

Improvement in Inpatient Glycemic Care: Pathways to Quality

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Abstract The management of inpatient hyperglycemia is a focus of quality improvement projects across many hospital systems while remaining a point of controversy among clinicians. The association of inpatient hyperglycemia with suboptimal hospital outcomes is accepted by clinical care teams; however, the clear benefits of targeting hyperglycemia as a mechanism to improve hospital outcomes remain contentious. Glycemic management is also frequently confused with efforts aimed at intensive glucose control, further adding to the confusion. Nonetheless, several regulatory agencies assign quality rankings based on attaining specified glycemic targets for selected groups of patients (Surgical Care Improvement Project (SCIP) measures). The current paper reviews the data supporting the benefits associated with inpatient glycemic control projects, the components of a successful glycemic control intervention, and utilization of the electronic medical record in implementing an inpatient glycemic control project.

Keywords Inpatient · Glycemic control · Hyperglycemia · Hypoglycemia · Insulin dosing algorithms · Glucometrics

This article is part of the Topical Collection on *Hospital Management of Diabetes*

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Introduction

Efforts at improving the efficiency and outcomes of inpatient care have gained increased scrutiny and the development of policies targeting specific patient groups. Inpatient hyperglycemia is a common event with an event rate of approximately 40 % of all hospitalizations and has gained particular attention as a quality metric [1]. Hyperglycemia is a common occurrence in patients with a known diagnosis of diabetes prior to an admission but is also a frequent event in patients without a prior diagnosis of diabetes. Inpatient hyperglycemia in particular hyperglycemia in the non-diabetic patient predicts poor outcomes related to hospitalization from increased length of stay (LOS), utilization of resources and mortality [1]. Additionally, traditional approaches to the management of inpatient hyperglycemia (sliding scale insulin) are reactive and associated with the additional episodes of hypoglycemia. Hypoglycemia is also associated with an increase in hospitalization-related complications. In the following manuscript, we review the components of a glycemic control project, pathways to implementing hyperglycemia management while avoiding hypoglycemia and the utility of integrating the electronic medical record for reporting of metrics, standardization of computer-based orders, and care pathways for specific patient groups (post-cardiothoracic surgery, diabetic ketoacidosis (DKA)).

Genesis of a System-Based Inpatient Glycemic Control Project

The stimulus for initiating our hospital system glycemic control project was to address two separate quality goals, glucose control of the post-cardiothoracic surgery patient and improvement in insulin use in the hospital to minimize hypoglycemic events. The overall change in the healthcare

environment heralds more focus on value-based reimbursement models with eventually Medicare penalties assigned for hospital-acquired complications; management of hyperglycemia and avoidance of hypoglycemia may be pivotal to attaining this overall goal. Initial resistance in our hospital system to targeted reduction of hyperglycemia rates was based largely on providers' misconception that improving hyperglycemia rates by initiation of insulin protocols would be linked with increasing hypoglycemic events. Additionally, the ongoing debate surrounding the role of intensive glucose control for the hospitalized patient required adoption of blood glucose goals for the post-operative cardiothoracic patient based on consensus, national surgical quality metrics, and historical cardiothoracic critical care (CSICU) policies rather than on evidence-based practice. These factors resulted in blood glucose goals in the CSICU (100–140 mg/dl) different from what was recommended for the general medical and surgical patients of 140–180 mg/dl, consistent with the practice prescribed by the combined American Diabetes Association and American Association of Clinical Endocrinologists (ADA/AACE) consensus guidelines of the management of inpatient hyperglycemia [2] Table 1.

Approaching the Problem

Glucometrics can provide helpful information that can be used to improve patient care [3, 4••, 5•]. There must be reliable methods for the collection of data, and the hospital staff, including nurses, physicians, pharmacists, and educators, need to be familiar with the technology for recording blood glucose values as well as ordering insulin and other diabetes medications. Successful inpatient glycemic management programs develop committees comprised of various hospital personnel, including individuals from the hospital administration, nurses, pharmacists and physicians, laboratory specialists, and others. The charge of the committee is to develop glycemic goals, to educate their colleagues with regard to those goals, and to develop order sets and protocols to assist with their implementation [4••].

Standardized insulin order sets are ultimately necessary for improving glucometrics. Order sets should be practical and easily implemented; otherwise, the staff will not utilize them.

Providers placing orders and caring for patients need to understand the benefits of using these order sets as well as the potential costs of not doing so [6, 7]. Champions of diabetic management can also serve an important role on each floor where diabetic patients are treated. They are at the point of service and can help troubleshoot potential problems with protocols developed by the inpatient glycemic control committee and provide re-education of staff on a regular basis.

An efficient blood glucose reporting system is necessary in order to gauge a system's progress in achieving inpatient blood glucose metrics. Generating standard blood glucose reports, either location based or provider based, can be used to guide protocol development in hyperglycemia management and identify service areas of success or in need of more attention by the glycemic control committee [8••] See Fig. 1.

Developing a Glycemic Control Committee and Establishing Goals

The components of a glycemic steering committee include as follows: develops glycemic goals, determines how to collect and analyze blood glucose data, creates and implements insulin order sets and protocols, and educates practitioners in the hospital with regard to those protocols. This group of individuals, often termed the "inpatient glycemic control," or a "glycemic management" committee, should meet regularly, usually at least monthly, and has a member representing a variety of hospital personnel involved in the care of patients likely to receive insulin [4••]. This includes, but is not limited to, a variety of physicians involved in the care of diabetic patients (endocrinologists, hospitalists, intensive care specialists, cardiologists, cardiothoracic surgeons, etc.), nurses and nurse leaders, physician assistants and nurse practitioners, pharmacists, diabetes educators, and dieticians.

As discussed by Munoz et al., the committee must also have representation from the hospital administration [4••]. These individuals, including the chief medical information officer and the vice president for medical affairs, are necessary for implementing the protocols developed by the committee. Without their help, the committee may have significant difficulties with moving glucometrics programs forward, and this

Table 1 Current recommendations for non-intensive care unit inpatient blood glucose targets

	ADA/AACE	SCIP
Pre meal or fasting	Less than 140 mg/dl	No specific recommendation
Random	Less than 180 mg/dl	No specific recommendation
0600 h 2-day post-op CT surgery	No specific recommendation	Less than 180 mg/dl

180 mg/dl=10 mmol/l

ADA American Diabetes Association, AACE American Association of Clinical Endocrinologists, SCIP Surgical Care Improvement Project, CT cardiothoracic surgery

Hospital Quality Leadership Hyperglycemic Report

Hyperglycemic (Percent Total Glucose Values >180%)

Hospital	Prior Month (Jun)	Current Month (Jul)	CYTD 2014	CY 2014 Goal %
SYSTEM	20.22%	20.81%	19.50%	19.16%
site 1	17.37%	17.93%	15.60%	19.16%
site 2	20.73%	23.68%	22.00%	19.16%
site 3	25.64%	25.51%	23.27%	19.16%
site 4	26.09%	25.33%	25.53%	19.16%
site 5	20.23%	19.57%	20.06%	19.16%
site 6	19.05%	22.14%	21.82%	19.16%
site 7	19.63%	21.25%	20.26%	19.16%
site 8	21.89%	20.89%	21.83%	19.16%

SYSTEM % Total Glucose Values >180%

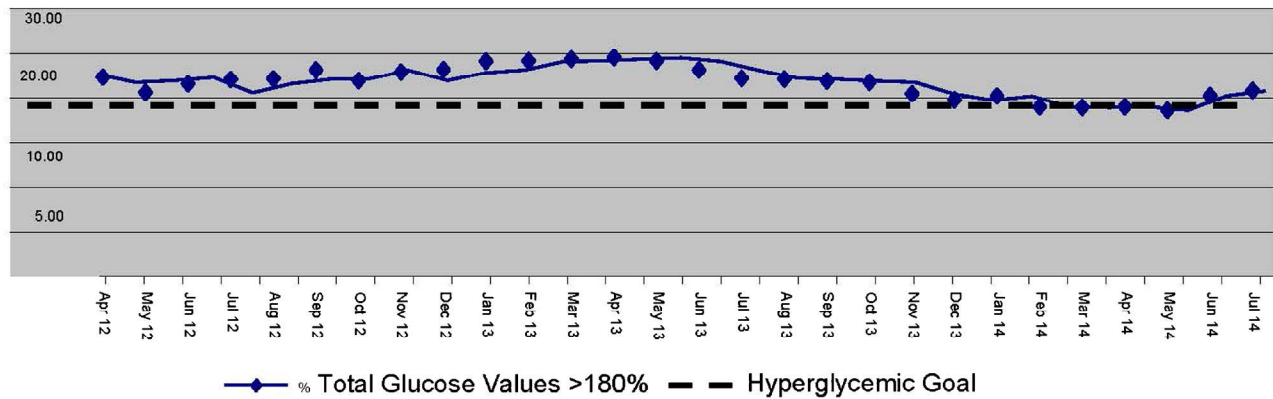


Fig. 1 Example of a simple report and trend analysis of glucometrics for a hospital system

relationship between providers and the hospital administration cannot be stressed enough.

The initial charge of the glyceemic control committee is to determine specific glyceemic goals for the different units within the hospital, including the general wards and the intensive care units. A discussion of the data supporting various target glucose ranges is beyond the scope of this review; however, guidance can be found in the joint consensus statement on inpatient glyceemic control published in 2009 by the American Association of Clinical Endocrinologists and the American Diabetes Association [2]. This report touches upon the importance of hospital glucometrics and suggests glucose targets as well as methods for achieving glucose control in various hospital settings [2]. In addition to setting glucose targets, the committee should outline the goals of their protocols specifically, what outcomes will the glucometrics help the hospital to

assess? These goals might include assessing the patient length of stay, readmission rates, and hospital-acquired complications.

Educating Providers and Developing Order Sets and Protocols

Once the glyceemic control committee has set glyceemic goals and determined required insulin protocols, it must develop educational programs that help hospital providers, including nurses, physicians, pharmacists, and in some cases, medical students, residents, and fellows, understand the reasons for establishing glyceemic goals and the methods for doing so in the hospital. The majority of hospitalized patients with hyperglycemia will receive insulin, and providers generally benefit

from receiving updated information on the different insulins available and their action.

Insulin accounts for a significant number of adverse drug events reported by hospitals, and many of these events are likely avoidable through proper prescribing practices. Providers should make adjustments as indicated by changes in nutrition as well as patient's current medical condition [9]. Providers must understand the differences between patients with either type 1 or type 2 diabetes and should be able to recognize and implement the appropriate management of hyperglycemic emergencies, including DKA and hyperosmolar hyperglycemic state. A general understanding of basal-bolus insulin use is critical, especially as there are still many providers who were trained to use "sliding-scale" insulin coverage which is no longer the standard of care [2, 10, 11]. In addition to understanding the different types of insulin available, their duration of action, and how and when to adjust insulin doses, staff needs to be aware of the various methods for delivering insulin, which increasingly includes the use of continuous subcutaneous insulin infusion or insulin pump therapy [12]. The American Society of Health-System Pharmacists (ASHP) Research and Education Foundation released a report in 2013 reviewing ten critical recommendations for improving insulin use in the hospital, which glycemic control committees may wish to utilize in developing their own local educational programs [13]. The authors focused on issues with respect to prescribing, storing and dispensing insulin, monitoring insulin use with regard to a patient's given nutrition (parenteral, tube feeding, etc.), collecting and analyzing glucometrics, and educating hospital staff.

Educational programs, which may include in-person lectures and grand round presentations, online webinars and conferences, and online web modules can improve staff confidence in the management of diabetes, diabetes and insulin knowledge, and adherence to committee developed protocols [14, 15, 16, 17–20]. The glycemic control committee should develop materials to distribute protocols and order sets and phone numbers of staff who can help answer questions. One example is laminated pocket cards that can hang from a provider's identification lanyard that outline specific glycemic targets and resources for staff to turn to when they have questions. The committee may wish to develop a questionnaire or self-assessment program that allows staff to test their knowledge before and after they have gone through an education program. The importance of repeating this education is critical, as updates to the order sets and protocols will occur over-time, and re-education will help to reinforce knowledge and will ensure that staff is prepared to manage any changes made to the existing methods for glucose control.

It can be challenging to create order sets and insulin use protocols, including those for use on the general ward, in the intensive care unit, and in particular patient populations such as those with diabetic ketoacidosis and in children with type 1

diabetes. They may involve subcutaneous insulin, or intravenous insulin, and may contain information about transitioning individuals from one delivery route to the other. It is important to keep order sets practical, but also detailed enough that they provide appropriate patient care. Standardized order sets have been shown to improve glucometrics, reduce hyperglycemia and hypoglycemia, and improve provider satisfaction [21]. Order sets may take the form of paper sheets, though this is becoming less prevalent as hospitals move toward the use of electronic medical records (EMRs). There are published examples of order sets, and a notable paper by Kennihan et al. reviews the successful design of protocols and orders that can be used with an EMR where computerized provider order entry (CPOE) is available [22]. The emergence of electronic medical records (Epic®, Cerner®, etc.) and computer-based insulin dosing algorithms ((CBIA) Glucommander®, GlucoseStabilizer®, Endo Tool® etc.) can facilitate the management of hyperglycemia while minimizing the risk of hypoglycemia.

Use of Computer-Based Insulin Dosing Algorithms

Computer software-driven programs now exist that enable providers to adjust insulin infusion rates and determine subcutaneous insulin doses at the point-of-care [23, 24]. These programs have been shown to be more effective in helping patients reach glycemic goals without increased risks for adverse events, including hypoglycemia, though not all available data support this finding [25•, 26–29]. These proprietary software packages also incur a financial cost to the institution—which can range from 500 to \$1500 (USD) per patient bed per year. Unfortunately, there are no large-scale clinical trial experiences comparing the efficacy and cost-effectiveness of computer-based insulin algorithms versus standardized insulin orders either paper based or electronic. Newton et al. found CBIA superior to standardized computer-based orders in achieving improved average blood glucose levels [25•], similar to our results. We have had significant experience at our institution using Glucommander (Glytec, LLC) in intravenous insulin infusions in both the cardiothoracic patient and in DKA [24]. Glucommander adjusts insulin based on the blood glucose trend, a derived projected blood glucose curve, and a multiplier (which represents insulin sensitivity) [24]. Adoption of a CBIA was driven by a desire to improve meeting SCIP measures in the cardiothoracic surgery patient and to reduce our hypoglycemia rate in the CSICU as well as across the Sentara healthcare system, an integrated EMR and glycemic control committee responsible for nine hospitals. Adoption of a CBIA across the Sentara health system was associated with an overall reduction in recorded hypoglycemic events (blood glucose (BG) <70 mg/dl) for patients from our baseline rate of approximately 2 to 0.9 % within 30 days of

Table 2 Computer-based insulin algorithm for intravenous insulin (Glucommander) improves overall glucometrics in the general intensive care units and adherence to hyperglycemia goals (SCIP-4 measure) in the

cardiothoracic patient (Data are pooled from 20,000 blood glucose measurements, system, and 8500 for the post-cardiothoracic surgery group)

Location	Baseline	90 days after Glucommander	Percent improvement	Baseline	90 days after Glucommander	Percent improvement
Blood glucose targets	<70 mg/dl	< 70 mg/dl		>180 mg/dl	>180 mg/dl	
Entire system	2.1 %	0.9 %	57 %	23.1 %	19.5 %	15 %
Cardiothoracic surgery	1.6 %	0.8 %	50 %	5 %	1 %	80 %

adoption of CBIA [30]. In our cardiac surgery patient group, adoption of CBIA was able to achieve compliance with SCIP measure of glucose control (post-op day 2 BG <200) 99 % of the time studies compared to our prior success rate of 95 % [31]. These two examples illustrate how a computer algorithm for intravenous insulin can improve both hyperglycemia rates and minimize occurrence of hypoglycemia, see Table 2.

Protocol-Driven Treatments for Hypoglycemia and Diabetic Ketoacidosis

Insulin products are designated as high-risk medications by the American Society of Health-System Pharmacists which recommends the use of protocol-driven insulin administration to minimize medical errors [13]. As more and more hospitals are migrating to electronic health records in compliance with “meaningful use” stipulations, it seems intuitive to generate electronic order sets to guide glycemic management. Furthermore, the ability of electronic records to import patient data such as weight, height, nutrition status (tube feed vs nil-per-os vs type of diet, use of steroids, etc.) assists the end user to efficiently use these order sets to calculate insulin doses which could be safe and effective at achieving euglycemia and preventing hypoglycemia.

Common hyperglycemic crises are DKA and hyperosmolar state both of which are potentially life-threatening emergencies. Retrospective chart reviews have indicated decreased resolution time of both the above conditions with the use of protocol implementation, without introducing significant increases in hypoglycemia or hypokalemia [32]. There are prospective clinical trials underway to establish the efficacy of computer-generated orders and use of computerized decision support tool in critically ill patients with hyperglycemia (clinical trial number NCT00655460) hyperglycemic crises. We have generated pilot data indicating efficient use of CBIA in the treatment of diabetic ketoacidosis in emergency department visits with safe discharges of such patient without readmission or repeat emergency department visits. Additionally, use of CBIA in patients admitted with DKA versus standard insulin infusion followed by basal bolus insulin therapy realized a shorter length of stay [30]. This benefit

was primarily a result of the CBIA preventing the intravenous infusion system (IVI) from being discontinued prematurely. Specific prompts for best practices in the management of DKA can easily be incorporated into a CBIA that is integrated with the EMR. Examples include reminders that acidosis is not resolved for a provider attempting to discontinue IVI when euglycemia is met in a patient with DKA or general recommendations for potassium or fluid replacement for a patient being treated for DKA.

Capturing and Analyzing the Data

Provider reimbursement for patient care is beginning to be linked to specific quality metrics. Through the Centers for Medicare and Medicaid Services (CMS), plans for provider incentives and penalties are driving hospitals toward the use of EMRs for collecting patient management information in both the outpatient and inpatient settings [33]. There are numerous examples of EMRs available for hospitals to purchase and use, and many of these are able to capture glucometrics. It is important to select an EMR that can communicate with the abovementioned computer software programs that drive insulin delivery, as well as blood glucose testing devices used on the floor [34–36]. The direct automatic transfer for point-of-care blood glucose data into the EMR is a critical piece of this, as it reduces the errors and confusion seen when busy staff members have to enter individual glucose values into the record themselves [34].

Table 3 Components of a glycemic control committee

1. Determine the glycemic goals for specific patient populations within the hospital system
2. Construct and disseminate hyperglycemia order sets and insulin protocols that are efficient yet practical to implement
3. Prepare staff through preparation of appropriate education materials and continuing educational programs
4. Analyze glucometric data utilizing the hospital electronic medical record
5. Prepare glucometric reports to assist in quantifying successes and recognize areas of excellence and areas that need further efforts at improvement

The glycemic control committee at the hospital should include information technology experts who are familiar with the EMR used at the institution, as these individuals will ensure that the appropriate glucometric data can be captured and recorded appropriately [4••]. The committee should also focus on how that data will be analyzed, as glucometric data often consists of thousands, if not hundreds of thousands of blood glucose values, and there are varying analytic models available with which one can interpret that information [37]. There must be a practical way to develop and to distribute reports highlighting key glucometrics, such as rates of hyperglycemia and hypoglycemia and that can provide real-time updates on progress to the committee and to the staff caring for the patients. Individuals and hospital units should be recognized for their hard work. This may involve financial incentives, hospital-/system-wide recognition via publications and websites, and specific nursing unit recognition.

Conclusions

Hyperglycemia encountered during hospitalization is common and associated with increased costs and hospital complications. A glycemic management team can effectively collect quality metrics and influence management of patients with hospital-associated hyperglycemia. Successes of such programs are related to support from hospital administration, information technology, nursing, pharmacy, and the medical staff. Integration of glycemic management within the electronic medical record improves ease of data reporting, simplifies providers' role in glycemic management, and is associated with improved outcomes. Recognition of the importance of avoiding excess hypoglycemia while managing hyperglycemia suggests adoption of different terminology. The authors suggest we begin advocating for improvements in inpatient *dysglycemia* to highlight the distinctions between intensive glycemic control and glycemic management. We recommend that the hospital have an organized and dedicated glycemic control committee. This multidisciplinary group will be tasked with [1] determining glycemic goals for different patient populations within the hospital [2], developing order sets and insulin protocols that are appropriately detailed and utilize the latest computer-driven technology while remaining practical to implement [3], educating staff through in-person lectures and online materials as well as determining how frequently to re-educate [4••], analyzing data with the assistance of an integrated hospital EMR, and [5•] creating reports that provide crucial glucometric data, such as rates of hyperglycemia and hypoglycemia within different areas of the hospital system, allowing the committee to recognize those areas that are successful and those which need more attention (Table 3).

Compliance with Ethics Guidelines

Conflict of Interest Joseph A. Aloï, Christopher Mulla, Jagdeesh Ullal, and David C. Lieb declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- Of major importance

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