Diabetes, Metabolic Syndrome and Obesity

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

# Glycemic Management of Patients with Hospital Hyperglycemia: A Retrospective Cohort Study on Adults Admitted in the Non-ICU Wards

Ruoxuan Zheng[1,2], Xiangman Zeng[1], Ruiting Shen[1], Yueqiu Wang[1], Jing Liu[1,3], Mingchen Zhang[1]

[1]Department of Endocrinology and Metabolism, Ningbo No.2 hospital, Ningbo, Zhejiang Province, People's Republic of China; [2]School of Medicine, Ningbo University, Ningbo, Zhejiang Province, People's Republic of China; [3]Cixi Biomedical Research Institute, Wenzhou Medical University, Ningbo, Zhejiang Province, People's Republic of China

Correspondence: Mingchen Zhang, Department of Endocrinology and Metabolism, Ningbo No.2 hospital, Ningbo, Zhejiang Province, People's Republic of China, Email zhangmc1015@163.com

**Purpose:** To identify the key populations for Hospital Hyperglycemia (HH) management and to assess recent trends in the management of HH.

**Patients and Methods:** This retrospective study analyzed 1,136,092 point-of-care blood glucose (POC-BG) measurements from 40,758 patients with HH in non-intensive care unit (non-ICU) wards at Ningbo No.2 hospital from January 2020 to December 2022. We compared glucose monitoring and management across varying years, age groups, and hospital departments.

**Results:** The overall incidence of HH was 16.87%. From 2020 to 2022, the number of patients with HH increased from 9,893 to 15,639, accompanied by a marginal improvement in average BG levels (slope difference, −8.137E-09 [CI, −8.742E-09 to −7.531E-09]; p <0.001). In the ≥80 years group, the median BG was 9.4 mmol/L, significantly higher than in other age groups (p<0.001). Hypoglycemia in this group was most frequently detected during nighttime and bedtime, with an incidence of 2.67%, significantly higher than at other times of the day (p<0.001). The daily POC-BG testing rate was significantly higher in the medical ward group than it in the surgical ward group (57.9% vs 51.7%, p<0.05). Proportions of glycemic targets days were 35.66% and 39.90% in the medical wards on day 1 and day 7, respectively (Day 7 39.90% vs Day 1 35.66%, p>0.05), and 46.16% and 45.07% in the surgical wards (Day 7 45.07% vs Day 1 46.16%, p>0.05), showing no significant improvements in glycemic control. Endocrinology consultations occurred at rates of 14.2% in the medical wards and 14.9% in the surgical wards (p>0.05).

**Conclusion:** Although the prevalence of HH is consistently high and the number of affected patients continues to rise, modest improvements in glycemic management have been observed. However, control among the elderly remains poor, with a notably high risk of hypoglycemia during nighttime and bedtime periods.

**Keywords:** hyperglycemia, glycemic management, glucose monitoring, hospitalization, diabetes mellitus

## Introduction

Hospital hyperglycemia (HH), defined as a blood glucose level exceeding 7.8 mmol/L (140 mg/dL) during hospitalization,[1] affects approximately 17.73% to 38% of patients in tertiary hospitals.[2–4] Extensive researches have confirmed that HH increases hospital patients' postoperative infection rates, healthcare costs, hospital stay duration, ICU admissions, and mortality risk, regardless of pre-existing diabetes status.[2,5–8]

According to the IDF 2021 Diabetes Map, China has the largest number of diabetic patients. There are 140 million diabetes patients and 170 million adults with impaired glucose tolerance in China.[9] However, the research on HH management is limited, especially in terms of large cohort studies. In order to identify the key populations for HH management and assess recent trends in its management, we conducted a retrospective analysis of glycemic control in 40,758 adult patients with HH between 2020 and 2022.

Received: 15 October 2024
Accepted: 31 December 2024
Published: 7 January 2025

# Materials and Methods

## Participants

This retrospective cohort study analyzed clinical data from 49,682 patients admitted to non-ICU wards, including 14 internal medicine wards, 18 surgical wards, and an endocrinology department, at Ningbo No.2 hospital between January 2020 and December 2022. Inclusion criteria: age ≥18 years; meeting the diagnostic criteria for HH; at least one POC-BG measurement during hospitalization. Exclusion criteria: age <18 years; hospital stay <1 day; subsequent hospitalization data for patients admitted more than once in the same year. A total of 40,758 patients with HH met the inclusion and exclusion criteria. This study was approved by the Ethics Committee of Ningbo No.2 hospital (No. YJ-NBEY-KY-2022-130-01). Individual informed consent was waived, as only anonymized data were used in this study, which was approved by the Ethics Committee of Ningbo No.2 hospital. Patients were classified as HH if any POC-BG readings >7.8 mmol/L (140 mg/dL) during their hospital stay.

## Data Collection

POC-BG measurements were performed using the OneTouch Verio Vue glucometer (Johnson & Johnson Co., Limited), and data were downloaded via the glycemic management platform. Glucose meters are calibrated regularly in accordance with the standards set by regulatory authorities. In addition, nurses responsible for blood glucose measurement have received training and undergo evaluations biannually. A total of 1,136,092 POC-BG measurements were collected from patients during the study period. HbA1c was measured by high-performance liquid chromatography (the Sysmex Glycohemoglobin Analyzer HLC-72SG8, Sysmex Corporation), Patient demographics, length of hospital stay, HbA1c levels, and endocrinology consultation data were extracted from the KingT Hospital Information System (HIS).

## Statistical Analysis

Data analysis was conducted on a "patient-day" basis, which represents each patient for each day of hospitalization. The average POC-BG value for each patient-day was calculated by summing all POC-BG measurements for that day and dividing by the total number of measurements. The overall average POC-BG values for different years, age groups, and departments were determined by summing the average POC-BG values for all patient-days within each group and dividing by the total number of measured-days. According to the American Diabetes Association (ADA) recommendations,[1] a "target glycemic day" was defined as a patient-day in which all POC-BG values were within the range of 3.9–10.0 mmol/L. A "hyperglycemic day" was defined as a patient-day with the highest POC-BG value >10 mmol/L, while a "hypoglycemic day" was defined as a patient-day in which the lowest POC-BG value is<3.9 mmol/L. The proportions of target glycemic days, hyperglycemic days, and hypoglycemic days were calculated as the respective ratios of these days to the total number of patient-days analyzed.

Graphs were created using GraphPad Prism version 10. Data analysis was conducted using SPSS version 26.0 (SPSS Inc). Results are presented as counts (n) and percentages (%), means ± standard deviations (SD), or medians and interquartile ranges, as appropriate. Categorical data were analyzed using the chi-square test, while continuous data were analyzed using one-way ANOVA or the Mann–Whitney *U*-test, as applicable. A p-value <0.05 was considered statistically significant.

# Results

## Glycemic Management Across Different Admission Years

The overall incidence of hospital hyperglycemia (HH) was 16.87%. The mean age was 65.32±13.41 years, with 40.5% of patients aged ≥70 years and 13.0% aged ≥80 years. Patients were divided into three groups based on the year of admission: the incidence of HH was 13.96% in 2020 (n=9,893), 18.29% in 2021 (n=15,226), and 17.88% in 2022 (n=15,639). The median frequency of POC-BG monitoring was 3 times per day across all three groups. The proportion of POC-BG monitoring days increased annually, reaching 55.0%, 56.4% and 58.0%, respectively (p<0.001). No significant differences were observed in the glycated hemoglobin (HbA1c) testing rates across the three groups, with rates of 54.2%, 54.6%, and 55.4%, respectively.

The median BG levels and interquartile ranges (IQR) for the three groups were 9.5 mmol/L (IQR 8.1–11.3 mmol/L), 9.2 mmol/L (IQR 7.9–11.0 mmol/L), and 9.1 mmol/L (IQR 7.8–10.9 mmol/L), respectively (p<0.001). HbA1c values were 7.2% (±2.0%), 7.1% (±1.9%), and 7.3% (±2.0%) for each year (p<0.001). Endocrinology consultation rates were 14.3%, 14.1%, and 15.4% for each respective year (p=0.006) (Table 1).

Figure 1A illustrates the annual distribution of the proportions of hyperglycemic days across distinct glucose thresholds for 2020, 2021, and 2022. In 2022, the proportions of days with glucose levels >10 mmol/L, >15 mmol/L, >20 mmol/L, and >25 mmol/L were 57.17%, 19.57%, 4.94%, and 1.11%, respectively, representing the lowest rates among the cohorts. (p < 0.001).

The proportions of hypoglycemic days (<3.9 mmol/L) and severe hypoglycemia (<3.0 mmol/L) were 1.70% and 0.38% for 2020, 1.69% and 0.36% for 2021, and 1.64% and 0.31% for 2022, respectively, with no significant differences (p > 0.05) shown in Figure 1B.

In the 2020 group, the proportion of target glycemic days increased from 36.0% on the first measurement day to 37.34% on the seventh day. Similarly, in the 2021 group, it rose from 40.85% to 41.38%, and in the 2022 group, it increased from 42.31% to 43.52%. The median BG levels decreased over the three-year period, but the proportion of glycemic target days during hospitalization did not significantly increase with the number of measurement days across three groups (p>0.05) (Figure 1C).

The average BG of patients with HH showed slight improvement during the study period, as illustrated in Figure 1D (slope difference, −8.137E-09 [CI, −8.742E-09 to −7.531E-09]; p<0.001).

**Table 1** Characteristics of Patients with HH and Glucose Management Across Various Years

| | 2020 | 2021 | 2022 | P value |
|---|---|---|---|---|
| N | 9893 | 15226 | 15639 | |
| HH rate (%) | 13.96 | 18.29 | 17.88 | |
| POCT measurements | 73,455 | 108,854 | 107,270 | |
| N (≥70years) (%) | 4406(44.5) | 6184(40.6) | 5903(37.7) | **<0.001** |
| Male sex (%) | 5844(59.1) | 8859(58.2) | 9123(58.3) | 0.347 |
| Age(years) | 66.9±13.5 | 65.2±13.4* | 64.4±13.3*† | **<0.001** |
| Admission ward (%) | | | | **<0.001** |
| Medical | 3314(33.5) | 5682(37.3) | 6147(39.3) | |
| Surgical | 5363(54.2) | 7732(50.8) | 7573(48.4) | |
| Endocrinology | 1216(12.3) | 1813(11.9) | 1919(12.3) | |
| Mean length of stay(days) | 9(6,15) | 9(6,14) * | 8(5,14) *† | **<0.001** |
| Capillary glucose | | | | |
| Measurements/day | 3(2,4) | 3(2,4) * | 3(2,4) *† | **<0.001** |
| Measured-day rate (%) | 55.0 | 56.4* | 58.0*† | **<0.001** |
| BG value (mmol/L) | 9.5 (8.1,11.3) | 9.2 (7.9,11.0) * | 9.1 (7.8,10.9) *† | **<0.001** |
| HbA1c | | | | |
| Measurement rate (%) | 5478(55.4) | 8308(54.6) | 8480(54.2) | 0.195 |
| Value (%) | 7.2±2.0 | 7.1±1.9* | 7.3±2.0† | **<0.001** |
| Endocrinology consultation | | | | **0.006** |
| Consultation rate (%) | 14.3 | 14.1 * | 15.4*† | |
| Number | 1238 | 1885* | 2107 *† | |

**Notes**: Data are presented as the means±SD, percentages or medians (25th to 75th percentiles). Bolded p-values indicate statistically significant differences. *p < 0.05 for vs 2020, indicating statistical significance after adjusting for multiple comparisons. †p < 0.05 for vs 2021, indicating statistical significance after adjusting for multiple comparisons.

**Abbreviations**: N(HH), number of inpatients with HH; N(≥70years), number of inpatients with HH over the age of 70; HH rate, percentage of inpatients with HH among total hospitalizations;HbA1c, hemoglobin A1c; BG value, blood glucose value.


https://doi.org/10.2147/DMSO.S501132

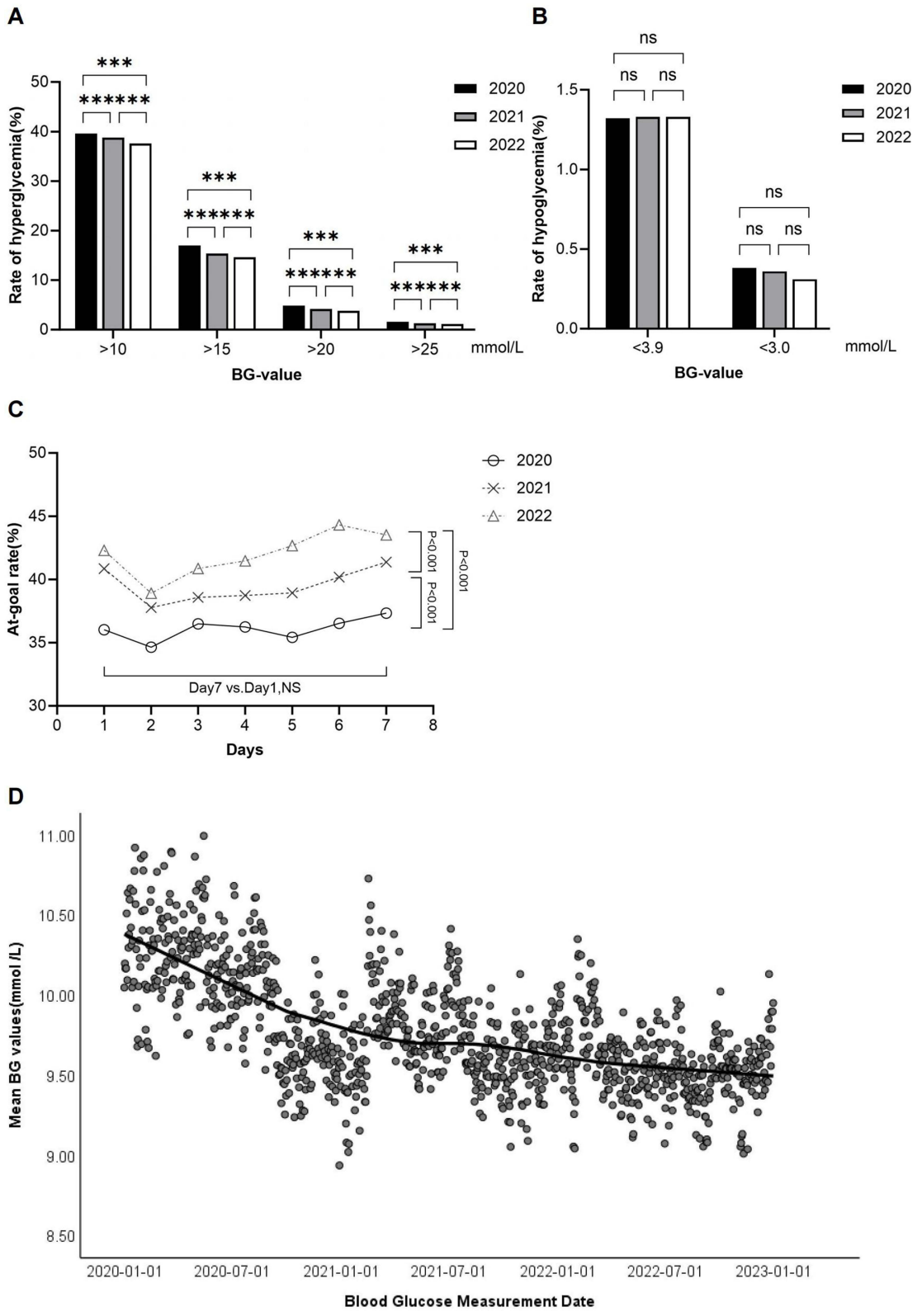


**Figure 1** (**A**) Rate of hyperglycemia in different years of each cutoff point (>10, >15, >20, >25 mmol/L). (**B**)Rate of hypoglycemia in different years of each cutoff point (<3.9, <3.0mmol/L). (**C**) Trend of at-goal rates in different years with increasing number of days. There is no statistically significant difference in the at-goal rate on the 7th day compared to the 1st day.(**D**) Trends in mean blood glucose values over time. *** $p < 0.001$.

## Glycemic Management of Patients Across Different Ages

Patients were categorized by age into five groups: 18–49 years (n=4628), 50–59 years (n=8049), 60–69 years (n=11588), 70–79 years (n=11804), and ≥80 years (n=5289). The average length of hospital stay for the 70–79 years and ≥80 years groups was 10 days significantly longer than that of the other age groups (p<0.001).

The median daily frequency of POC-BG monitoring for each age group was 3 (IQR 2–4 times). The proportions of days with POC-BG monitoring were 51.2%, 54.4%, 56.7%, 58.4%, and 59.5% for the 18–49, 50–59, 60–69, 70–79, and ≥80 years groups, respectively (p<0.001). The HbA1c testing rates for the 18–49, 50–59 and 60–69 years groups were 50.6%, 53.7%, and 53.7%, respectively, rising to 55.5% in the 70–79 years group and 59.8% in the ≥80 years group (p<0.001).

Median BG levels increased with age. For the 70–79 and ≥80 years groups, BG levels were 9.3 mmol/L (IQR 8.0–11.0 mmol/L) and 9.4 mmol/L (IQR 8.0–11.3 mmol/L) respectively, significantly higher than those in the 18–49, 50–59, 60–69 years groups, where BG levels were 9.0 mmol/L (IQR 7.7–10.9 mmol/L), 9.2 mmol/L (IQR 7.9–11.0 mmol/L), and 9.2 mmol/L (IQR 8.0–11.0 mmol/L), respectively (p<0.001). Endocrinology consultation rates were 14.6%, 14.9%, 14.4%, 14.8%, and 14.3% for the respective age groups, with no statistically significant differences (p>0.05) (Table 2).

The proportion of hyperglycemic days with glucose levels >10 mmol/L was 60.51% in the ≥80 years group and 60.63% in the 70–79 years group, both significantly higher than those in the other three groups (56.16%, 58.69%,and 59.52% respectively) (p<0.001). In the ≥80 years group, the proportion of days with BG levels >15 mmol/L was 21.36%, significantly higher than the 20.61% in the 70–79 years group (p<0.001). (Figure 2A).

The proportion of hypoglycemic days (<3.9 mmol/L) was 1.86% in the ≥80 years group, significantly higher than 1.63% in the 50–59 years group, 1.60% in the 60–69 years group, and 1.65% in the 70–79 years group (p<0.01). The proportion of severe hypoglycemia (<3.0 mmol/L) was 0.46% in the ≥80 years group, higher than 0.34% in the 50–59 years group, 0.32% in the 60–69 years group, and 0.33% in the 70–79 years group (p<0.01). Additionally, in the ≥80 years group, hypoglycemia was most frequently detected at nighttime and bedtime POC-BG measurements, with a rate of 2.67%, significantly higher than at other times of the day (p<0.01). (Figure 2B and C).

**Table 2** Characteristics of Patients with HH and Glucose Management Across Various Age Groups

| | **18–49** | **50–59** | **60–69** | **70–79** | **≥80** | **P value** |
|---|---|---|---|---|---|---|
| N | 4628 | 8049 | 11588 | 11204 | 5289 | |
| POCT measurements | 26408 | 51736 | 81515 | 86559 | 43361 | |
| Male sex (%) | 3048(65.9) | 4939(61.4) | 6877(59.3) | 6109(54.5) | 2852(53.9) | **<0.001** |
| Admission ward (%) | | | | | | **<0.001** |
| Medical | 1436(31) | 2841(35.3) | 4185(36.1) | 4209(37.6) | 2472(46.7) | |
| Surgical | 1985(42.9) | 3875(48.1) | 6153(53.1) | 6142(54.8) | 2512(47.5) | |
| Endocrinology | 1207(26.1) | 1333(16.6) | 1250(10.8) | 853(7.6) | 305(5.8) | |
| Length of stay (days) | 8(5,12) | 8(5,13) | 9(6,14) | 10(6,15) | 10(6,15) | **<0.001** |
| Capillary glucose | | | | | | |
| Measurements/day | 3(2,4) | 3(2,4) | 3(2,4) | 3(2,4) | 3(2,4) | **<0.001** |
| Measured-day rate (%) | 51.2 | 54.4 | 56.7 | 58.4 | 59.5 | **<0.001** |
| BG value (mmol/L) | 9.0(7.7,10.9) | 9.2 (7.9,11.0) | 9.2(8.0,11.0) | 9.3(8.0,11.0) | 9.4(8.0,11.3) | **<0.001** |
| HbA1c | | | | | | |
| Measurement rate (%) | 2344(50.6) | 4321(53.7) | 6223(53.7) | 6216(55.5) | 3162(59.8) | **<0.001** |
| Value (%) | 7.8±2.7 | 7.3±2.1 | 7.1±1.8 | 7.0±1.7 | 7.0±1.7 | **<0.001** |
| Endocrinology consultation | | | | | | 0.855 |
| Consultation rate (%) | 14.6 | 14.9 | 14.4 | 14.8 | 14.3 | |
| Number | 501 | 999 | 1491 | 1528 | 711 | |

**Notes**: Data are presented as the means±SD, percentages or medians (25th to 75th percentiles). Bolded p-values indicate statistically significant differences.

**Abbreviations**: N(HH), number of inpatients with HH;HbA1c, hemoglobin A1c; BG value, blood glucose value.


https://doi.org/10.2147/DMSO.S501132

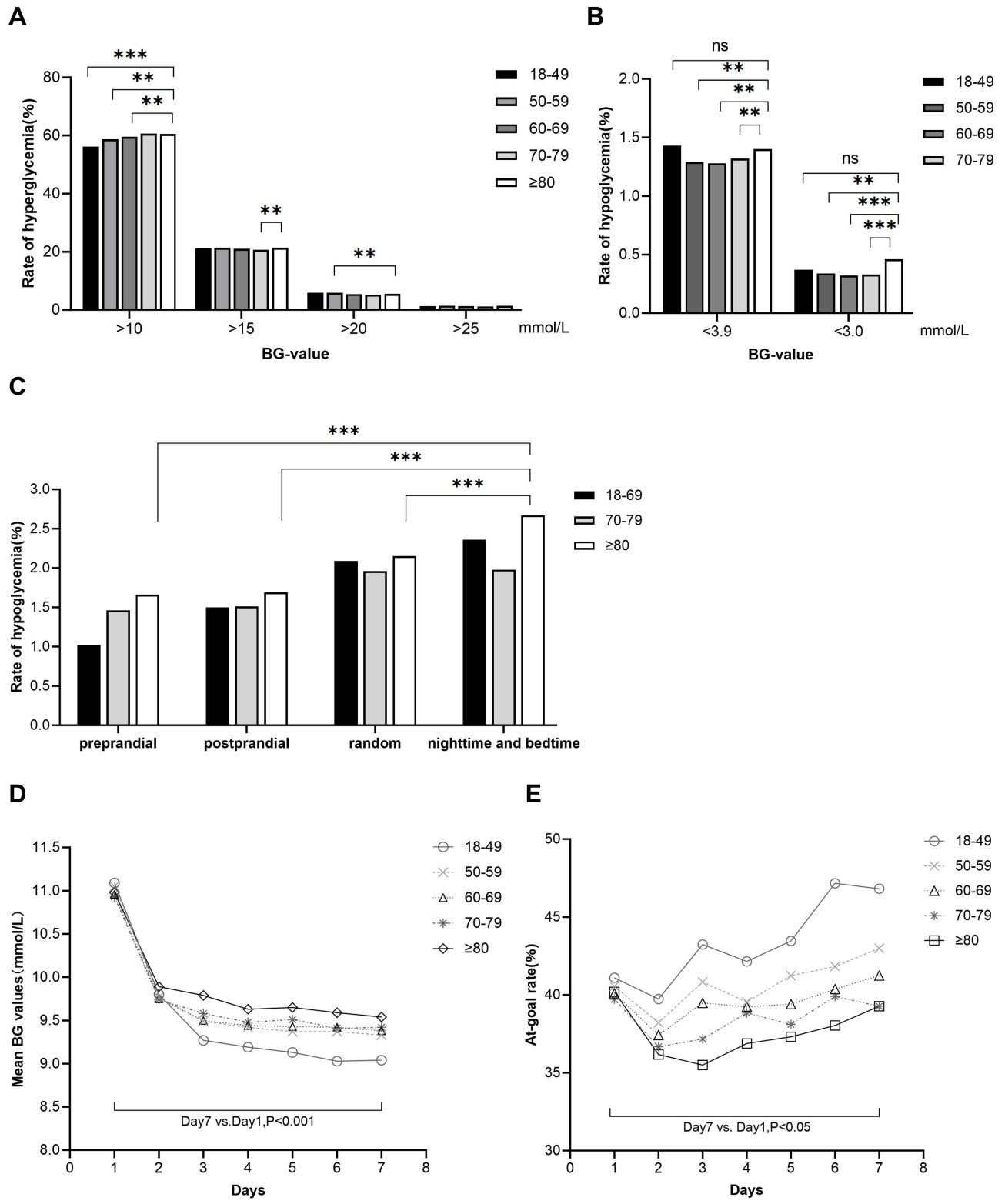


**Figure 2** (**A**)Rate of hyperglycemia in different age groups of each cutoff point (>10, >15, >20, >25mmol/L). (**B**)Rate of hypoglycemia in different age groups of each cutoff point (<3.9, <3.0mmol/L). (**C**) Hypoglycemia rates in different age groups during various POC-BG test times. (**D**) Trend of mean BG values in different age groups with increasing number of days. (**E**) Trend of at-goal rates in different age groups with increasing number of days.** $p < 0.01$,*** $p < 0.001$.

In the ≥80 years group, the BG level on day 1 of measurement was 10.98 mmol/L, which decreased to 9.54 mmol/L by the day 7, showing the smallest reduction among all groups (p<0.001). The proportion of glycemic target days slightly declined with the increasing number of measurement days in both the 70–79 years group and the ≥80 years group. In the 70–79 years group, the proportion decreased from 39.72% on day 1 to 39.27% on day 7 (p<0.05), while in the ≥80 years group, it decreased from 40.19% to 39.28% (p<0.01) (Figure 2D and E).

## Glycemic Management Across Different Departments

Patients were divided into three groups based on their admission departments: non-endocrine internal medicine group (n=15,143), surgical group (n=20,667), and endocrinology group (n=4,948). The average ages for the three groups were 66.8 years (±13.4), 65.9 years (±12.6), and 66.8 years (±13.4); the proportion of patients aged over 70 were 44.1%, 41.9%, and 23.4% respectively. (p<0.001).

The median daily BG monitoring frequency was 3 times in both medical and surgical groups (p<0.05), whereas it was 6 times in the endocrinology group. The proportion of POC-BG monitored days was 57.9% in the medical group, significantly higher than 51.7% in the surgical group (p<0.05), and substantially lower than 90.9% in the endocrinology group. Additionally, the HbA1c testing rate was 66.7% in the medical group, significantly higher than 42.5% in the surgical group (p<0.05), and comparable to 68.2% in the endocrinology group.

The median average BG in the medical group was 9.4 mmol/L (IQR 8.0–11.4 mmol/L), significantly higher than 9.0 mmol/L (IQR 7.7–10.7 mmol/L) in the surgical group (p<0.05). The average HbA1c levels were 6.9±1.7% in both groups, with no statistically significant difference (p>0.05). The endocrinology consultation rates were similar between the two groups, at 14.2% and 14.9%, respectively (p>0.05) (Table 3).

In the medical group, the proportions of daily monitoring frequencies <4, =4, and >4 were 60.05%, 34.76%, and 5.19%, respectively. In the surgical group, these proportions were 68.96%, 24.23%, and 6.81%. In the endocrinology group, they were 27.77%, 11.3%, and 60.93%. Overall, the daily monitoring frequency in the medical group was higher than that in the surgical group (Figure 3A).

**Table 3** Characteristics of Patients and Glucose Management Across Various Admission Departments

| | Medical | Surgical | Endocrinology | P value |
|---|---|---|---|---|
| N (HH) | 15143 | 20667 | 4948 | |
| POCT measurements | 108059 | 149643 | 31878 | |
| Male sex (%) | 9043(59.7) | 11829(57.2) * | 2953(59.7) † | **<0.001** |
| Age(years) | 66.8±13.4 | 65.9±12.6* | 58.4±14.6*† | **<0.001** |
| N (≥70years) (%) | 6681(44.1) | 8654(41.9) * | 1158(23.4) *† | **<0.001** |
| Mean length of stay(days) | 8(5,11) | 9(6,15) * | 6(5,7) *† | **<0.001** |
| Capillary glucose | | | | |
| Measurements/day | 3(2,4) | 3(2,4) * | 5(3,6) *† | **<0.001** |
| Measured-day rate (%) | 57.9 | 51.7* | 90.9*† | **<0.001** |
| BG value (mmol/L) | 9.4(8.0,11.4) | 9.0 (7.7,10.7) * | 9.9 (8.6,11.2) *† | **<0.001** |
| HbA1c | | | | |
| Rate of measurement (%) | 10098(66.7) | 11875(42.5) * | 3375(68.2) *† | **<0.001** |
| Value (%) | 6.9±1.7 | 6.9±1.7 | 8.6±2.5*† | **<0.001** |
| Endocrinology consultation (%) | | | | 0.054 |
| Consultation rate (%) | 14.2 | 14.9 | NA | |
| Number | 2148 | 3082 | NA | |

**Notes**: Data are presented as the means±SD, percentages or medians (25th to 75th percentiles). Bolded p-values indicate statistically significant differences. *p < 0.05 for vs medical wards, indicating statistical significance after adjusting for multiple comparisons. †p < 0.05 for vs surgical wards, indicating statistical significance after adjusting for multiple comparisons.

**Abbreviations**: N(HH), number of inpatients with HH; N(≥70years), number of inpatients with HH over the age of 70;HbA1c, hemoglobin A1c; BG value, blood glucose value.


https://doi.org/10.2147/DMSO.S501132

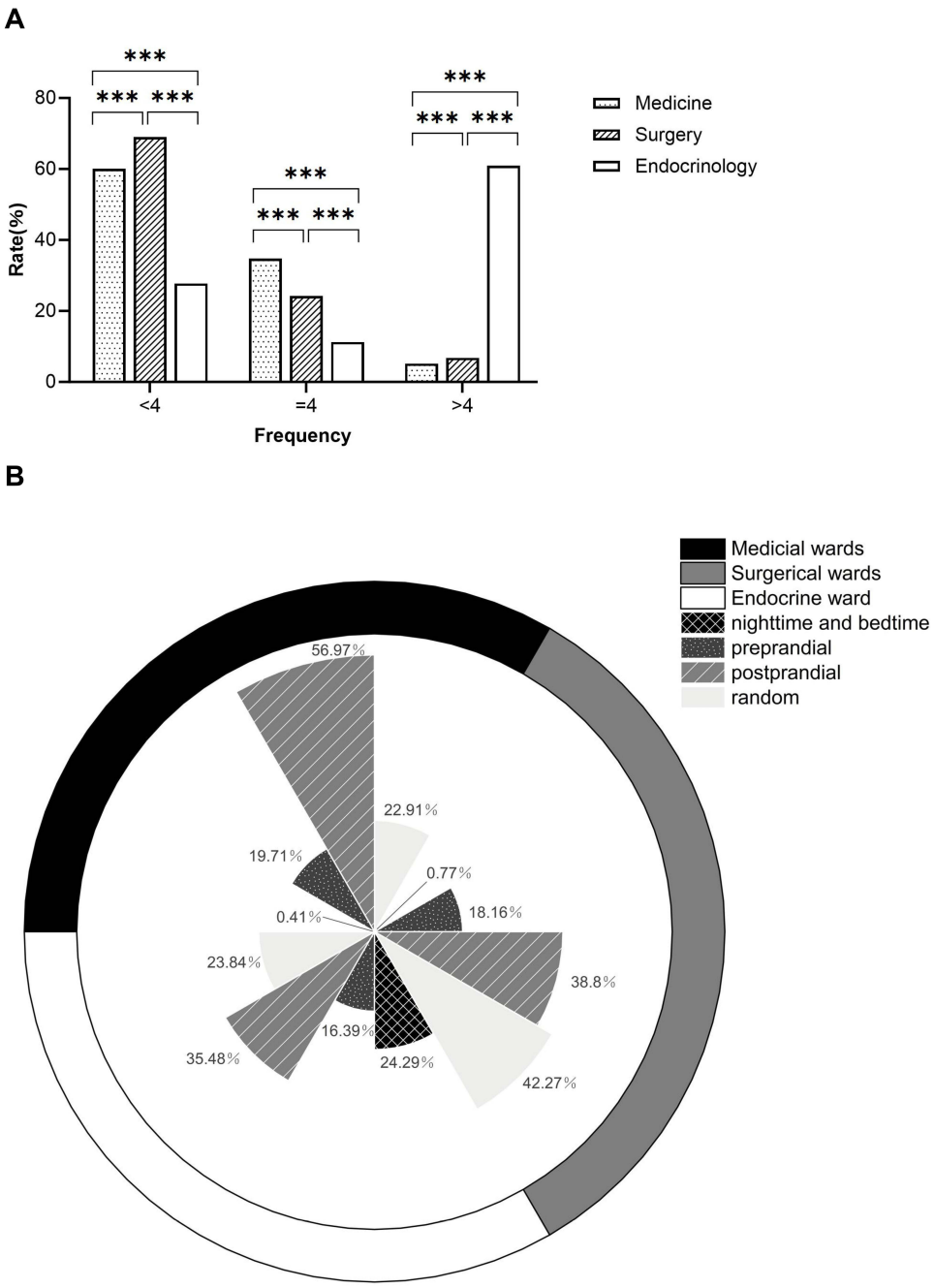


**Figure 3** (**A**) Proportion of patient-days with POC-BG testing <4, =4 and >4 times in different ward groups. (**B**) Proportion of POC-BG testing at different times (preprandial, postprandial, random,nighttime and bedtime) in different ward groups. *** $p < 0.001$.

In the medical group, postprandial monitoring was the most common, accounting for 56.97%, while nighttime and bedtime monitoring were the least frequent, comprising only 0.41%. In the surgical group, random glucose monitoring was predominant, representing 42.27% of measurements, while nighttime and bedtime monitoring being the least frequent at 0.77%. The endocrinology group demonstrated a more balanced distribution of glucose monitoring times, with postprandial monitoring being most common at 35.48%; nighttime and bedtime monitoring accounted for 24.29%, significantly higher than other groups ($p<0.001$) (Figure 3B).

In the medical group, the proportions of days with BG levels >10, >15, >20, and >25 mmol/L were 62.85%, 24.00%, 6.75%, and 1.72%, respectively, significantly higher than those in the surgical group, which were 53.97%, 16.69%,

3.86%, and 0.80% (p<0.001). The endocrinology group recorded the highest hyperglycemia rates across all thresholds, with proportions of 74.50%, 31.13%, 9.05%, and 2.21%, respectively (p<0.001) (Figure 4A).

The proportions of hypoglycemia days (<3.9 mmol/L) and severe hypoglycemia days (<3.0 mmol/L) were 1.73% and 0.41% in the medical group, significantly higher than 1.52% and 0.32% in the surgical group (p<0.001). Incidence of hypoglycemia was highest in the endocrinology group, at 2.25% for hypoglycemia and 0.30% for severe hypoglycemia. Hypoglycemia during random glucose monitoring was most frequent in the medical group at 2.69%, significantly higher than the surgical group's 1.69% ($p < 0.001$). Nighttime and bedtime hypoglycemia was most common in the surgical group, with an incidence of 3.22%. Additionally, the endocrinology group had the highest incidence of hypoglycemia during random monitoring times, with a rate of 3.07% (Figure 4B and C).

The mean POC-BG values in the medical group decreased from 11.18 mmol/L on day 1 to 9.75 mmol/L on day 7, showing a reduction of 12.8% (p<0.001). In the surgical group, the mean POC-BG values decreased from 10.53 mmol/L on day 1 to 9.16 mmol/L on day 7, showing a reduction of 13.0% (p<0.001). No significant difference in the reduction was observed between the two groups. The endocrinology group showed a greater reduction of 25.0%, with POC-BG values decreasing from 12.30 mmol/L on day 1 to 9.22 mmol/L on day 7 ($p < 0.001$). Regarding the proportion of glycemic target days, the medical group had 46.16% on day 1 and 45.07% on day 7, with no statistically significant difference observed between day 1 and day 7 ($p > 0.05$). The surgical group had 35.66% on day 1 and 39.90% on day 7, also showing no significant change between day 1 and day 7 ($p > 0.05$). In contrast, the endocrinology group experienced a significant increase in the proportion of glycemic target days, rising from 20.88% on day 1 to 36.29% on day 7 ($p < 0.001$).(Figure 4D and E).

## Discussion

This study analyzed the POC-BG data of 40,758 hH patients in non-ICU wards of a tertiary hospital in China from 2020 to 2022. The findings reveal a high incidence of HH, with a rapidly increasing number of HH patients. Although overall glycemic management has shown slight improvements, it remains suboptimal in both medical and surgical departments, and the involvement of endocrinologists in managing HH has been insufficient. Notably, patients over 80 years old exhibited the highest incidence of both the proportion of hyperglycemia and hypoglycemia days, yet did not receive adequate attention.

During the study period, the overall incidence of HH was 16.87%, with the number of patients increasing from 9,893 to 15,639. This upward trend may be associated with the increasing number of hospitalized patients and the rising prevalence of diabetes. The study indicates that the average BG level for patients with HH over three years was 9.74 mmol/L, with the proportion of target day comprising 28.5% of the overall period. The findings are consistent with the previous studies. Domestic studies have shown an average BG level of 9.72 mmol/L and a target day proportion of 26.38% for HH patients,[10] while international studies have reported average BG levels of 8.94–9.50 mmol/L[11] and the proportion of glycemic target days was 28.6%[12] for non-ICU hospitalized patients. Thus, there is a clear need to prioritize improving HH management in clinical practice.

In China, the prevalence of diabetes mellitus is 23.9% among those aged 60–69 and 27.3% in those aged ≥70 years.[13] In this study, the average age of HH patients was 65.32 years, with 28.4% aged 60–69 years, 27.4% aged 70–79 years, and 13.0% aged ≥80 years. The median BG level for patients aged ≥80 was 9.4 mmol/L, underscoring the challenge of managing glucose levels in older populations. Our findings indicate that hyperglycemia (>10mmol/L) was occurred on 60.51% of days, while hypoglycemia (<3.9mmol/L) observed on 1.86% of days. In addition to the high incidence of hyperglycemia in elderly HH patients, those aged ≥80 had the highest incidence of nighttime and bedtime hypoglycemia. However, these monitoring times accounted for only 2.2% of the total BG monitor. Other studies have shown that among inpatients with a mean age of 73.1±12.5 years, 7.2% experienced hypoglycemia, with 41.2% of these episodes occurring at night.[14] These all underscore the need for enhanced management of nocturnal hypoglycemia in hospitalized patients, especially in elderly patients. Currently, there is limited literature on the glycemic management and glucose monitoring in elderly patients with HH. Elderly patients with diabetes, particularly those with a long duration of the disease, are at a higher risk of hypoglycemia due to the use of sulfonylureas and insulin. Additionally, elderly individuals are more susceptible to severe cardiovascular events triggered by hypoglycemia;[15,16] and the decline in sympathetic nervous

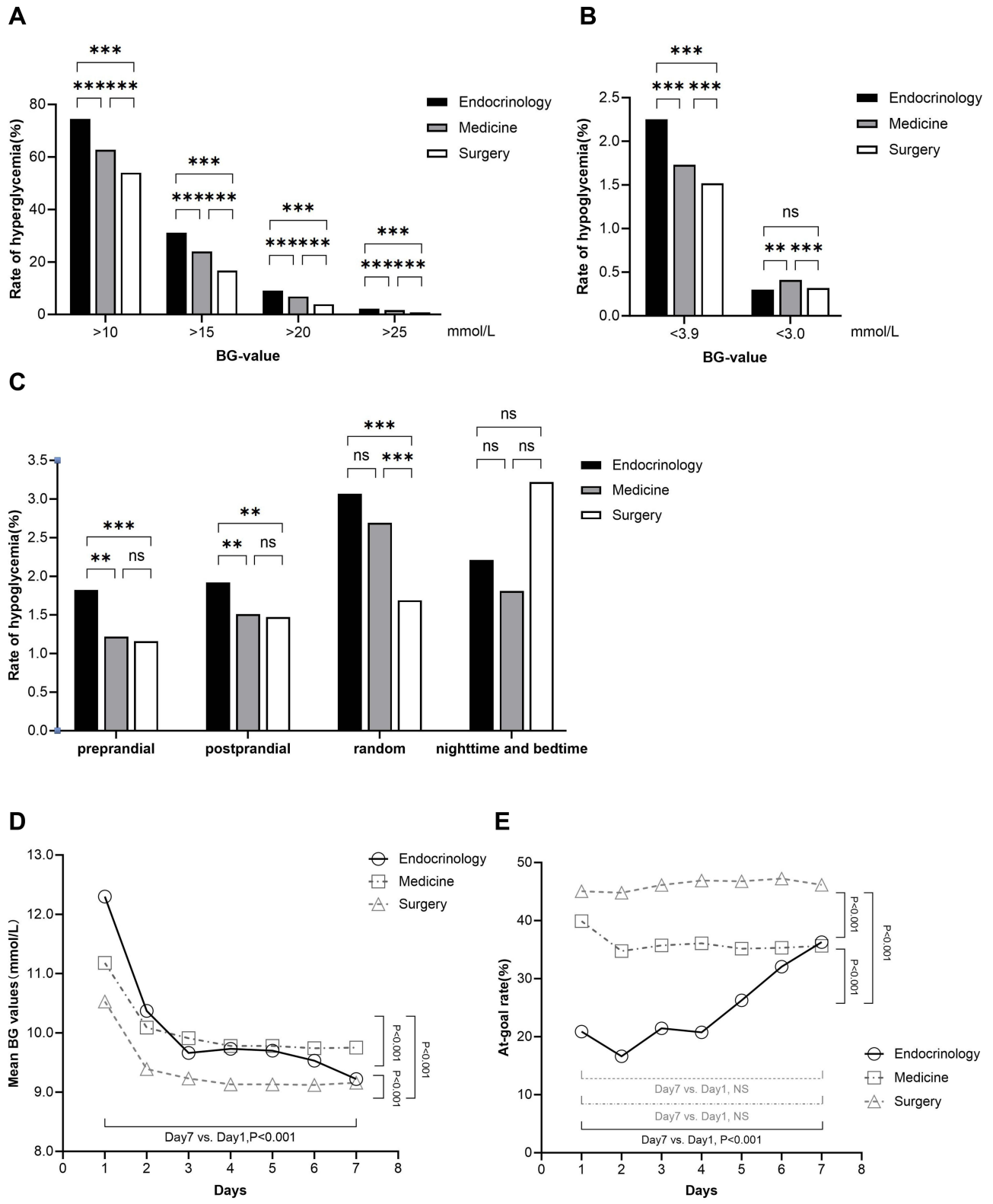


**Figure 4** (**A**)Rate of hyperglycemia in different ward groups of each cutoff point (>10, >15, >20, >25mmol/L). (**B**)Rate of hypoglycemia in different ward groups of each cutoff point (<3.9, <3.0mmol/L). (**C**) Hypoglycemia rates in different ward groups during various POC-BG test times. (**D**) Trend of mean BG values in different ward groups with increasing number of days. (**E**) Trend of at-goal rates in different ward groups with increasing number of days.** $p < 0.01$,*** $p < 0.001$.

system function in this population can easily lead to hypoglycemic coma.[17–22] Therefore, it is crucial to focus on glucose monitoring for elderly patients with HH, particularly during nighttime and bedtime periods. Our study showed patients aged over 80 years exhibited the highest incidence of both hyperglycemia and hypoglycemia days. However, the endocrinology consultation rate for these elderly HH patients was only 14.3%, highlighting a significant gap in their glycemic management.

Studies suggest that over 80% of hospitalized hyperglycemia patients are admitted to non-endocrinology departments due to primary diseases or diabetes-related complications.[23] In our study, 87.9% of hospitalized hyperglycemia patients were treated in non-endocrinology departments. The proportions of patient-days with <4 blood glucose monitoring frequencies were 60.05% and 68.96% in the medical and surgical groups, respectively. A cross-sectional study of 5790 patients with HH found that the frequencies of <4 times BG monitoring in the medicinal and surgical departments of the hospital were 54.01% and 63.83%, respectively.[10] Furthermore, our study showed no improvement of glucose levels in both internal and surgical wards for patients with HH during their hospitalization. These findings indicate significant challenges in the glycemic management of patients with HH in both medical and surgical wards. The rate of endocrinology consultations was less than 15%, and due to the limited number of endocrinologists, achieving improvements in HH management through increased consultations is less likely.

Current literatures increasingly support the integration of blood glucose monitoring systems (BGMS) and artificial intelligence (AI)-driven algorithms as transformative tools in the management of HH. Studies have demonstrated that BGMS not only facilitates increased involvement of endocrinologists in hospital-wide glycemic management but also effectively reduces average BG levels and the incidence of adverse glucose events.[24,25] Further, AI-developed algorithm systems offer various forms of glycemic management, including risk stratification for hypoglycemia using validated risk calculators[26] and reducing insulin dose errors through computerized insulin dosing systems,[27] improving target BG rates without increasing hypoglycemia incidence[19,28]. Future research should focus on longitudinal studies to assess the long-term impacts of these technologies on patient outcomes and healthcare systems.

This study utilized large sample data to comprehensively analyze the glycemic management status of HH patients over three consecutive years. However, the study excluded critically ill and emergency patients, did not differentiate HH patients with diabetic and stress-induced hyperglycemia, and lacked a detailed discussion of treatment plans.

## Conclusion

Although the prevalence of hyperglycemia in hospital is consistently high and the number of affected patients continues to rise, slight improvements in blood glucose management have been observed. In the elderly, however, glycemic control remains poor, with a particularly high risk of hypoglycemia during the night and in bed.

Future initiatives should prioritize the development of BGMS, and the integration of AI-based systems could substantially enhance the management of HH.

## Data Sharing Statement

The data generated during the current study are available from the corresponding author Mingchen Zhang to zhangmc1015@163.com with publication after approval of a proposal.

## Ethics Approval and Informed Consent

This study was approved by the Ethics Committee of Ningbo No.2 hospital (No. YJ-NBEY-KY-2022-130-01). Individual informed consent was waived, as only anonymized data were used in this study, which was approved by the Ethics Committee of Ningbo No.2 hospital. The study adhered to the principles outlined in the Declaration of Helsinki.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

## Funding

This study was supported by National Natural Science Foundation of China (No. 72274189) and Ningbo Public Service Technology Foundation (No. 2022S046). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Disclosure

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

## References

1. ElSayed NA, Aleppo G, Aroda VR, et al. 16. Diabetes care in the hospital: standards of care in diabetes-2023. *Diabetes Care*. 2023;46(Suppl 1): S267–S278. doi:10.2337/dc23-S016
2. Seisa MO. A systematic review supporting the endocrine society clinical practice guideline for the management of hyperglycemia in adults hospitalized for noncritical illness or undergoing elective surgical procedures. *J Clin Endocrinol Metab*. 2022;107:2139–2147.
3. Momesso DP, Costa RC, Costa JLF, et al. Impact of an inpatient multidisciplinary glucose control management program. *Arch Endocrinol Metab*. 2018;62(5):514–522. doi:10.20945/2359-3997000000071
4. Umpierrez GE, Isaacs SD, Bazargan N, You X, Thaler LM, Kitabchi AE. Hyperglycemia an independent marker of in-hospital mortality in patients with undiagnosed diabetes. *J Clin Endocrinol Metab*. 2002;87:978–982. doi:10.1210/jcem.87.3.8341
5. Korytkowski MT, Muniyappa R, Antinori-Lent K, et al. Management of hyperglycemia in hospitalized adult patients in non-critical care settings: an endocrine society clinical practice guideline. *J Clin Endocrinol Metab*. 2022;107(8):2101–2128. doi:10.1210/clinem/dgac278
6. Pasquel FJ, Lansang MC, Dhatariya K, Umpierrez GE. Management of diabetes and hyperglycaemia in the hospital. *Lancet Diabetes Endocrinol*. 2021;9(3):174–188. doi:10.1016/S2213-8587(20)30381-8
7. Kyi M, Wang J, Fourlanos S. Increased hyperglycemia and hospital-acquired infections following withdrawal of the RAPIDS early intervention model of diabetes care in medical and surgical inpatients. *Diabetes Care*. 2021;44(2):e25–e26. doi:10.2337/dc20-2469
8. Kesavadev J, Misra A, Saboo B, et al. Blood glucose levels should be considered as a new vital sign indicative of prognosis during hospitalization. *Diabetes Metab Syndr*. 2021;15(1):221–227. doi:10.1016/j.dsx.2020.12.032
9. IDF Diabetes Atlas 10th edition. 2021 Available from: https://diabetesatlasorg/. Accessed January 03, 2025.
10. Sun X, Gui M, Huang H, et al. Investigation of daily glucose profile of inpatients in non-endocrinology Departments in Chinese Population. *Front Public Health*. 2020;8:8. doi:10.3389/fpubh.2020.00008
11. Swanson CM, Potter DJ, Kongable GL, Cook CB. Update on inpatient glycemic control in hospitals in the United States. *Endocr Pract*. 2011;17 (6):853–861. doi:10.4158/EP11042.OR
12. Moreira ED, Silveira PCB, Neves RCS, Souza C, Nunes ZO, Almeida MDCC. Glycemic control and diabetes management in hospitalized patients in Brazil. *Diabetol Metab Syndr*. 2013;5(1):62. doi:10.1186/1758-5996-5-62
13. Wang L, Peng W, Zhao Z, et al. Prevalence and treatment of diabetes in China, 2013–2018. *JAMA*. 2021;326(24):2498. doi:10.1001/ jama.2021.22208
14. Dwyer P, Drinkwater JJ, Fegan PG, Davis WA, Davis TME. A prospective six-month audit of inpatient hypoglycemia in step-down general medical and geriatric wards. *Int J Med Sci*. 2021;18(16):3744–3747. doi:10.7150/ijms.63381
15. Khunti K, Davies M, Majeed A, Thorsted BL, Wolden ML, Paul SK. Hypoglycemia and risk of cardiovascular disease and all-cause mortality in insulin-treated people with type 1 and type 2 diabetes: a cohort study. *Diabetes Care*. 2015;38(2):316–322. doi:10.2337/dc14-0920
16. Wright RJ, Frier BM. Vascular disease and diabetes: is hypoglycaemia an aggravating factor? *Diabetes Metab Res Rev*. 2008;24(5):353–363. doi:10.1002/dmrr.865
17. Pleus S, Freckmann G, Schauer S, et al. Self-monitoring of blood glucose as an integral part in the management of people with type 2 diabetes mellitus. *Diabetes Ther*. 2022;13(5):829–846. doi:10.1007/s13300-022-01254-8
18. ElSayed NA, Aleppo G, Aroda VR, et al. 13. Older adults: standards of care in diabetes—2023. *Diabetes Care*. 2023;46(Supplement_1):S216–S229. doi:10.2337/dc23-S013
19. DeCarlo K, Wallia A. Inpatient management of T2DM and hyperglycemia in older adults. *Curr Diab Rep*. 2019;19(10). doi:10.1007/s11892-019-1209-3
20. Umpierrez GE, Pasquel FJ. Management of inpatient hyperglycemia and diabetes in older adults. *Diabetes Care*. 2017;40(4):509–517. doi:10.2337/ dc16-0989
21. Chia CW, Egan JM, Ferrucci L. Age-related changes in glucose metabolism, hyperglycemia, and cardiovascular risk. *Circ Res*. 2018;123 (7):886–904. doi:10.1161/CIRCRESAHA.118.312806
22. Zeyda M, Stulnig TM. Obesity, inflammation, and insulin resistance – a mini-review. *Gerontology*. 2009;55(4):379–386. doi:10.1159/000212758
23. Everett E, Mathioudakis N. Inpatient glycemic management of non-cardiac CVD: focus on stroke and PVD. *Curr Diab Rep*. 2018;18(8):49. doi:10.1007/s11892-018-1026-0
24. Sheen Y-J, Huang -C-C, Huang S-C, et al. Implementation of an electronic dashboard with a remote management system to improve glycemic management among hospitalized adults. *Endocr Pract*. 2020;26(2):179–191. doi:10.4158/EP-2019-0264
25. Rushakoff RJ, Sullivan MM, MacMaster HW, et al. Association between a virtual glucose management service and glycemic control in hospitalized adult patients. *Ann Intern Med*. 2017;166(9):621. doi:10.7326/M16-1413
26. Karter AJ, Warton EM, Lipska KJ, et al. Development and validation of a tool to identify patients with type 2 diabetes at high risk of hypoglycemia-related emergency department or hospital use. *JAMA Intern Med*. 2017;177(10):1461. doi:10.1001/jamainternmed.2017.3844
27. Ullal J, Aloi JA. Subcutaneous insulin dosing calculators for inpatient glucose control. *Curr Diab Rep*. 2019;19(11). doi:10.1007/s11892-019-1254-y
28. Davis GM, Galindo RJ, Migdal AL, Umpierrez GE. Diabetes technology in the inpatient setting for management of hyperglycemia. *Endocrinol Metab Clin North Am*. 2020;49(1):79–93. doi:10.1016/j.ecl.2019.11.002