



# Glucometrics: Where Are We Now?

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## Abstract

**Purpose of Review** Inpatient glucose data analysis, or glucometrics, has developed alongside the growing emphasis on glycemic control in the hospital. Shortcomings in the initial capabilities for glucometrics have pushed advancements in defining meaningful units of measurement and methods for capturing glucose data. This review addresses the growth in glucometrics and ends with its promising new state.

**Recent Findings** Standardization, allowing for benchmarking and purposeful comparison, has been a goal of the field. The National Quality Foundation glycemic measures and recently enacted Center for Medicare and Medicaid Services (CMS) electronic quality measures for hypo- and hyperglycemia have allowed for improved integration and consistency.

**Summary** Prior systems have culminated in an upcoming measure from the Center for Disease Control and Prevention's National Healthcare Safety Network. It is poised to create a new gold standard for glucometrics by expanding and refining the CMS metrics, which should empower both local improvement and benchmarking as the program matures.

**Keywords** Diabetes · Hospital · Hypoglycemia · Hyperglycemia · Metrics · Glucometrics

## Introduction

Inpatient dysglycemia is associated with poorer patient outcomes and higher financial costs. As the prevalence of diabetes and hyperglycemia in the hospital rise, there has been growing interest in addressing inpatient glucose control [1–4]. Key to improving inpatient glycemic control in any institution is the use of standardized glucose performance metrics or “**glucometrics**.” Glucometrics have lacked national definitions, clarity, and standards, but efforts from national organizations have helped move this field forward. The National Quality Foundation (NQF) hypoglycemia and hyperglycemia measures were an important step and led to the current implementation of the Center for Medicare and Medicaid Services (CMS) electronic clinical quality measures (eQMs) that will ideally help raise awareness and attention to the important problem of inpatient dysglycemia. The future state of inpatient blood glucose analysis is evolving with National Healthcare Safety Network (NHSN) measures and a reporting system currently being developed which could establish a new gold standard for glucometrics. The goal of this review is to discuss glucometrics, including its definition and scope as well as its role in patient care and safety in the hospital.

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## Glucometrics

Glucometrics is the “systematic analysis of inpatient blood glucose data” and is used to track glycemic control over time [5]. The rationale to use glucometrics is manifold; it includes allowing for the assessment of quality improvement (QI) projects and to justify the provision of resources for such initiatives including assessing differences in control between hospital units, prioritizing QI efforts, reassuring staff of safety and effectiveness of protocols, and to gauge the impact of efforts with a balanced scorecard. Also, while a consensus on how to define and report them is yet to be established, glucometrics allows for data comparison among patient care units and hospitals that report data similarly [6–8]. Moreover, interest in inpatient glycemic control is evolving now to include pay for performance models. Hospital readmission reduction programs, non-payment for hospital-acquired conditions programs, and financial incentive for quality improvement, such as the Quality Payment Model from the Center for Medicare and Medicaid Services that will be addressed in next sections, are potential areas of impact [9]. Thus, having a means to track performance on glycemic measures may become a financial essential for hospitals [10, 11].

## Case Selection

Integral to developing a systematic analysis of blood glucose data is defining the population, values, and methods to be included and excluded. Investigations of inpatient glycemic management helped reveal the most clinically meaningful and practical measures. In terms of target population, patients with diabetic ketoacidosis (DKA) or hyperosmolar hyperglycemic state, pediatric patients, or patients who are pregnant should preferably be separated out and analyzed independently as targets and management protocols are distinct. Comfort care patients should be excluded in data analysis if possible. Other populations often excluded, to allow for meaningful interpretation of inpatient glucose data, are patients with less than one day in hospital or less than 4–5 total glucose readings. Glucose values from the first day of hospitalization, given this may be more reflective of home glycemic management and other factors that do not reflect inpatient management, and values after day 14 of a hospital stay may be considered for exclusion, although these values remain a part of some current benchmarking sources [11]. Repeat glucose values are often performed after a hypoglycemic excursion, and these readings should be scrutinized with the initial low reading discounted if the reflex reading is normal. A hypoglycemic

“event” needs to be clearly defined during data extraction so as not to include repeated low measurements within the same occurrence. Hypoglycemia in patients not on an anti-hyperglycemic agent, which can occur in critical illness or liver failure, should also not be a part of this analysis if possible. In reality, addressing all of these exclusion criteria is arduous and requires a robust data analysis. It is difficult to compare data sets without knowing which of these exclusions have been applied, and therefore, it should be clearly stated when discussing glucometrics data locally, and when comparing to other data sets. This issue makes the case for national standardized metrics to allow benchmarking across systems and comparison over time.

When discussing glucose values, point-of-care (POC) testing of capillary blood glucose (BG) is a practical, real-time method of measurement commonly used in most hospitals and therefore the standard for inclusion in analysis. However, especially in critical care settings, there are limitations to POC BG accuracy and inclusion of additional glucose measurement methods may be appropriate. With benefits in glucose trend detection and hypoglycemia prevention, continuous glucose monitoring (CGM) may have potential future consideration in the field of glucometrics [4, 12]. However, at this time, CGM is not included in standard analyses as more investigation is needed to validate its accuracy, use, and safety.

## Units of Analyses

There are different units of analyses used in glucometrics, each with their own advantages and disadvantages. Table 1 describes the most common units of analysis, the denominators used in calculations, and the advantages and disadvantages of each.

The following example (Fig. 1) uses all three units of analysis to determine the rate of hypoglycemia, demonstrating the different, but complementary information that each method provides.

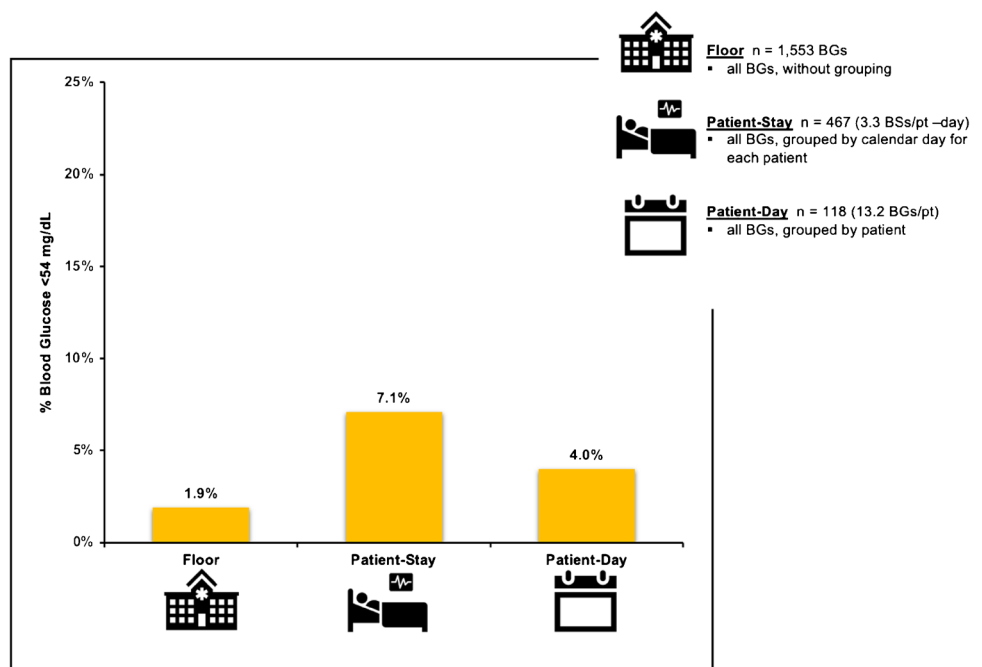
In one month, 1,483 glucose measurements were obtained from 112 patients representing 447 monitored patient days. With hypoglycemia defined as BG < 54 mg/dL, the results showed the following: 28 of 1,483 measurements (1.9%) were hypoglycemic, 8 of 112 patients (7.1%) had at least one hypoglycemic episode over their stay, and 18 of 447 monitored days (4.0%) had at least one hypoglycemic episode.

Different methods of analysis have been used to try to best capture and summarize glucose values in evaluating glycemic control. The hyperglycemic index, which is a method of analysis assessing hyperglycemic values over length of stay without inclusion of hypoglycemia, has not found benefit versus use of mean glucose [7].

**Table 1** Units of analysis for measuring glucose [5, 7, 10]

Unit of analysis	Denominator	Example	Advantages	Disadvantages
Glucose value	All glucose values for all patients in the targeted cohort	5% of 10,000 glucose values were < 70 mg/dL	Simplest measure, most statistical power given largest sample size	Less clinically significant Cannot distinguish 10 hypoglycemia readings in 1 patient vs. 1 hypoglycemia event in 10 patients Diluted by longer lengths of stay and by patients with frequent glucose readings
Patient-stay	All patients who meet the inclusion criteria	5% of all patient stays had a glucose value < 80 mg/dL	More clinically meaningful than glucose value	Does not control for length of stay and uneven distribution of glucose readings
Patient-day	Total number of glucose monitored days	5% of all patient days had a glucose value < 80 mg/dL	Controls for length of stay and variable distribution of glucose readings Clinically useful and most actionable	Might be viewed as more complicated to generate and interpret

**Fig. 1** Comparing hypoglycemia rates using all three units of analysis



### More Description of Metrics

Table 2 provides information on additional metrics building on glucose values, patient days, and patient stays units and examples of hypoglycemia management analysis. Some of these are outcome metrics, and others, related to hypoglycemia are process metrics. A combination of metric types are often useful to measure impact of QI efforts on both the long and short term.

Evaluating glycemic control in non-critical care versus critical care settings should be done separately, as several factors make comparison between them difficult. For one,

glycemic targets in these settings are at different levels and varying consistency. In non-critical care settings, the American Diabetes Association (ADA) and the American Association of Clinical Endocrinologists (AACE) recommend to target fasting glucose < 140 mg/dL and random glucose < 180 mg/dL while the Endocrine Society recommends to maintain glucose in the range of 100 to 180 mg/dL [11, 12]. More than differing targets, variability in the definition of hyperglycemia and severe hyperglycemia also remains. In critical care settings, inconsistencies in recommendations are also present. After the NICE SUGAR trial found increased mortality and hypoglycemia in “very

**Table 2** Measures of variants and other glucometrics [8, 11]

Metric	Unit of analysis	Example
Readings in or out of desired range	Glucose values	Percentage of patient-days in X month were within 80–180 mg/dL
	Patient-days Patient-stays	Percentage of patient-days in X month were above vs. had at least one value above 299 mg/dL
Readings that meet defined measurements of glycemic control variants (i.e., severe hypoglycemia and severe hyperglycemia)	Glucose values	Percentage of patients-days in X month were < 40 mg/dL vs. had at least 1 value < 40 mg/dL
	Patient-days Patient-stays	
Hypoglycemia management	Time to repeat testing	Mean/median time from hypoglycemia event to repeat testing in X month was X minutes
	Time to resolution	Mean/median time from hypoglycemia event to resolution with documented glucose reading was X minutes
	Number of patients with repeat testing within specified time	X% of patients with glucose < 70 mg/dL in X month were rechecked within X minutes
	Number of patients with > 1 hypoglycemic day during hospital stay	X% of patients with more than 1 day with $\geq 1$ glucose reading < 70 mg/dL

tight” versus moderate glycemic control, societies revised guidelines to recommend initiation of insulin therapy for glucose  $\geq 180$  mg/dL and to maintain levels between 140 to 180 mg/dL in critically ill patients. The Society of Critical Care Medicine, however, continues to recommend maintaining glucoses between 100 to 150 mg/dL but emphasizing hypoglycemia prevention [11].

Another factor that obfuscates the comparison between non-critical care and critical care settings is the differing methods to achieve glycemic control in these settings. Scheduled subcutaneous insulin administration is the preferred method in the non-critically ill settings, while insulin infusion is recommended for most critically ill patients [11]. With these different methods come different frequencies of glucose checks, with insulin infusion far outnumbering subcutaneous insulin in the opportunities to adjust insulin therapy to reach or maintain glycemic control.

### Standardization: a Work in Progress

As noted above, despite glucometrics having a higher than ever visibility, there has been a lack of consensus as several organizations propose different types of measures and even how to determine and calculate them. The absence of consensus has been a key barrier to the development of a systematic analysis of glucose data. Standardization is necessary to be able to compare systems internally over time, such as a floor unit after a quality intervention made, and organizations externally to each other. While there has been debate on practical definitions, goal glycemic targets, and

meaningful methods of data analysis, there is now an evolving consensus in a number of these areas.

Hypoglycemia can be defined in multiple ways as no one cut-off serves all purposes. The ADA currently categorizes hypoglycemia into levels with level 1 being BG of less than 70 mg/dL, level 2 BG less than 54 mg/dL, and level 3 as characterized not by a value but by mental status change or an episode necessitating outside assistance [4]. A variety of cut-off points as well as use of both patient-day and patient-stay unit of analyses is helpful for improvement efforts as BG of < 70 mg/dL is most sensitive to change, < 54 mg/dL is always clinically relevant, and < 40 mg/dL is a cut-off often established as a never event [5].

Defining hyperglycemia and clarifying the unit of measurement are important for assessing improvement in metrics as well as having uniform criteria for patients to include in the analysis of glycemic control. While governing societies vary in the proposed definition of goal glycemic targets, all agree BG > 300 mg/dL is a safety issue and taking some action if BG is persistently > 180 mg/dL is desirable.

### Historical Regulatory Measures

Regulatory measures for glycemia were initially introduced in 2008, as part of the Surgical Care Improvement Project (SCIP) as well as in the Inpatient Prospective Payment System (IPPS). SCIP’s initial goals included reduction of surgical complications. The SCIP INF 4 measure was a glycemic measure introduced to help

meet this goal, with the aim of a 0600 AM post-operative serum glucose of less than 200 mg/dL in cardiovascular surgical patients. This measure, and all the SCIP measures, were discontinued in 2015 [13] as sites achieved this goal successfully without a clear relation to improvements in outcomes [14].

The 2008 IPPS final rule included glycemic conditions that were at risk for hospital acquired condition (HAC) payment reduction. Hospital acquired DKA or hypoglycemia coma, for instance, was included in this CMS rule.

## Attempts to Craft Better Metrics

Given the significant complexity and expense of developing reproducible and comparable local measures of glycemic control, multiple external sources have established their own reporting systems. These external sources include the Remote Automated Laboratory Systems (RALS) application, the Yale Web-based system (no longer in service), and the Society of Hospital Medicine (SHM) Glucometrics Web-based system. While these sources differ in their exact metrics and reports and have varying methods of data upload and ability to provide benchmarking, they have helped move the field forward by establishing a systematic approach to accessible glucometrics that institutions can use to help support improvement efforts.

## Vizient

The Vizient (Formerly University of HealthSystem Consortium) clinical database provides a variety of analytics, including a hypoglycemic metric. With over 1000 hospitals, enrolled sites can comparatively evaluate themselves for hypoglycemia. While Vizient's exact measures are proprietary and not available for publication, their inclusions and details are generally not part of other data sets, which limits the ability to compare to other similarly reported metrics, from RALS data or SHM for instance.

## NQF

In 2014, the National Quality Foundation (NQF) designed a hypoglycemia measure (NQF 2363) and hyperglycemia measure (NQF 2362), which were endorsed in Spring 2019 after being tested and validated at 6 hospitals [15, 16••]. This initial measure evaluated hypoglycemia events as patient-days and allowed for repeat events if they occurred more than 20 h later. Ultimately, these measures were not introduced due to challenges in the query for abstracting

the data from the electronic health record (EHR), costs related to data extraction, and lack of standards. Iterative improvements in the measure allow for easier electronic capture from the EHR and evolved into NQF 3503e for severe hypoglycemia and 3533e for severe hyperglycemia [17].

## CMS eQMs

In the state of wide variation, limited improvement over time, and lack of clarity of metrics, CMS finalized two new metrics based on these NQF measures with the final rule announced August 13, 2021. The aims of the metrics are to raise awareness, reduce variation, and spur improvements in the quality of glycemia management by driving reduction in preventable harm.

The eQMs are part of the Hospital Inpatient Quality Reporting Program (IQR) and categorized as Preventable Healthcare Harm. In this program, CMS collects data electronically from hospitals with reported data publicly displayed, available on the Hospital Care Compare website [18].

The reporting period for these measures begins January 2023, with payment determination beginning in the CMS fiscal year of 2025 (October). This is a pay for reporting program, different than other pay for performance programs. Hospitals will choose 4 of the 11 eQMs to report, one will be a required opioid related measure, and sites can choose both, one or none of the glycemia measures to report. If hospitals do not report eQMs, they face a payment reduction of one quarter of their annual payment rate update. Table 3 provides details on the severe hypoglycemia and hyperglycemia measures.

Both will include only designated inpatient stays, though the event could have occurred in the emergency room or during an observation period of an inpatient stay.

As seen with other regulatory measures, such as sepsis bundle [19], or congestive heart failure [20] regulatory measures can have an immediate impact on the delivery of care. One major limitation of these measures to drive improvement will be the availability of results long after the events have occurred: in October of the year after reporting begins. In addition, hypoglycemia and hyperglycemia are balancing measures, meaning hyperglycemia reduction at the expense of additional hypoglycemia would not deliver the intended results. Hence, being aware of both measures is important for improvement. Ideally, both measures are tracked together. In addition, these measures do not specify results based on location, such as intensive care unit (ICU) or non-ICU setting, which, as described earlier, ICU and non-ICU locations have different processes (intravenous versus subcutaneous insulin management, for instance) and may have differing results of hypoglycemia and hyperglycemia.

**Table 3** eQCM glycemia measures

	Severe hypoglycemia	Severe hyperglycemia
Numerator	Number of hospitalized patients with a BG <40 mg/dL and glucose lowering medicine within 24 h	# hyperglycemic days (300 mg/dL)
Denominator	All patients 18 years and up discharged from inpatient hospital where they were administered at least one anti-hyperglycemic medication	Total number eligible days of population of 18 years and up discharged from inpatient hospital with diagnosis of diabetes, administration of at least one anti-diabetic medication, or presence of one BG 200 mg/dL
Exclusion	Age < 18 yrs old BG < 40 mg/dL if repeat value within 5 min is > 80 mg/dL	First 24 h of hospital stay or last time period before discharge (if < 24 h) Encounters > 10 days are truncated to equal 10 days Age < 18 yrs old
Unit of analysis	Patient stay	Patient day

### NHSN/CDC Measures: an Emerging Gold Standard

The Center for Disease Control and Prevention's National Healthcare Safety Network (NHSN) is the largest healthcare event tracking system in the US. NHSN is creating a glycemic control module that will build on the strengths of the new CMS eQCM measures, while augmenting these measures in ways that will overcome many of their limitations [21•]. The NHSN measures have the goals of being timelier, more comprehensive, and more granular, with the capacity to drive local improvement efforts that the eQCMs lack. More timely measures can help hospitals understand the impact of introduced quality improvements. In addition, process metrics such as recurrent hypoglycemia and resolution time of hypoglycemia assist sites in evaluating the impact of process improvements. Hospitals will also be able to see more metric results, such as < 54 mg/dl, < 70 mg/dl, and various hyperglycemia outcome metrics. For hyperglycemia, NHSN plans to include more patient days and patient

stay metrics, as well as metrics depicting the percent BGs in range and day weighted mean BG for specified cohorts. More details on the specifics abilities of the early, current, and developing glucometrics systems are presented below in Table 4.

### Strengths and Weaknesses of Current State

Despite years of discussion, we are still reaching toward achieving "glucometric harmonization." As noted above, quality focused organizations are still proposing metrics utilizing different inclusions, exclusions, numerators, denominators, and glucose thresholds to be analyzed. However, there is emerging consensus on many factors including need for different cut-off values for hypo and hyperglycemia, associating hypoglycemia with prior exposure to hypoglycemia inducing agent when feasible, excluding hypoglycemia when rapid repeat values are in normal range, and need to monitor recurrent hypoglycemic days. With the addition of glycemic

**Table 4** Similarities and differences of CMS, NHSN, RALS, and SHM glucometrics

	CMS	NHSN	RALS	SHM
Hypoglycemia metric	< 40	< 40, < 54, < 70	< 40, < 70	< 40, < 54, < 70
Hyperglycemia metric	> 300	> 180, > 300	> 180	> 180, > 299
Utilizes chemistry glucose in addition to POCT	●	●		
Analyzes time to hypoglycemia resolution		●		●
Use both patient-day and patient-stay in certain situations	●	●		●
Analyzes recurrent hypoglycemia days		●		●
Not using glucose readings as unit of analysis	●	●	●	●
Excludes glucose values from first day	●	●		
Truncates long stays	●	●		●
Include exposure to insulin or other hypoglycemic agents for hypoglycemia metrics	●	●		
Exclude hypoglycemia event if repeat test within short interval is normal	●	●		●
Include diabetes, prior insulin, prior days with hyperglycemia for hyperglycemia metrics	●	●		
Critical care vs. non-critical care data are separate		●	●	●

measures to the CMS eCQM system, there is now a start to accountability in reporting with financial incentive.

Glucometrics should not exist in a vacuum. The reason inpatient glucose is relevant is because of the association of dysglycemia with poorer inpatient outcomes. Therefore, reporting glucometrics in relation to clinical outcomes, such as surgical site infections or sepsis, would be more informative. Because insulin therapy in the hospital is one of the primary means of controlling blood glucose, reporting glucometrics in association with insulin metrics (also known as insulinometrics) could be more informative in how providers are managing hyperglycemia [6]. Finally, understanding hospital policies and procedures in relation to glucose management (e.g., prevention and treatment of hypoglycemia) in relationship to glucose control could lead to dissemination of best practices. SHM and NHSN measures on time to resolution of hypoglycemia were implemented to address this important point.

The final pathway to glucometric harmonization is data source harmonization. If POC glucose data is to be used in benchmarking initiatives, then measurements should be performed on the same instrument type. Given the difficulty of attaining this in reality, data sources are often merged. While aggregating blood glucose and POC glucose values together has its challenges in analysis, potential benefits include not missing a significant hyper or hypoglycemic event. This remains an area without consensus.

## Future State

The development of eCQMs allows capture of data from the EHR to enable integration of real time patient care and collection of glucose data. The CMS eCQM and subsequent NHSN modules have created standardization in the field, such as on levels of unacceptably low BG and severe hyperglycemia, allowing for improved benchmarking and quality improvement. The topic of specific glucose targets will likely be ongoing as there has been evidence for varying intensities of target glucose ranges depending on the person's pre-existing glycemic background and hospital circumstance [22•]. However, SHM and NHSN allow for separation of glucose data by units and care types which is a step toward tackling this issue. With the struggles of sites lacking the informatics resources to do this work of data collection and analysis, NHSN is stepping in to fill that need and may ultimately be where sites go to create glucometrics.

## Conclusion

The importance of inpatient glucose data analysis allowing for improved glycemic management has been emphasized by many studies, professional societies, and now national

entities. While differences have existed for years in regard to glucose targets and methods of analysis, there is developing consensus in this area. Patient-day and patient-stay metrics have been found to be clinically meaningful. RALS system and SHM center provided the start to benchmarking. A major development in the standardization of glucometrics, and highlighting the significance of its use, came from NQF hyperglycemia and hypoglycemia measures which led to the implementation of glycemic measures in the 2022 CMS eCQM program. The emerging NHSN modules aim to take momentum from the recent eCQM measures and expand with benchmarking and real time monitoring of severe hypoglycemia and hyperglycemia in the hospital. We anticipate inclusion of these metrics in future pay for reporting and pay for performance programs, as well as playing a role in the hospital accreditation process. The progress in the field of glucometrics is important in continuing to improve the health and outcomes of the large population of people with diabetes and hyperglycemia in the hospital.

## Declarations

**Competing Interests** Jordan Messler is a paid employee of Glytec, Chief Medical Officer. Gregory A Maynard acts as a subject matter expert for SHM and NHSN Glucometrics. The other authors declare no competing interests.

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