

# Finding the Sweet Spot: the Last Blood Glucose Measured in the Hospital and 30-Day Outcomes—a Retrospective Study

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## INTRODUCTION

Even though clinicians caring for hospitalized patients frequently encounter abnormal glucose values at hospital discharge, and hyperglycemia is associated with worse hospital outcomes, little data exists on the prognostic relevance of the last blood glucose (BG) measurement in the hospital.<sup>1–3</sup> We parse the association between the last BG measurement in the hospital and 30-day readmission/mortality and test the following hypotheses: (1) Patients with dysglycemia on the last BG measurement in the hospital experience higher rates of 30-day death and readmissions. (2) The risk increases with the severity of dysglycemia (defined as glucose > 100 mg/dL or < 70 mg/dL) regardless of diagnosis of diabetes mellitus (DM).

## METHODS

We obtained institutional review board approval from the University of Minnesota and created an electronic medical record (EMR)-derived dataset of 126,527 emergent hospital admissions for 67,308 patients within a six-hospital network in the Twin Cities area, MN, from 2012 to 2016. Patients were excluded if they were non-emergent admissions, were less than 18 years of age, did not consent to their medical record being used for research purposes, had less than 31 days of follow-up mortality data, or were not Minnesota residents. Data were collected on patient characteristics, comorbidities, and outcomes. Among 67,308 patients with multiple hospitalizations, we randomly selected a single encounter for each patient to minimize bias in outcome assessment. All laboratory and physiologic data was time-stamped and was obtained within at least 24 h of the end of the hospitalization. Blood glucose values obtained from finger stick blood tests or as part of a laboratory panel were included in the dataset. The last available measurement during an encounter was used for analyses. Blood glucose values were categorized as follows: < 70 mg/dL, 70–100 mg/dL, 100–200 mg/dL, 200–300 mg/dL, 300–400 mg/dL, and > 400 mg/dL.

The relative risk (RR) of 30-day death or readmission within each range of BG was modeled using Poisson regression with robust error variance. The primary outcome was death or readmission within 30 days of the index hospitalization; inpatient deaths were excluded to examine post-discharge outcomes. We adjusted the models for age, sex, race, AHRQ comorbidities, BMI, and length of stay. The 70–100 mg/dL range was treated as the reference range for the RR calculation. Analysis was done using R-Studio. R packages—tidyverse, icd, nephro, ggplot2, mcgv, sandwich, lmetest, and tableone—were used.

## RESULTS

We describe the patient demographic, clinical, and laboratory characteristics in Table 1. The lowest rate of post-discharge 30-day readmission/death was observed when the final BG was within 70–100 mg/dL (6.1%; Fig. 1). The adjusted RR of post-discharge events rose in tandem with the final BG (Fig. 1, 100–150 mg/dL—RR, 1.08; 150–200 mg/dL—RR, 1.24; 200–300 mg/dL—RR, 1.48; 300–400 mg/dL—RR, 2.16) and plateaued at maximal odds when the final BG was greater than 400 mg/dL (Fig. 1; RR, 2.51). Patients with hypoglycemia (final BG values of less than 70 mg/dL) also had a higher risk (Fig. 1; RR, 1.87). Hyperglycemic patients who had a diagnosis of DM during the encounter had a significantly *lower* rate of 30-day adverse events than those who did not carry a DM diagnosis (100–150 mg/dL: 9.6% versus 8.1%, 150–200 mg/dL: 23.2% versus 16.9%;  $p < 0.05$ ).

## DISCUSSION

We found a progressively higher risk of 30-day readmission/death after hospital discharge as the last hospital BG deviated from the 70–100 mg/dL range. Twenty-five to fifty percent of hospitalized patients meet the criteria for DM, pre-DM, or hyperglycemia, but these conditions commonly go unrecognized.<sup>2</sup> Relatively “mild” elevations in the final BG—especially when unaccompanied by an explicit diagnosis of DM—were associated with a higher risk of 30-day mortality and readmission in our dataset. While we observed increased risks at deviations

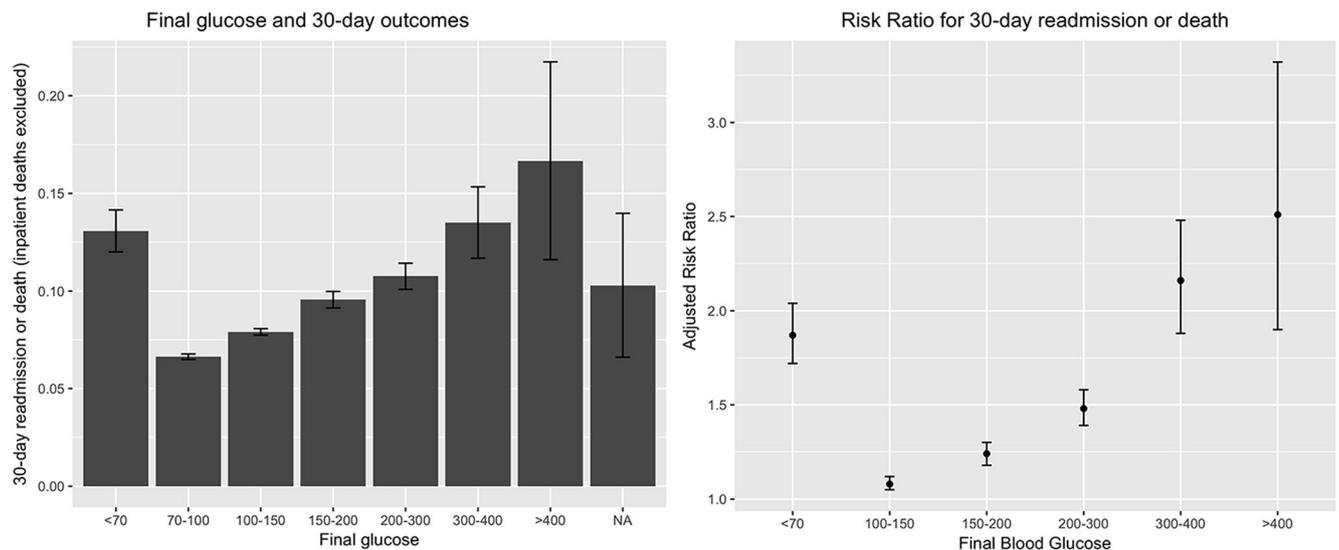
**Table 1 Clinical, Demographic, and Laboratory Characteristics of the Cohort. Stratified by Death or Readmission Within 30 Days. Median Values With Interquartile Ranges (Within Brackets) Are Reported for the Continuous Variables. Proportions With Percentages (Within Parenthesis) Are Reported for the Categorical Variables**

	Stratified by death or readmission within 30 days		p value
	Patients who did not have 30-day death or readmission within 30 days	Patients who had death or readmission within 30 days	
Number of patients	60,095	7213	
Age (years)	60.08 [43.72, 75.31]	71.65 [58.53, 83.86]	< 0.001
Albumin (g/dL)	3.50 [3.00, 4.00]	2.70 [2.20, 3.30]	< 0.001
Total bilirubin (mg/dL)	0.60 [0.40, 0.90]	0.80 [0.40, 1.50]	< 0.001
Creatinine (mg/dL)	0.81 [0.67, 1.01]	1.00 [0.72, 1.59]	< 0.001
Blood glucose (mg/dL)	101.00 [90.00, 121.00]	111.00 [93.00, 141.00]	< 0.001
Sodium (mEq/L)	139.00 [137.00, 141.00]	139.00 [136.00, 142.00]	0.432
Hemoglobin (g/dL)	12.10 [10.30, 13.60]	10.20 [8.80, 11.90]	< 0.001
Platelet count ( $\times 10^9$ per liter)	210.00 [164.00, 264.00]	185.00 [121.00, 256.00]	< 0.001
Length of stay (days)	3.00 [2.00, 4.00]	4.00 [2.00, 7.00]	< 0.001
Discharge disposition (%)			< 0.001
Acute rehab facility	864 (1.44)	51 (0.71)	
Expired	0(0.00)	2239 (31.04)	
Home IV drug therapy	573 (0.95)	55 (0.76)	
Home or self-care	40,923 (68.10)	1690 (23.43)	
Home health care service	5234 (8.71)	682 (9.46)	
Hospice/home	431 (0.72)	489 (6.78)	
Left against medical advice	594 (0.99)	45 (0.62)	
Other	1567 (2.60)	359 (4.98)	
Psychiatric hospital	703 (1.17)	35 (0.49)	
Short-term hospital	1203 (2.00)	335 (4.64)	
Skilled nursing facility	8003 (13.32)	1233 (17.09)	
BMI (kg/m <sup>2</sup> )	27.26 [23.42, 32.12]	26.32 [22.40, 31.18]	< 0.001
Sex = male (%)	28,906 (48.10)	3636 (50.41)	< 0.001
Race (%)			
White	50,831 (84.58)	6244 (86.57)	< 0.001

from 70 to 100 mg/dL, the target range for pre-meal glucose is typically considered < 140 mg/dL for hospitalized patients.<sup>4</sup> Lower target values than this have shown negative outcomes in multiple studies.<sup>5</sup>

Although we adjusted for comorbidities, our findings could be confounded by unmeasured medical or social

factors in dysglycemic patients. Studying the effectiveness of interventions that improve the identification and management of inpatient dysglycemia—such as automated flagging of asymptomatic random BG values of  $\geq 100$  mg/dL—may improve post-discharge outcomes and answer some of the questions raised by our data.<sup>6</sup>



**Figure 1** The last blood glucose measured during a hospitalization and 30-day mortality and readmission. Left panel: proportion of patients who died or readmitted within 30 days of the hospitalization across the range of final BG values. Error bars represent the 95% standard errors around the proportion estimate. Right panel: risk ratio of 30-day death or readmission after hospital discharge compared to reference risk when the last BG is within the 70–100 mg/dL. Ninety-five percent confidence intervals of the estimates are indicated by the error bars.

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**Compliance with Ethical Standards:**

**Conflict of Interest:** The authors declare that they do not have a conflict of interest.

**Disclaimer:** The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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