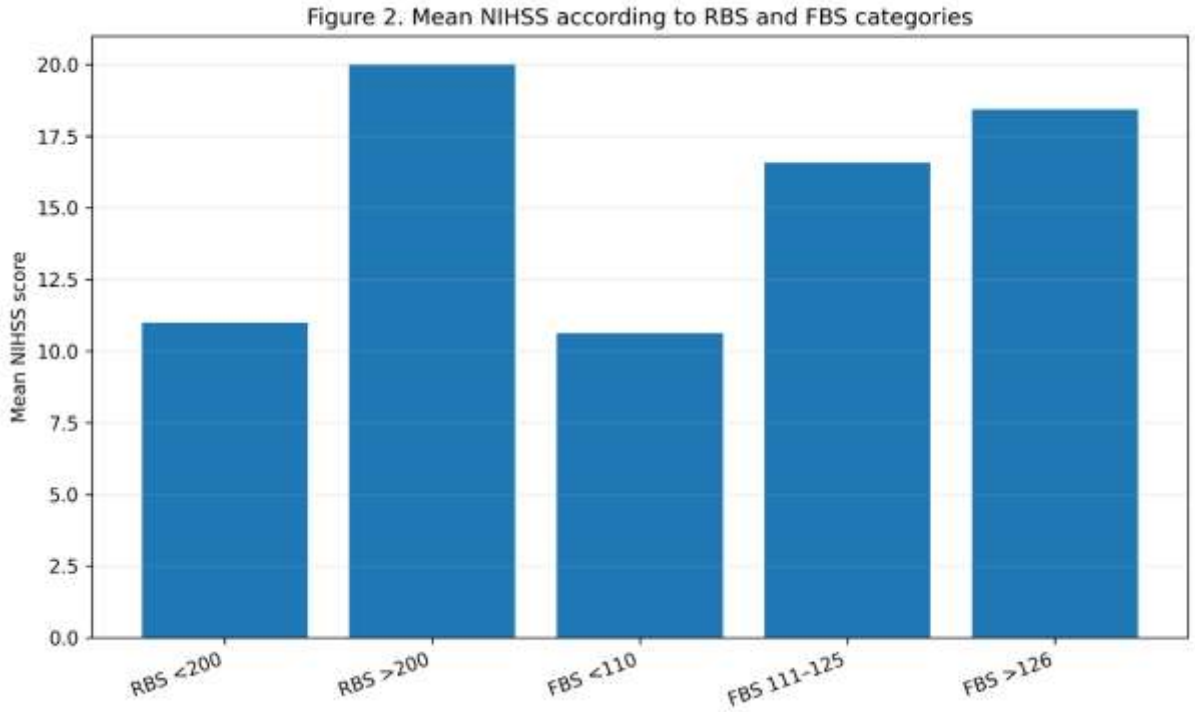

Figure 2. Association between RBS and FBS categories and mean NIHSS.
Grouped bar chart demonstrating increasing NIHSS across higher RBS and FBS categories.

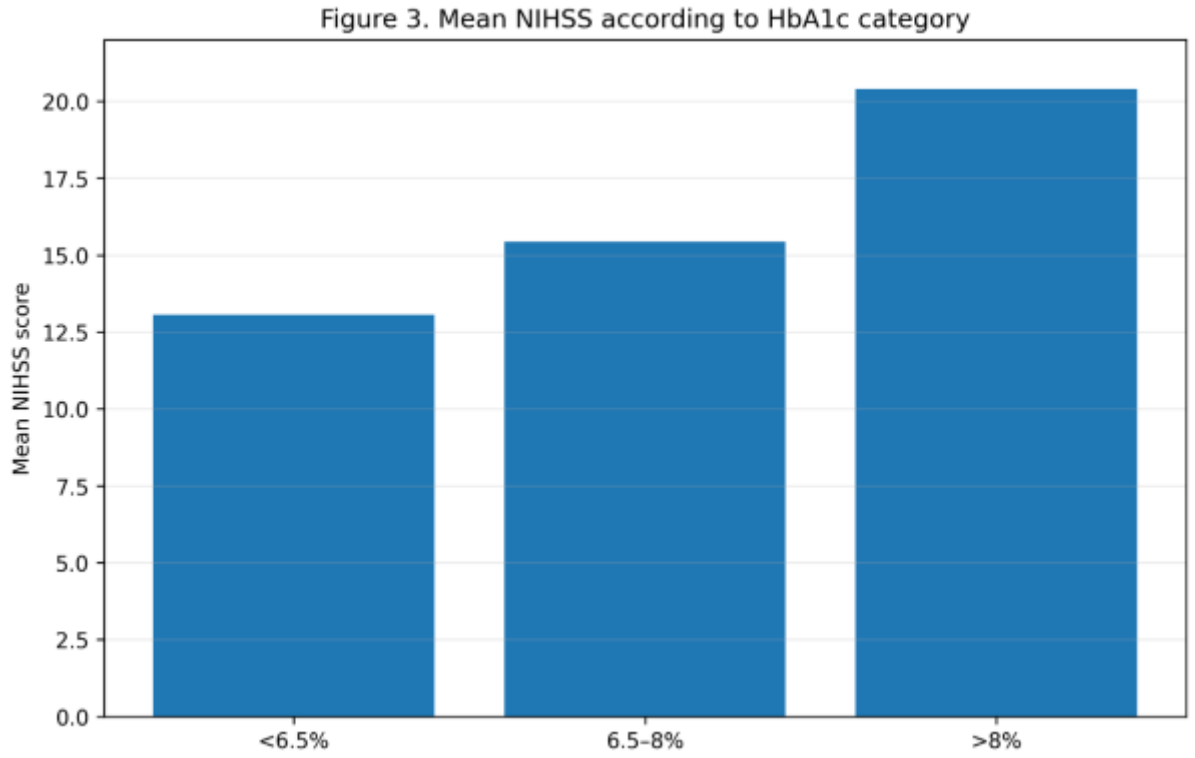

Figure 3. Association between HbA1c category and mean NIHSS.
Bar chart showing mean NIHSS of 13.06, 15.44 and 20.40 across HbA1c categories <6.5%, 6.5–8% and >8%, respectively.

Glycemic Status and Stroke Severity

Mean NIHSS differed substantially according to the study-defined glycemic-status categories.

Table 6. Mean NIHSS according to glycemic status

Glycemic status	Mean NIHSS	SD
Diabetes mellitus	18.51	7.08
Stress hyperglycemia	18.77	7.26
Euglycemia	9.15	5.06
ANOVA	**F=23.1658**	**p<0.00001**

Participants classified as having diabetes mellitus or stress hyperglycemia had substantially higher mean NIHSS scores than participants classified as euglycemic.

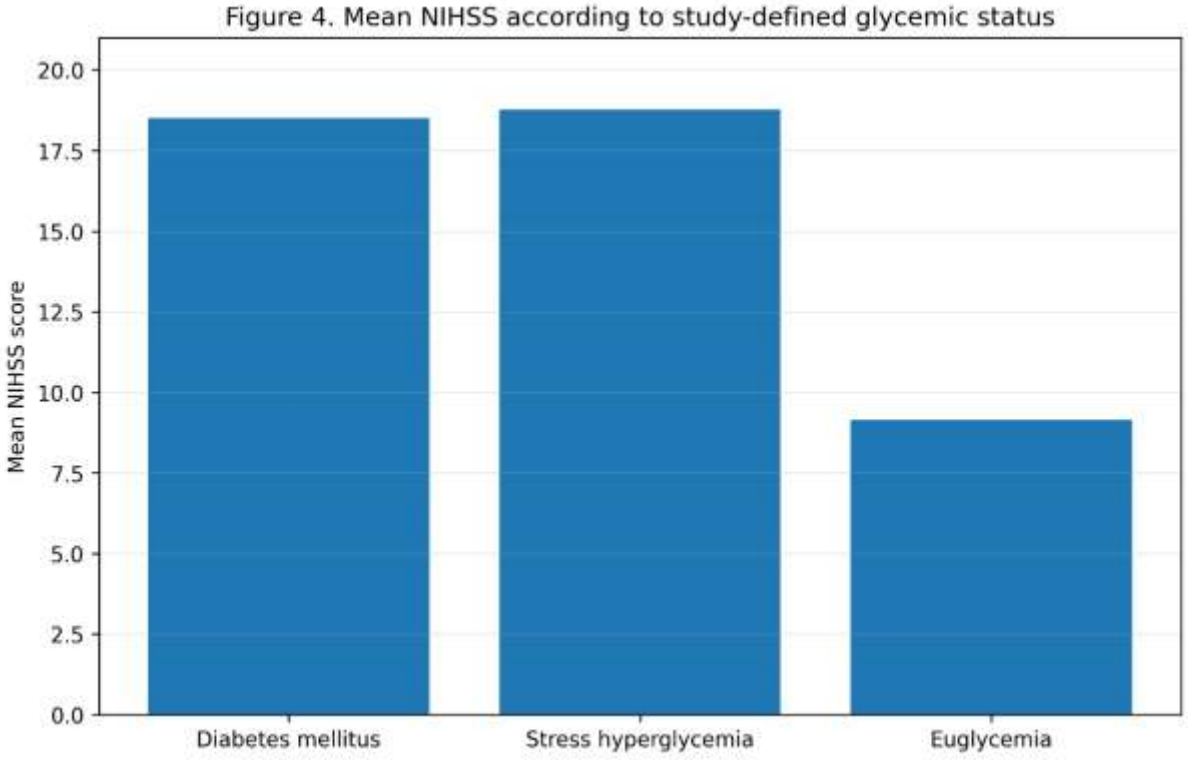

Figure 4. Mean NIHSS according to study-defined glycemic status.
Bar chart comparing mean NIHSS among diabetes mellitus, stress hyperglycemia and euglycemia groups.

Discussion

The main finding of this study was that higher glycemic measurements were consistently associated with greater neurological severity at presentation. RBS >200 mg/dL and FBS >126 mg/dL and HbA1c >8% were associated with high NIHSS scores significantly. Subjects diagnosed with diabetes mellitus or stress hyperglycemia also had significantly higher NIHSS scores than those diagnosed as euglycemic.

The findings are clinically relevant because hyperglycemia is frequent in acute ischemic stroke and may represent both chronic metabolic disease and acute physiologic stress. A meta-analysis of hospitalized stroke patients found diabetes in approximately one-third of patients and reported that acute hyperglycemia

and diabetes were associated with poorer outcomes in many, although not all, studies. In this study 60% of patients had RBS >200 mg/dL [2] () The corresponding mean NIHSS was 20.00, compared with 10.98 among participants with RBS <200 mg/dL. This large difference is consistent with the observational literature associating acute hyperglycemia with increased neurologic impairment. Stress hyperglycemia may arise from activation of the sympathetic nervous system and hypothalamic-pituitary-adrenal axis during acute cerebral ischemia, producing increased hepatic glucose output and impaired peripheral glucose utilization. [3,4] ()

The association was also observed with FBS. Mean NIHSS increased from 10.63 in participants with FBS <110 mg/dL to 18.45 in those with FBS >126 mg/dL. These findings suggest that abnormal glucose metabolism was associated with neurological severity across both lower-term and acute metabolic measurements. However, because this study was observational and glucose measurements were obtained in the setting of acute stroke, the findings cannot establish that hyperglycemia caused the greater neurological deficit.

The same pattern was observed for HbA1c. Mean NIHSS was 20.40 in participants with HbA1c >8% compared with 13.06 in those with HbA1c <6.5%. HbA1c represents glycemic exposure over a longer period and therefore provides complementary information to the admission glucose. Previous studies have shown that an increase in HbA1c is associated with an increased risk of ischemic stroke, especially in diabetic patients . [9] () The differentiation between chronic diabetes and acute stress hyperglycemia is especially important. In the present analysis, the mean NIHSS was 18.51 in participants classified as having diabetes mellitus and 18.77 in participants classified as having stress hyperglycemia, compared with 9.15 in those classified as euglycemic. Recent systematic reviews and meta-analyses have also suggested an association between higher stress hyperglycemia ratios and poor neurological or functional outcomes after acute ischemic stroke. [4,5] ()

Significant neurologic improvement during the hospitalization was also demonstrated in the present study. The mean NIHSS score decreased from 15.49 on admission to 11.77 at discharge (p=0.001). This improvement should be viewed as a general change during acute hospitalization and not specifically linked to correction of hyperglycemia, as the effect of a pre-defined glucose-lowering intervention was not assessed in the study.

The SHINE trial did not find a benefit of intensive glucose control (target 80 to 130 mg/dL) compared with standard treatment (target 80 to 179 mg/dL) on favorable functional outcome at 90 days. [7] () Modern AHA/ASA guidance therefore does not recommend intensive glucose lowering to 80–130 mg/dL to improve functional outcome, although treatment of significant hyperglycemia and avoidance of hypoglycemia are clinically important. [8] (American Heart Association/American Stroke Association)

Our findings therefore support the use of glycemic assessment as a marker of clinical severity, but not aggressive glucose lowering as a treatment strategy. This distinction is important because the observed association between hyperglycemia and stroke severity does not imply that hyperglycemia is a modifiable mediator of neurologic injury.

There is a possible biological link between hyperglycemia and ischemic brain injury. Hyperglycemia may lead to oxidative stress, endothelial dysfunction, inflammatory activity, and tissue acidosis in ischemic tissue, which may contribute to cellular injury and impaired recovery. The association of increased stress hyperglycemia ratio with poor outcomes seen in large observational cohorts provides additional support for the possibility that acute metabolic stress represents an important component of the systemic response to severe stroke. [4,10,11] ()

The study also has relevance to resource-limited hospital settings. RBS, FBS and HbA1c are widely available investigations and can be obtained early during hospitalization. Their association with NIHSS may help clinicians recognize patients with a greater burden of metabolic abnormality. However, these parameters should be considered alongside established measures of stroke severity, imaging findings and other clinical characteristics rather than used as standalone prognostic tools.

Strengths and Limitations

Strengths

1. The study evaluated both acute and longer-term glycemic parameters.
2. Neurological severity was assessed using the standardized NIHSS.
3. NIHSS was documented at both admission and discharge.
4. The study included CT-confirmed acute cerebral infarction.
5. The analysis included separate assessment of RBS, FBS and HbA1c.

Limitations

1. The study was conducted at a single tertiary-care hospital and included only 100 participants, limiting generalizability.
2. The observational design permits identification of associations but does not establish causality.
3. The study did not assess long-term functional outcomes such as modified Rankin Scale at 90 days.
4. Stress hyperglycemia ratio was not calculated, despite increasing evidence supporting its use in stroke research.
5. The study did not perform multivariable regression to determine whether glycemic parameters were independently associated with NIHSS after adjustment for age, hypertension, diabetes and other potential confounders.
6. Treatment details concerning glucose management were not incorporated into the analysis.
7. The source thesis contains internal discrepancies in the recorded prevalence of diabetes and hypertension. These values were not artificially reconciled in this manuscript.
8. The thesis also contains inconsistent descriptions of the sampling method; therefore, a definitive sampling designation has not been imposed.
9. The study excluded cardioembolic and brainstem/cerebellar infarctions according to the original protocol, potentially limiting applicability to the broader acute ischemic stroke population.
10. Because NIHSS was measured only during hospitalization, the findings should not be interpreted as evidence of long-term prognosis.

Conclusion

Glycemic aberrations were common in this hospital-based study of 100 cases of acute ischemic stroke. 60% had RBS >200 mg/dL, 65% had FBS >126 mg/dL and 58% had HbA1c >8%. Higher categories of RBS, FBS and HbA1c were significantly associated with higher NIHSS score. Those with diabetes mellitus or stress hyperglycemia also had greater neurological severity than those classified as euglycemic.

Although the mean NIHSS significantly improved from admission to discharge, the observational design limits our ability to attribute this to effects of glycemic management. Overall, glycemic abnormalities seem to be clinically relevant markers of neurological severity in acute ischemic stroke, supporting early metabolic assessment as part of comprehensive stroke evaluation.

Conflict of interest

To be completed by the authors.

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To be completed by the authors.

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