# Assessing Inpatient Glycemic Control: What Are the Next Steps?

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## Abstract

Despite the emergence of glucometrics (i.e., systematic analysis of data on blood glucose levels of inpatients) as a subject of high interest, there remains a lack of standardization on how glucose parameters are measured and reported. This dilemma must be resolved before a national benchmarking process can be developed that will allow institutions to track and compare inpatient glucose control performance against established guidelines and that can also be supported by quality care organizations. In this article, we review some of the questions that need to be resolved through consensus and review of the evidence, and discuss some of the limitations in analyzing and reporting inpatient glucose data that must be addressed (or at least accepted as limitations) before hospitals can commit resources to gathering, compiling, and presenting inpatient glucose statistics as a health care quality measure. Standards must include consensus on which measures to report, the unit of analysis, definitions of targets for hyperglycemia treatment, a definition of hypoglycemia, determination of how data should be gathered (from chart review or from laboratory information systems), and which type of sample (blood or point of care) should be used for analysis of glycemic control. Hospitals and/or their representatives should be included in the discussion. For inpatient glucose control to remain a focus of interest, further dialogue and consensus on the topic are needed.

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## Introduction

Glucometrics has been defined as the "systematic analysis of inpatient blood glucose data."[1] The rationale for tracking and reporting inpatient glucose control statistics is based on several factors. First, there are clinical scenarios where better glucose control has been shown to improve patient outcomes, and hospitals will want to know if hyperglycemia is managed adequately in those population subsets.[2,3] Second, several U.S. quality improvement organizations have recognized the value of better glycemic management; some have developed educational resources to help institutions achieve better inpatient diabetes and hyperglycemia care.[4–6] Third, a recent survey of U.S. hospitals indicated that many have either fully or partially implemented inpatient diabetes quality improvement programs and as these initiatives go live, they will require metrics by which to assess

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**Abbreviations:** (POC-BG) point-of-care blood glucose

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their impact on glucose control.[7] Yet, nearly one-third of these hospitals have indicated that they had no metrics in place to assess the outcomes of their glucose management programs. Finally, pay-for-performance requirements are beginning to emerge that are applicable to inpatient diabetes management.[8,9] Reports on the status of inpatient glucose control in large samples of hospitals are now available.[10,11]

Glucose control is by no means the only component of inpatient hyperglycemia care in need of attention. Other matters, such as patient and staff education and transition of care (e.g., from the inpatient to the outpatient setting)[12] are also important. Nonetheless, assessment of inpatient glucose control remains of prime interest. Despite the emergence of glucometrics as a high visibility subject, the lack of standardization or agreement on what should be measured or how it should be reported remains a dilemma and further discussion of the topic is needed. A national benchmarking process will first require consensus and advocacy from quality care organizations that will allow institutions to track, report, and compare inpatient glucose control performance against agreed-upon standards. Moreover, adequate comparison of hyperglycemia management strategies and assessment of results of future prospective randomized control trials relating to glucose control and outcomes

will require a common set of metrics to allow adequate comparisons to be made. In this article, we review some of the questions, which must be resolved through consensus and review of the evidence, and discuss some of the limitations inherent in data acquisition, analysis, and reporting that must be addressed (or at least accepted as limitations) before hospitals can commit resources to gathering, compiling, and presenting their inpatient glucose statistics as a health care quality measure.

## Which Metric Should be Used?

Inpatient glycemic control has been analyzed and published in numerous ways. Assessment of the status of inpatient glucose management can be thought of as comprising two analytic components: choice of the measurement itself and the unit of analysis.[1,2,4,5,13,14] Types of measurement have recently been grouped into three domains: metrics reflecting glycemic exposure, those expressing efficacy of control, and those providing information on the rate of related adverse events (**Table 1**).[5] The preferred metrics for the three domains of glycemic control will have to be determined through consensus. Likewise, an agreement will have to be reached on the standards for assessing the adequacy and quality of glycemic control in relation to these three domains.

### Table 1.
### Commonly Reported Measures of Inpatient Glucose Control[1,2,4,13,14,35]

| Measure | Example |
|---|---|
| Glycemic exposure | |
| Measures of central tendency | Mean, median, standard deviation |
| Hemoglobin A1c | Determined at admission, reflects outpatient control but correlated with inpatient outcomes |
| Time-weighted average | Area under the glucose curve for all glucose values |
| Hyperglycemic index | Area under the glucose curve is calculated but only above a predefined glucose target |
| Efficacy of control | |
| Target range | Whether predefined target range was achieved and duration of time in target range |
| Glucose variability | The degree of variation in glucose levels |
| Rate of adverse events | Rate of hypoglycemia; occurrence of surgical site infections; rate of extreme hyperglycemia |
| Units of analysis | |
| Patient | Proportion of patients with a single hyper- or hypoglycemic event |
| Measurement | Proportion of glucose measurements that are hyper- or hypoglycemic |
| Patient day | Mean glucose values (or other measures such as glucose variability) is calculated per patient per day and can be analyzed by measures of central tendency or other methods |
| Hospital stay | Mean glucose (or other measures) is calculated per patient day and all patient day means are then averaged across all patient days during a hospital stay to get patient day-weighted mean which can be used for analysis. |

Examples of metrics that assess glycemic exposure are those that consider composite glucose measures over time (e.g., mean glucose value for a particular length of hospital stay; time-averaged glucose calculations). Efficacy of control would reflect the ability to achieve desired glucose target ranges or the amount of glucose variability—a measure that has been linked to mortality in critically patients.[15–18] Examples of reportable adverse clinical events would be rates of hypoglycemia associated with attempts to reduce inpatient glucose levels or surgical site infections as a complication of persistent or severe hyperglycemia. The unit of analysis could consist of any number of denominators, including a specific population of interest, location in the hospital (e.g., intensive care unit), number of measurements per patient, and per patient day or per hospital stay. The strengths and weaknesses of each type of metric and unit of analysis have already been reviewed extensively by others and will not be addressed here.[1,5,13–15]

Clearly, inpatient glucose data can be and has been presented in various ways and, ultimately, a consensus will be necessary on the optimal measure and unit of analysis. Criteria that guide the decision about which parameters are most informative will need to be developed after reviewing the evidence and input from clinical experts and should be standard for all inpatient populations with hyperglycemia. Such criteria might include evidence supporting how well a metric predicts a desired outcome (e.g., postsurgical infection rate, mortality), how well measures compare with each other in predicting the desired outcome, and parsimony.

The strength of an association between a particular metric and a specific hospital outcome could be used to drive the decision about what should be analyzed and reported. There are several candidate measures that have been linked to outcomes. For instance, mean glucose values are associated with mortality in critically ill patients and in trauma patients.[19–21] Another example is the hyperglycemic index, which has been linked to increased mortality among patients with acute myocardial infarction.[22] Although hemoglobin A1c at admission reflects only the history of the glycemic exposure rather than the effectiveness of inpatient hyperglycemia management, it has been associated with increased mortality in patients with acute myocardial infarction[23] and with poorer outcomes in patients undergoing coronary artery bypass and vascular surgery.[24–26] Finally, the severity and frequency of hypoglycemia have been linked to higher inpatient mortality[27–33] and,

hence, hypoglycemia metrics should be part of a total glucometrics package.

Essentially, as noted earlier, most glucometrics are capable of giving the desired information—the degree of glucose control and its relationship to a particular outcome. A second criterion that can be used to identify a standard glucometric is how well one methodological approach compares with another. One study demonstrated that the hyperglycemic index was superior in predicting mortality in critically ill patients compared to other measures of glucose control.[34] However, in a separate analysis conducted by the same authors, the mean glucose averaged over the entire hospital length of stay compared favorably with other measures, including the hyperglycemic index, in its association with determining mortality in patients with acute myocardial infarction. These authors suggested that mean hospital glucose was the most practical metric of hyperglycemia-associated risk.[22] In trauma patients, mean glucose represented the best measure for predicting mortality versus either admission or maximum glucose levels.[17] Another study assessed the value of different units of analysis for inpatient hyperglycemia and concluded that patient-day measures best reflected the quality of glycemic control.[1] An evaluation of three different clusters of glucometrics (measures of central tendency, measures of dispersion or variability, and minimum glucose) in a mixed population of critically ill patients found them to all be closely associated with mortality.[14] Finally, several methods of calculating glycemic variability in the hospital, such as standard deviation and mean amplitude glucose excursion, have been proposed.[35] A systematic review of the literature indicates that most of these measures of variability successfully predict mortality.[36]

The third criterion, parsimony, must also be considered. Simplicity is needed in both calculation and presentation of data. For instance, metrics such as the hyperglycemic index or patient day–weighted mean or time-weighted mean would be a more complex programming challenge for hospitals with limited informatics expertise, whereas mean glucose would be determined and understood more easily by clinicians, hospital administrators, lay persons, third-party payers, and government regulatory bodies. Hospitals must await a consensus on how quality improvement organizations wish to have inpatient glucose data analyzed and reported so that all stakeholders can see and interpret the same measure in the same way.

## What Are Hospital Interests?

Recommendations for inpatient glucose metrics have historically been driven by regulatory agencies, quality improvement agencies, and professional societies.[4,5,37]

Data from the survey cited earlier found hospitals interested in a variety of metrics, including infection rates and length of stay, but the top three metrics that hospitals were interested in tracking were frequency of hypoglycemia, frequency of hyperglycemia, and average glucose by hospital unit.[7] Thus, whichever consensus inpatient glucose reporting measures are adopted, some consideration should be given to those areas of greatest interest to hospitals and to the data they find most meaningful to pass on to their stakeholders. Hospital representation in the discussion on glucometrics should be paramount to ensure buy-in and compliance with the standardized measures that are adopted.

## Which Glucose Ranges Should Hospitals Be Targeting?

Considerable debate exists over which glucose targets should be achieved in hospitalized patients, particularly in critically ill patients. No randomized controlled trials have examined the impact of glucose control in general medical or surgical patients who are not critically ill, and recommended glucose targets for such patients are based on expert opinion. No optimal glucose range has been identified and different "safe and acceptable" inpatient glycemic goals have been proposed by different organizations. For instance, the American Diabetes Association and the American Association of Clinical Endocrinologists both suggest a target fasting glucose of <140 mg/dl and a random level of <180 mg/dl in noncritically ill patients and a range of 140 mg/dl to 180 mg/dl in critically ill patients. For cardiac surgery patients, glucose control is defined as serum glucose levels <200 mg/dl, collected at or closest to 6:00 a.m. on each of the first two postoperative days.[6] This inconsistency in recommended glucose targets may partially explain the variation in glucose goals practiced by different hospitals across the United States.[7] Additionally, neither individual practitioners[38–41] nor hospitals[7] have standardized definitions for biochemical hypoglycemia. These standards should be established before implementation of a national benchmarking process.

## Which Data Source Should Be Analyzed?

Evaluation of inpatient glucose control will likely utilize retrospective methodologies. Two approaches can be considered for collection of retrospective information on inpatient glucose management: (1) reviewing a convenience sample of medical records or (2) mining data from electronic laboratory information systems. Chart abstraction, a technique employed by some,[9] would require extensive man-hours to extract data on a few patients, whereas use of electronic data allows the examination of large numbers of values for all patients. Moreover, current connectivity capabilities allow the linking of point-of-care blood glucose (POC-BG) devices to electronic laboratory information systems.[11]

Although the capability to download and store glucose values exists, a significant number (59%) of U.S. hospitals report not having the ability to extract or analyze those data.[7] If hospitals are going to be asked to provide information on their inpatient glucose control efforts, then inexpensive, accessible informatics tools must be made available that will enable them to gather and report the necessary data. For hospitals with limited internal information technology capabilities, applications exist that allow institutions to connect to and import hospital-specific glucose values into external data management systems.[42,43] One such commercial system has permitted assessment of large samples of glucose data from a sizable number of U.S. hospitals.[11] Data from this analysis suggest that there are variations in glucose control by hospital size, type, and geographic region.

Utilizing electronic data would seem to be the most efficient way to gather and analyze large samples of glucose data, but this approach does have limitations. Analyses of large numbers of glucose data exported from electronic laboratory information systems represent aggregate data. Although it is possible to differentiate various populations for analysis based on location (e.g., critically ill patients from noncritically ill patients)[11] or diagnostic codes, it may not be possible to segregate individual samples on the basis of the relationship of the timing of the sample to meals. Thus, hospitals would find it difficult to determine whether separate recommended targets are being met for fasting and nonfasting glucose values.[3]

Additionally, POC-BG data may be limited by sampling sites of opportunity, with measurements being obtained from numerous nonequivalent sources (e.g., capillary, arterial, venous) that do not yield comparable results on POC-BG devices.[44,45] Finally, adequate filters would have to be applied when analyzing aggregate data to exclude measurements obtained in close proximity to each other that may represent repeat or erroneous values. An example of such an occurrence might be the rechecking of an unexpectedly extreme high or low result. In the case

of hypoglycemia assessment, analyzing the lowest value in a string of closely spaced low values is one approach to overcoming this limitation of defining a single hypoglycemic episode.[46] Overcoming these data quality issues will likely require individualized institutional approaches, as hospitals typically have different electronic medical record platforms and informatics resources.

### Which Sample Sources Should Be Analyzed?

No consensus recommendations exist about which source of blood sampling should be used in the analysis of inpatient glycemic control. Both blood (e.g., plasma)[10,47] and POC-BG (capillary bedside) sources[1,11,48] have been used to assess inpatient glycemic control. Technology exists for frequent sampling to determine blood glucose levels,[49] but these devices are not yet deployable throughout the hospital in the numbers needed to manage all inpatients with hyperglycemia. Continuous glucose monitoring systems that measure glucose levels in insterstitial fluid throughout the day also show promise,[49] but their widespread use is probably not practical because of equipment costs and the staff training that is required to operate such devices. However, POC-BG technology allows frequent and rapid assessment of glucose levels, the devices are portable, and the techniques are easy to learn. Moreover, clinicians depend on real-time results of POC-BG testing to make immediate adjustments in therapy for hyperglycemia rather than waiting for clinical laboratory results. POC-BG measurements are the preferred method hospitals use for monitoring glucose levels[7] and are an integral part of inpatient glucose control initiatives.[45]

Nonetheless, POC-BG measurements have potential drawbacks that may affect data quality by introducing errors into analyses that could subsequently affect conclusions about a hospital's glycemic control. Chief among these are the possible inaccuracy of POC-BG values relative to reference laboratory blood glucose measures, particularly in critically ill patients.[44,50–52] The accuracy of POC-BG measurements can also be affected by the presence of interfering substances (high uric acid or bilirubin levels and certain drugs such as acetominophen).[44,53] Thus, while blood glucose determinations provide accuracy, POC-BG determinations provide a large number of measurements. Hospitals will need guidance as to which of these two sample sources should be used to assess management of inpatient hyperglycemia. Additionally, new glucose monitoring technology will need to meet standards relating to accuracy, timeliness, ease of use, and cost that are applicable to the inpatient setting.

## Conclusions

Assessment of inpatient glucose control has become an integral part of overall efforts to improve management of hyperglycemia among inpatients with and without diabetes. Standardization is required for the development of a benchmarking process, which would allow hospitals to compare their regional and national performance and would provide statistics for all stakeholders.

These standards must include agreement on the (1) preferred type of measurement and unit of analysis, (2) definitions of and targets for hyperglycemia and hypoglycemia, (3) method of data accrual (chart review vs electronic extraction), and (4) source of analyzed sample (blood vs POC-BG). Hospitals and/or their representatives should be included in the discussion on how best to proceed. Further dialogue and consensus on the topic are needed so that care of inpatients with hyperglycemia can be optimized.

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