AN UPDATE ON INPATIENT GLYCEMIC CONTROL IN U.S. HOSPITALS

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Running title: Inpatient Glycemic Control Update

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Abstract

Objective: To provide data on glucose control in US hospitals, analyzing measurements from the largest number of facilities to date.

Methods: Point-of-care bedside glucose (POC-BG) tests were extracted from 575 hospitals from January 2009 to December 2009 using a laboratory information management system. Glycemic control for patients in the intensive care unit (ICU) and non-ICU areas was assessed by calculating patient-day-weighted mean POC-BG values and rates of hypoglycemia and hyperglycemia. The relationship of POC-BG levels with hospital characteristics was determined.

Results: A total of 49,191,313 POC-BG measurements (12,176,299 ICU; 37,015,014 non-ICU) were obtained from 3,484,795 patients (653,359 ICU; 2,831,436 non-ICU). The mean POC-BG was 167 mg/dL for ICU patients and 166 mg/dL for non-ICU patients. The prevalence of hyperglycemia (>180 mg/dL) was 32.2% in ICU patients and 32.0% in non-ICU patients. The prevalence of hypoglycemia (<70 mg/dL) was 6.3% in ICU patients and 5.7% in non-ICU patients. Patient-day-weighted mean POC-BG levels varied according to hospital size ($P<.01$), type ($P<.01$), and geographic location ($P<.01$) for ICU and non-ICU patients, with larger (≥400 beds), academic, and Western hospitals having the lowest mean POC-BG. The percentage of patient days in the ICU characterized by hypoglycemia was highest among larger and academic hospitals ($P<.05$) and least among hospitals in the Northeast ($P<.001$).

Conclusions: Hyperglycemia is common in US hospitals, and glycemic control may vary according to hospital characteristics. Increased hospital participation in data warehousing may support a national benchmarking process for the development of best practices to manage inpatient hyperglycemia.

Keywords: glucose; hospital; hyperglycemia; hypoglycemia; inpatient; intensive care

Abbreviations

ICU, intensive care unit

POC-BG, point-of-care bedside glucose

SD, standard deviation

Introduction

Many quality improvement organizations have been focusing on improving the management of inpatient hyperglycemia. A recent survey of US hospitals demonstrated that the frequency of hypoglycemia and hyperglycemia were the top 2 metrics of interest to hospitals, and many have either fully or at least partially implemented inpatient diabetes quality improvement programs (1). Several quality improvement organizations are promoting the need for better inpatient glycemic control and have developed educational resources to help hospitals achieve better management (2-5). Finally, there are several clinical scenarios where better glucose control has been shown to improve patient outcomes (6-8).

Debate may continue over what glucose targets should be achieved (9); however, because of the national focus on inpatient glycemic control, hospitals increasingly may want to track glucose levels in their patients. Glucose targets for both critically ill and noncritically ill patients have been proposed (9). For instance, the recommended target glucose range is 140 to 180 mg/dL for critically ill patients and a random level of less than 180 mg/dL for noncritically ill patients (9). Thus, as hospitals continue to develop and implement inpatient diabetes glycemic control programs, national benchmarking will allow institutions to compare their performance against recommended standards. We have been reporting data on glucose control from a progressively larger number of US hospitals; these data have provided insight into the status of inpatient hyperglycemia and hypoglycemia (10,11). We can now provide an update from more than 500 hospitals—the largest sampling to date—and further describe differences in glucose control according to hospital characteristics.

Methods

Data Collection

Data collection methods have been previously outlined (10,11). Briefly, the hospitals in this analysis used standard bedside glucose meters (Accu-Chek Inform, Roche Diagnostics, Indianapolis, Indiana), downloaded to a point-of-care test information management system (Remote Automated Laboratory System-Plus [RALS-Plus]; Medical Automation Systems, Charlottesville, Virginia) (10-12), which is the largest national data repository for inpatient glucose data. Patient-specific data (eg, age, sex, race, diagnosis codes) are not provided by participating hospitals, but individual patients can be selected on the basis of a unique anonymous identifier (11). Our most recent report (11) comprised data spanning January to December 2007. This report includes inpatient data from January 2009 through December 2009. All data analyzed were from adult inpatients.

Hospital Selection

As in our previous study (11), all 1,225 US hospitals that have RALS-Plus capability and participate in the RALS-Annual Report were invited to share data; 575 agreed to participate and completed a business agreement. Participating institutions provided written permission to remotely access their glucose data and combine these data with those of other hospitals into a single database. Patient data were deidentified and consent for retrospective analysis and reporting was waived. The analysis was also approved by the Mayo Clinic Institutional Review Board. Confidentiality was guaranteed for participating hospitals and their data (11). Characteristics of participating hospitals, including number of beds and type (academic, urban community, rural community), were obtained as previously described (11).

Statistical Analysis

Glucose data were separated into intensive care unit (ICU) and non-ICU data sets on the basis of download location designated by the RALS database. The data were expressed according to the number of patient-days during which measurements were obtained (11,13). The patient-day point-of-care bedside glucose (POC-BG) mean was calculated by totaling the POC-BG values for a unique patient-day and dividing the total by the number of measurements performed on that day. Patient-day averages were aggregated to the hospital level and averaged to compute the patient-day-weighted mean POC-BG level for each hospital.

We determined the proportion of patient-days with a patient-day-weighted mean POC-BG value higher than 180, 200, 250, 300, 350, and 400 mg/dL. We also determined the percentage of patient-days with at least 1 POC-BG value less than 70, 60, 50, and 40 mg/dL, as previously described (11). This analysis allowed us to evaluate the frequency of severities of hyperglycemia and hypoglycemia in the data.

Lastly, continuing to use the methods applied in our previous study (11), we examined the relationship between hospital patient-day-weighted mean POC-BG values and the number of hospital beds, hospital type (academic, urban community, rural community), and by US geographic region. We also tested for differences in the number of patient-days characterized by hypoglycemia according to these same hospital characteristics. Comparisons between continuous variables were conducted using Mann-Whitney tests, and categorical variables (hospital characteristics) were analyzed using analysis of variance χ^2 tests. All analyses were done using SPSS 15.0 (SPSS, Chicago, Illinois). Statistics for ICU and non-ICU glucose data were computed separately. Data are expressed as mean (standard deviation [SD]) where applicable.

Results

Characteristics of Participating Hospitals

Of the 575 participating hospitals (Table 1), 47.4% had fewer than 200 beds, 21.6% had 200 to 299 beds, 13.9% had 300 to 399 beds, and 17.0% had 400 beds or more; 533 hospitals had ICUs. The majority (71.5%) were urban community hospitals; 25.9% were rural community hospitals and 2.6% were academic facilities. Geographically, 47.8% of hospitals were located in the South, 20.4% in the Midwest, 19.1% in the West, and 12.7% in the Northeast. The χ^2 analysis showed that our study sample differed from the national population of hospitals by size, type, and region ($P<.05$) but was comparable overall to the hospitals that use the RALS-Plus system (Table 1).

Overall Glycemic Control

A total of 49,191,313 POC-BG measurements (12,176,299 from the ICU and 37,015,014 from non-ICU areas) were obtained from 3,484,795 patients (653,359 ICU, 2,831,436 non-ICU). The average number of measurements was 18.6 per ICU patient and 13.1 per non-ICU patient. The mean number of measurements taken per patient-day was 4.8 for ICU patients and 3.3 for non-ICU patients. The overall patient-day-weighted mean (SD) POC-BG was 167 (15) mg/dL (median, 168 mg/dL) for ICU measurements and 166 (11) mg/dL (median, 166 mg/dL) for non-ICU measurements. The distributions of patient-day-weighted mean POC-BG values for ICU and non-ICU settings are shown in Figure 1.

Hyperglycemia and Hypoglycemia Prevalence

For ICU patients, 32.2% of patient-days had at least 1 POC-BG value higher than 180 mg/dL, as did 32.0% of non-ICU patients. Hyperglycemia was common in both the ICU (Fig. 2A) and non-ICU (Fig. 2B) settings, with nearly a third of patient-day-weighted mean POC-BG values higher than 180 mg/dL and almost a quarter higher than

200 mg/dL. Rarely, more severe hyperglycemia (>300 mg/dL) was identified in both settings. When examining the occurrence of hypoglycemia, 6.3% of patient-days had POC-BG values less than 70 mg/dL in the ICU and 5.7% had levels less than 70 mg/dL in non-ICU areas (Fig. 3A and 3B). Moderate (<60 mg/dL) and severe (<40-50 mg/dL) hypoglycemia was rare in both settings, as was observed in our previous analysis (11).

Relationship of Glucose Control With Hospital Characteristics

Patient-day-weighted mean POC-BG values, both ICU and non-ICU, differed significantly according to hospital size, type, and geographic location. In the analysis of ICU data, hospitals with fewer than 200 beds had significantly higher patient-day-weighted mean POC-BG levels than those with 200 to 299 beds ($P<.001$), 300 to 399 beds ($P<.001$), and 400 beds or more ($P<.001$); hospitals with 200 to 299 beds also had higher POC-BG values than hospitals with 300 to 399 beds ($P<.05$) and 400 beds or more ($P<.001$) (Fig. 4A). Rural community hospitals (Fig. 4B) had higher patient-day-weighted mean POC-BG values than urban community and academic hospitals (both $P<.001$). Finally, for ICUs in hospitals located in the West (Fig. 4C), POC-BG values were significantly lower than those in the Midwest and South (both $P<.01$).

For non-ICU data, differences in patient-day-weighted mean POC-BG levels based on hospital characteristics were also seen. Significantly higher patient-day-weighted mean POC-BG values were detected in non-ICU areas of hospitals with fewer than 200 beds (Fig. 5A) compared with those with 300 to 399 beds ($P<.01$) and 400 beds or more ($P<.001$). In addition, rural community hospitals had significantly higher patient-day-weighted mean POC-BG values (Fig. 5B) compared with academic ($P<.01$) and urban community ($P<.001$) hospitals, and Western US hospitals (Fig. 5C) had significantly lower values than those in the South and Northeast (both $P<.001$).

Additionally, we detected differences in ICU hypoglycemia rates for all levels (<40 mg/dL through <70 mg/dL) on the basis of hospital size, type, and region (all

P<.05). The percentage of patient-days with hypoglycemia was highest in hospitals with 400 beds or more and in academic hospitals (Fig. 6A and 6B) but was lowest among hospitals in the Northeast (Fig. 6C). Comparison of non-ICU hypoglycemia rates by hospital characteristics revealed differences only by region, with Northeast hospitals having the lowest percentage of days characterized by hypoglycemia (*P*<.001; data not shown).

Discussion

Diabetes mellitus is an increasingly common diagnosis encountered and managed in the inpatient setting (14,15). Although glucose control guidelines are still evolving for hospitalized patients, it is generally accepted that extremes of inpatient hyperglycemia and hypoglycemia should be avoided because they have the potential to negatively affect patient outcome. Tracking data on inpatient glucose control may become increasingly important as hospitals are graded on an outcome-driven basis. Analyses such as these can serve as a glucose barometer for the country as a whole and a starting point for hospitals to compare their own data and performance in hopes of identifying and implementing safe, effective inpatient glycemic control protocols.

This updated analysis shows both similarities and differences with data from our last report (11). As seen in our previous analysis, a wide distribution of patient-day-weighted mean glucose values was observed in data derived from both the ICU and non-ICU areas. There are no standardized glucose ranges that hospitals are currently targeting (1), and this variation in practice may account in part for the wide distribution of values observed here. The prevalence of hyperglycemia remains high in both the ICU and non-ICU in this data set, as it was in our previous analysis, while the prevalence of severe hypoglycemia was low. Further statistical analysis will be needed of the subset of 126 hospitals evaluated both in 2007 and in these data to ascertain whether changes in glycemic control have occurred.

Findings of better glucose control in larger or academic institutions and in hospitals in the West persist in this data set and are similar to findings from the previous analysis (11). A new observation in this analysis is the finding that hypoglycemia rates differ by hospital characteristics as well, particularly in the ICU data. Hospitals with the lowest patient-day-weighted mean POC-BG levels (large, academic) also experienced more hypoglycemia. Hospitals in the Northeast with the highest patient-day-weighted mean POC-BG levels had the lowest number of patient days characterized by hypoglycemia. Longitudinal analyses of data will permit an assessment of how well hospitals are balancing competing priorities: reducing hyperglycemia while minimizing hypoglycemia.

Without detailed hospital-specific information (such as type of insulin protocols used) or patient level data to adjust for comorbid conditions such as severity of illness or diabetes diagnosis, the basis for these hospital differences cannot be determined. However, one possibility is that perhaps the lower glucose levels in the larger or academic facilities reflect the availability of specialists, size and experience of nursing staff, nurse-to-patient ratio, or the availability of institutionally developed protocols. Another explanation for observed differences is that hospitals of certain types or in particular geographic locations might have progressed further in efforts to enhance their diabetes inpatient management (1). As we determined in our previous study (11), all that can be concluded from this analysis is that POC-BG data vary on the basis of hospital size, type, and location, and nothing can be stated as to whether one type of hospital has better inpatient glucose management methods than another, especially since some hospital types are underrepresented in this sample relative to the national sample. The differences in patient-day-weighted mean glucose values, although statistically significant, may not have clinical implications in terms of being associated with different patient outcomes, and further investigation is required.

In addition to the above considerations, volunteer-dependent hospital involvement creating selection bias (ie, hospitals may not elect to participate if control is poor or they lack the staffing or the electronic environment to participate) and the lack of a statistically representative sample of US hospitals are also limitations. Finally, the type of glucose data evaluated (POC-BG) may not be the optimal method of assessing glycemic control. Although bedside glucose measurements are the most common method hospitals report using to assess inpatient glucose control (1) and the primary means by which day-to-day therapeutic decisions are made about adjusting hyperglycemia therapy in the hospital, it is known that POC-BG values can differ from whole blood values, particularly in the ICU setting (16,17).

Despite these limitations and issues, to our knowledge this report is the most extensive review of the state of inpatient glucose control in US hospitals. The data are unique in that they provide an assessment of a large number of US hospitals of varying characteristics and geographic regions. An analysis such as this can allow a determination of glucose control over time and is an example of a benchmarking process against which comparisons can be made. Variation in glucose control according to hospital characteristics observed in our earlier report persists, and the reasons underlying these differences require further investigation. Increased hospital participation in data collection could permit an investigation and assessment of how best practices improve inpatient hyperglycemia management.

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Table 1. Characteristics of Study and US Hospitals[a]

Characteristic	Study Hospitals (n=575)	RALS-Plus Hospitals[b] (n=1,225)	US Hospitals (n=4,936)
No. of beds			
<200	273 (47.4)	510 (41.6)	3,532 (71.6)
200-299	124 (21.6)	284 (23.2)	619 (12.5)
300-399	80 (13.9)	193 (15.8)	368 (7.5)
≥400	98 (17.0)	238 (19.4)	417 (8.4)
Hospital type			
Academic	15 (2.6)	74 (6.0)	413 (8.4)
Urban community	412 (71.5)	835 (68.2)	2,514 (50.9)
Rural community	148 (25.9)	316 (25.8)	2,009 (40.7)
Region			
Northeast	73 (12.7)	206 (16.8)	680 (13.8)
Midwest	117 (20.4)	521 (42.5)	1,422 (28.8)
South	275 (47.8)	259 (21.1)	1,919 (38.9)
West	110 (19.1)	239 (19.5)	915 (18.5)

[a] All values are number (percentage). The data are based on American Hospital Association's Hospital Statistics, published by 2007 Health Forum LLC, USA, 2007.

[b] These data were derived from a convenience sample of hospitals using the Remote Automated Laboratory System Plus (RALS-Plus) and representative of RALS-Plus hospitals by all characteristics (*P*=NS) but not representative of all US hospitals by size, type, or region (*P*<.05).

Adapted from Cook et al (11). Used with permission.

Legends

Fig. 1. Distribution of patient-day-weighted mean point-of-care bedside glucose values for (A) intensive care unit (ICU) and (B) non-ICU settings.

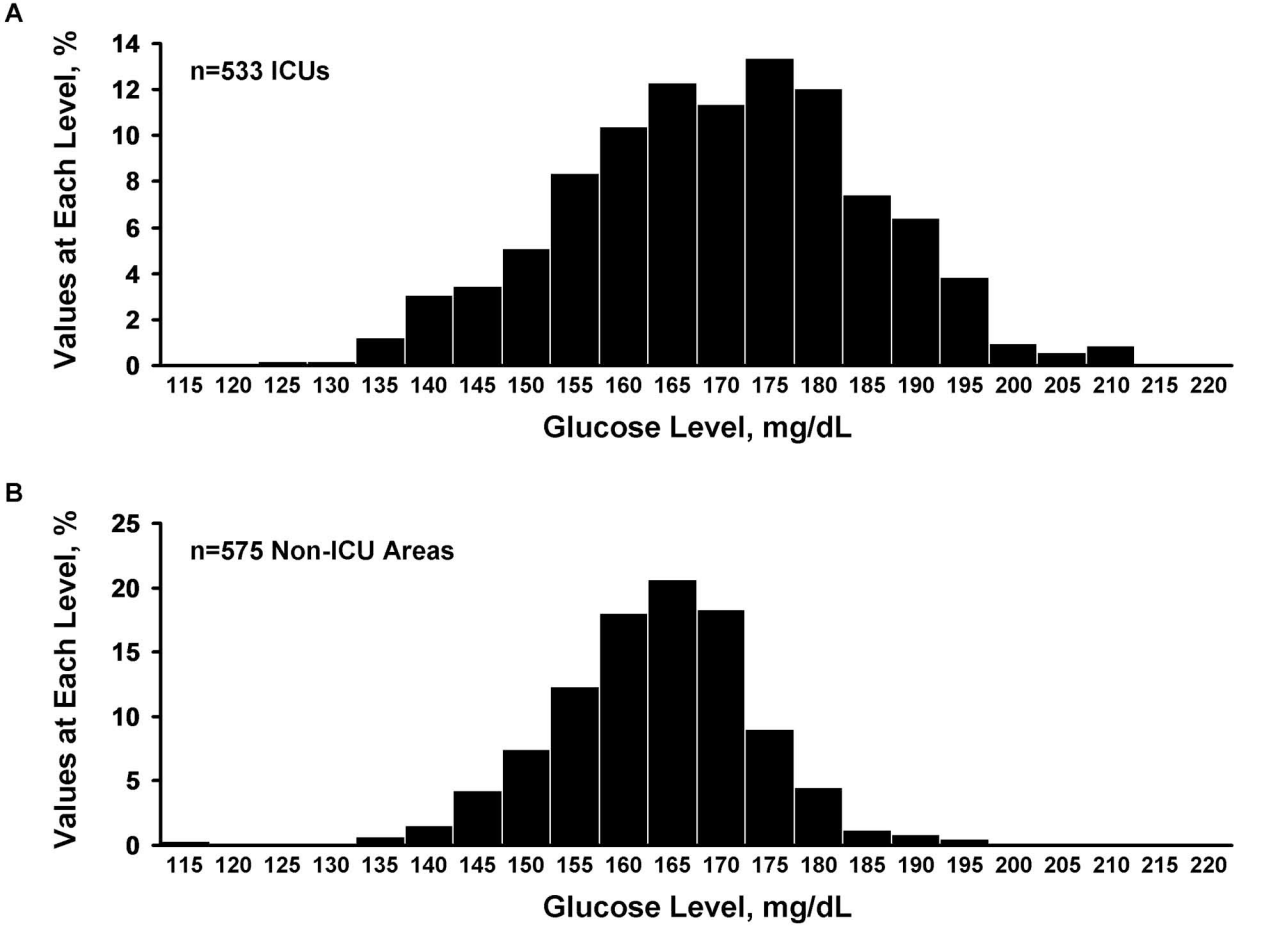
Fig. 2. Percentage of patient-days where patient-day weighted mean POC-BG values exceeded different cut points in the (A) intensive care unit (ICU) and (B) non-ICU settings. POC-BG indicates point-of-care bedside glucose.

Fig. 3. Percentage of patient-days where a hypoglycemic event (<70 mg/dL) occurred in the (A) intensive care unit (ICU) and (B) non-ICU settings.

Fig. 4. Relationship of patient-day weighted mean glucose values in the intensive care unit with (A) hospital size, (B) hospital type, and (C) geographic location. Values varied significantly by size, type, and location (see text). POC-BG indicates point-of-care bedside glucose.

Fig. 5. Relationship of patient-day weighted mean glucose values in the non–intensive care unit areas with (A) hospital size, (B) hospital type, and (C) geographic location. Values varied significantly by size, type, and location (see text). POC-BG indicates point-of-care bedside glucose.

Fig. 6. Percentage of intensive care unit patient-days with glucose less than 70 mg/dL by (A) hospital size, (B) hospital type, and (C) geographic region. Values varied significantly across size, type, and location (see text). Identical statistical differences were detected when comparing glucose levels less than 40, 50, and 60 mg/dL.


A
n=533 ICUs
Values at Each Level, %
0
2
4
6
8
10
12
14
115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220
Glucose Level, mg/dL
B
n=575 Non-ICU Areas
Values at Each Level, %
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5
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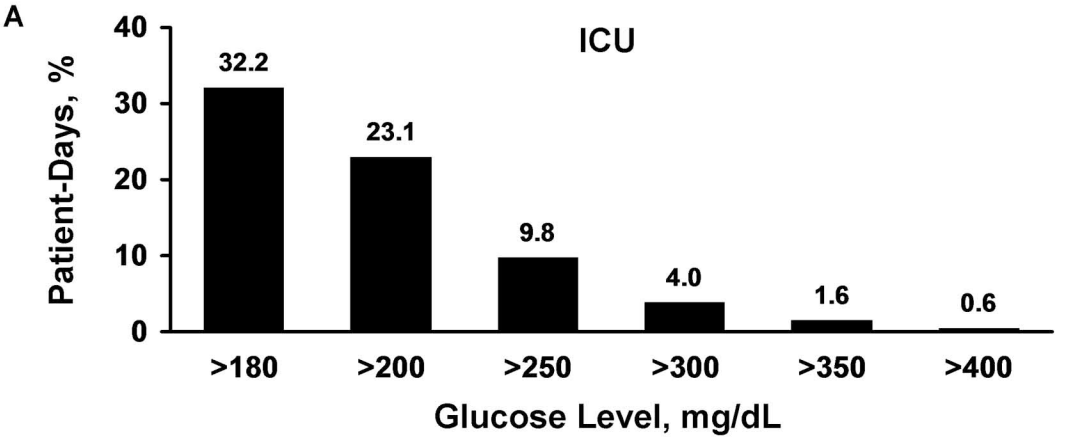
115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220
Glucose Level, mg/dL


A
ICU
Patient-Days, %
40
30
20
10
0
32.2
23.1
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4.0
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>180
>200
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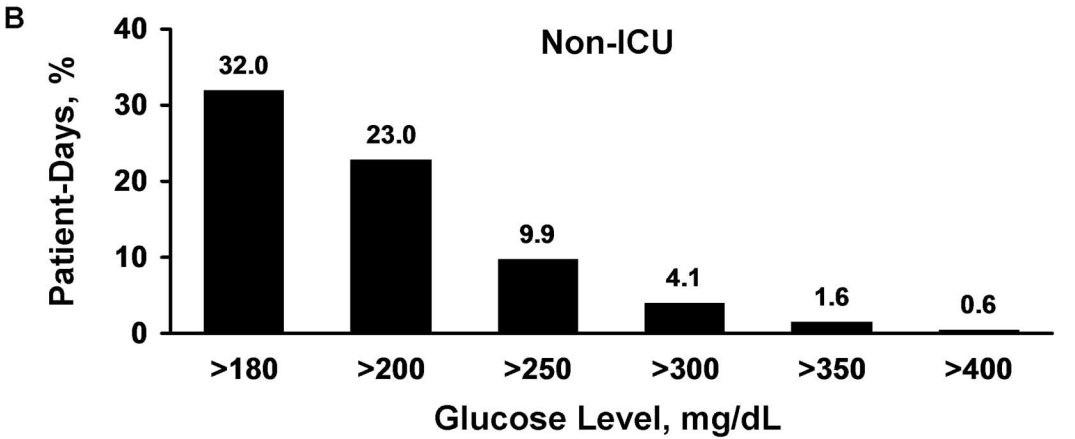
>300
>350
>400
Glucose Level, mg/dL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Patient-Days, %
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30
20
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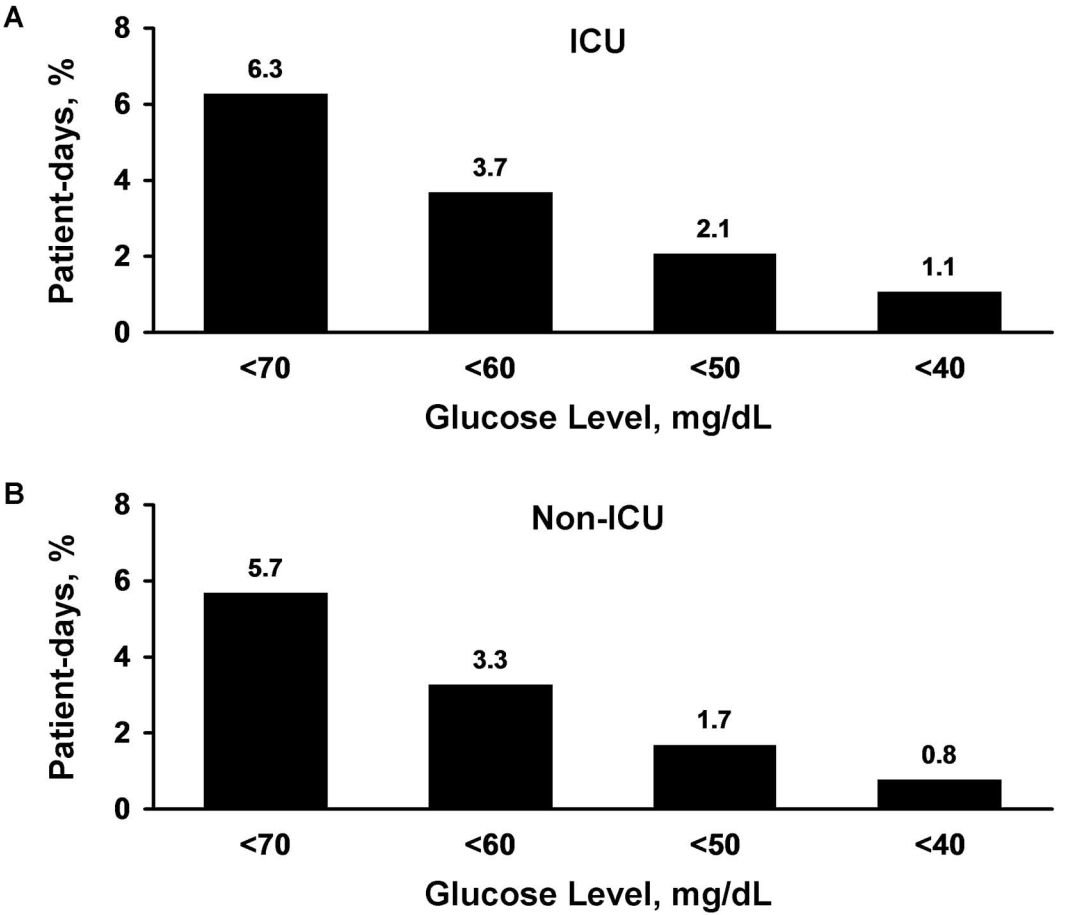
>400
Glucose Level, mg/dL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ICU
Patient-days, %
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2
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6.3
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1.1
<70
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<50
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Glucose Level, mg/dL
B
Non-ICU
Patient-days, %
8
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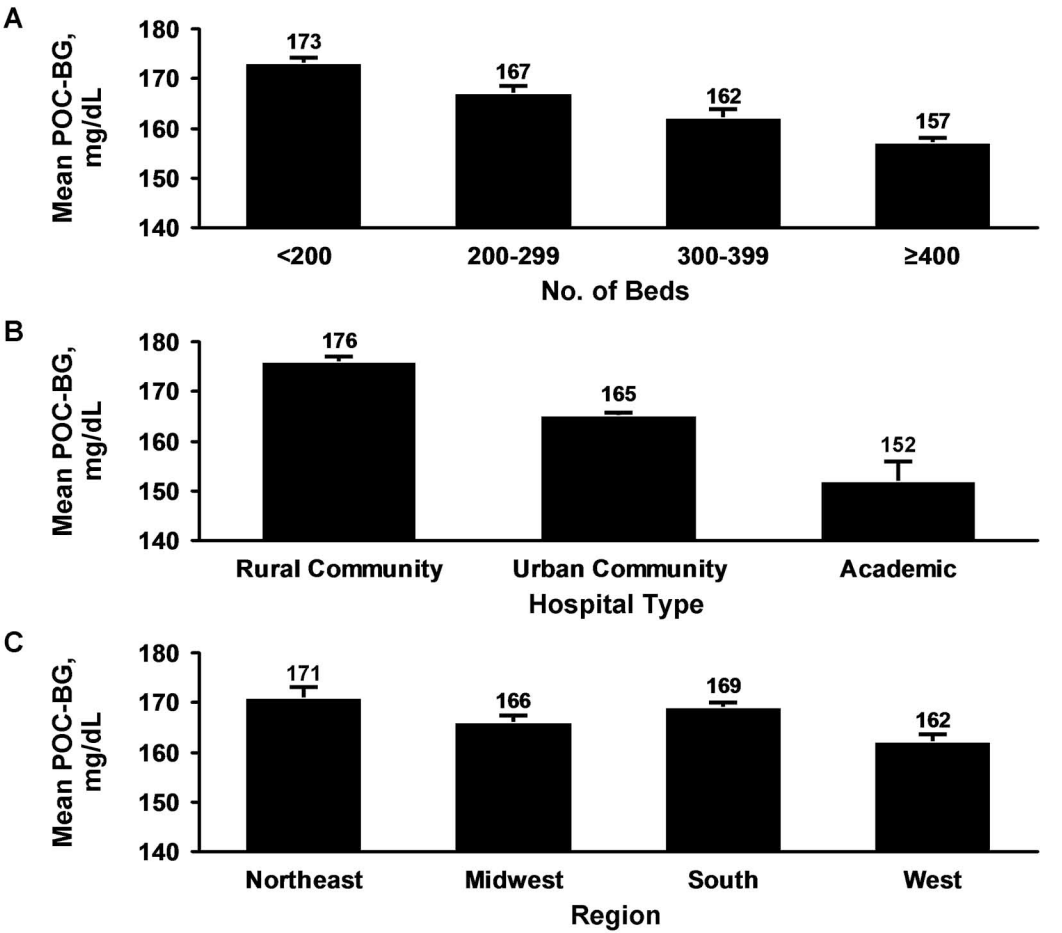
Glucose Level, mg/dL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Mean POC-BG, mg/dL
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170
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173
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200-299
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No. of Beds
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Mean POC-BG, mg/dL
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170
160
150
140
176
165
152
Rural Community
Urban Community
Academic
Hospital Type
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Mean POC-BG, mg/dL
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Northeast
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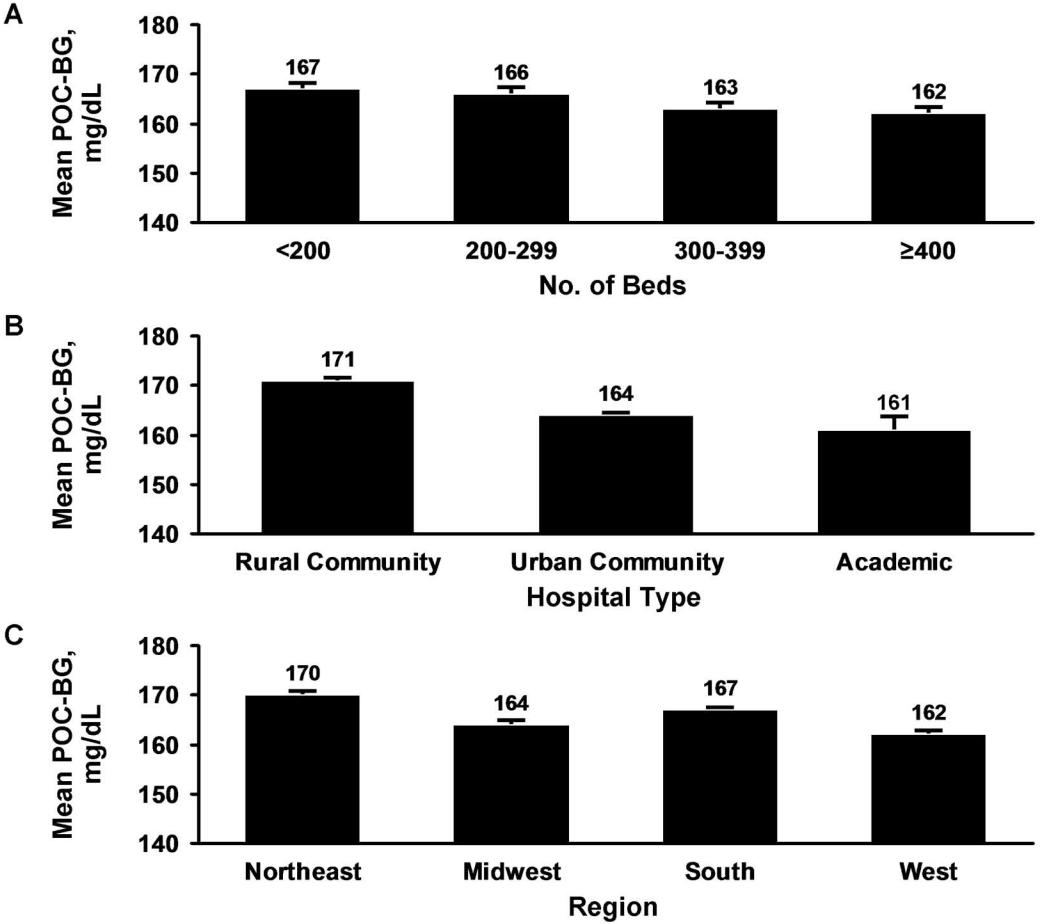
West
Region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Mean POC-BG, mg/dL
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No. of Beds
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Mean POC-BG, mg/dL
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Rural Community
Urban Community
Academic
Hospital Type
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Northeast
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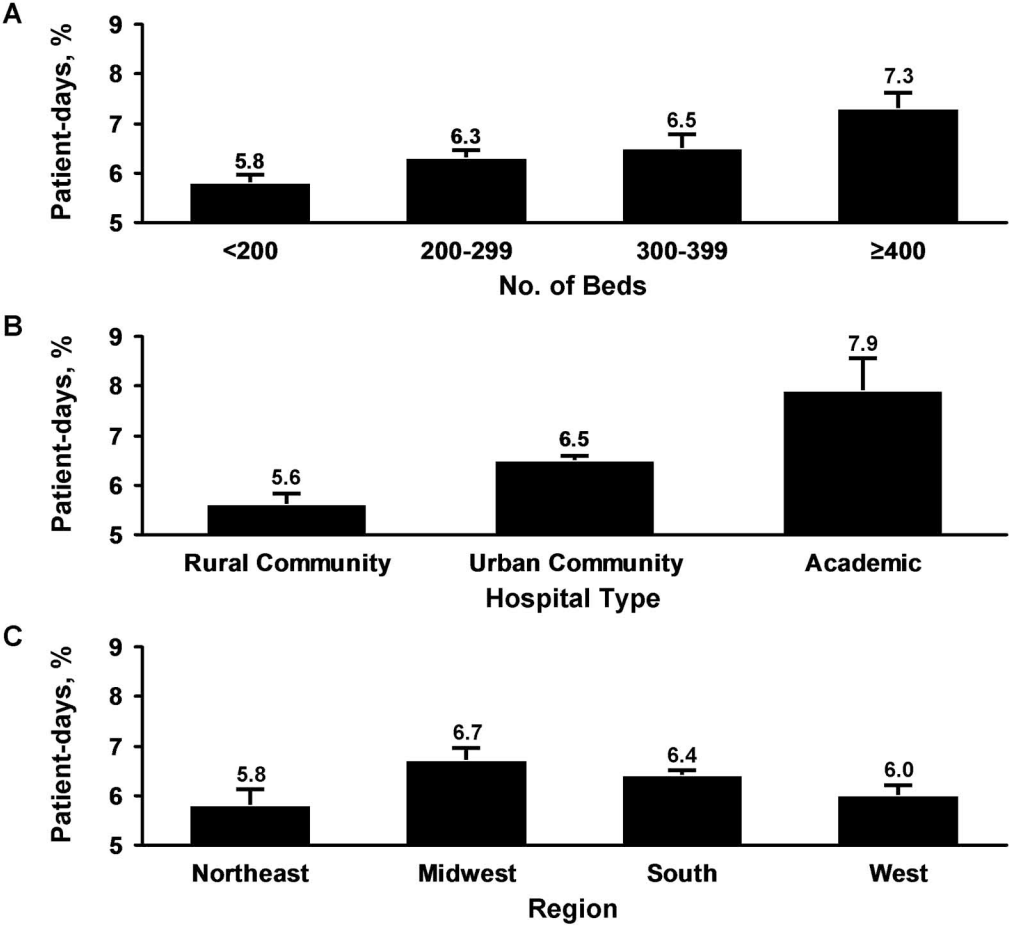
Region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Patient-days, %
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200-299
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No. of Beds
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Patient-days, %
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Rural Community
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Patient-days, %
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South
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