A Diabetes Management Service to Improve Inpatient Glycemic Control

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Abstract

- Objective: To describe the development and implementation of a hospital diabetes management service.
- Methods: Review of the literature and account of the activities of the service and system changes implemented.
- Results: There is ample evidence that glycemic control is important for all patients in the acute care setting. It is probable that safe and effective targets will vary with the patient’s acuity, diagnoses, and clinical setting. Tight control is probably most appropriate for the sickest patients in critical care settings; conversely, healthier patients in less acute settings should probably have less aggressive targets that minimize risk of hypoglycemia. Achieving glycemic control in the hospital is possible with the use of IV insulin infusions guided by frequent blood glucose monitoring, and by using subcutaneous insulin and insulin analogues. An IV insulin protocol has been shown to be safer and more effective than ad-lib titration of IV insulin.
- Conclusion: The ideal method for glucose control will depend on the clinical setting, anticipated nutritional intake, and the ability to monitor glucose levels and adjust the insulin regimen as clinical conditions change. Continued studies are needed to determine appropriate and specific glycemic control goals and the optimal protocols for achieving them.

Hyperglycemia is common among hospitalized patients. While the morbidity associated with long-standing hyperglycemia is well established, hyperglycemia in the acute care setting until recently was thought to be a “normal” and “adaptive” response to illness. However, in vitro and in vivo observations suggest that hyperglycemia, even short lived, results in an increase in inflammatory mediators, immunocompromise, infections, nutritional deficits, and fluid and electrolyte derangements [1].

It is estimated that hyperglycemia occurs in close to 38% of people admitted to the hospital, with an estimated 33% of these having no known history of diabetes [2]. Because diabetes is usually not the patient’s primary diagnosis, treatment efforts are often aimed toward management of the problems for which the patient was admitted, and attention to glucose management may be minimal.

Increasing evidence suggests that focused diabetes management of critically ill patients reduces morbidity and mortality and is cost-effective [1]. In this paper, we summarize the evidence that has emerged in the past few years examining hyperglycemia and its control in hospitalized patients and describe our approach to inpatient glycemic control at Brigham and Women’s Hospital (BWH) in Boston, MA.

Review of Studies of In-hospital Hyperglycemia Treatment and Effect on Outcomes

The first evidence that even short-term hyperglycemia is deleterious came from studies of surgical patients. Pomposelli and colleagues [3] noted an almost threefold increase in postoperative wound infections in patients undergoing “clean” surgery if even a single blood glucose (BG) measurement was over 220 mg/dL in the first 48 perioperative hours on every-6-hour monitoring. Zerr and colleagues [4] observed a similar phenomenon in patients undergoing heart surgery. Initially, a direct relationship between deep sternal wound infections and BG levels on the first and second postoperative days was observed. The authors then sought to lower postoperative BG levels, first with a subcutaneous insulin protocol and then with an intravenous (IV) insulin infusion, the first version of the now-famous Portland Protocol. Maintaining BG levels under 200 mg/dL led to a reduction in wound infection rates (from 2% to 0.6%)—rates comparable with those seen in the nondiabetic population [5]. Subsequently, more effective glycemic control has been associated with additional improvements in outcomes, including improved pump function and fewer arrhythmias [6]. Najarian et al [7] saw a reduction in infections, length of stay, and readmissions by lowering the mean BG from 186.9 mg/dL to 172.5 mg/dL in a non–intensive care unit (ICU)
glycemic control

vascular surgery population. There is compelling evidence that even modest control of BG levels can improve surgical outcomes in both the ICU and in less acute environments.

Patients presenting with acute coronary syndrome are frequently hyperglycemic. While about one third are known to have diabetes, 10% to 15% are newly identified in this acute setting. These patients are at particularly high risk for poor outcomes. A meta-analysis of 15 studies revealed increased risk of death and pump failure in patients admitted for acute myocardial infarction who had “stress hyperglycemia” but no diagnosis of diabetes prior to presentation. The risk of death was 3.9-fold higher in patients with BG 110 to 144 mg/dL than in patients with BG levels in the normal range. Further increases of BG levels were also associated with increased risk of congestive heart failure and cardiogenic shock. The prognostic implications of hyperglycemia in patients with preexisting diabetes were not as significant as they were in patients with hyperglycemia not known to have established diabetes [8]. These patients do better with BG levels under 140 to 150 mg/dL but have increased morbidity from hypoglycemia [9]. The role of insulin in the setting of acute coronary syndrome has been studied extensively to determine its possible direct beneficial effect on inflammatory growth factors, correction of elevated triglyceride levels, and improved endothelial function [10]. However, when insulin is used in conjunction with glucose (and potassium), no benefits are seen unless the BG levels are targeted and successfully improved [8]. The benefit seems to be conferred by the protection of tissues that have insulin-independent glucose uptake, including the brain and vascular endothelium. There also appears to be a protective effect on hepatic mitochondrial structure [11].

Hyperglycemia on admission to the hospital has been noted to be associated with a worse prognosis in other clinical contexts. In critically ill patients, adverse outcomes are correlated with poorer control and higher insulin requirements. However, patients with preexisting diabetes may be resistant to the effect of hyperglycemia: outcomes in diabetic patients appear worse when BG levels are over 200 mg/dL, while patients with no previous history of diabetes are adversely affected at lower BG levels (> 144 mg/dL) [12]. This is also true on the general medical ward, where patients with newly noted hyperglycemia had a significantly higher mortality rate and lower functional outcomes than patients with known diabetes [13].

Effects of Intensive Treatment

In a landmark study, Van den Berghe and colleagues [14] reported their experience in a single surgical ICU where the majority of patients were recovering from open heart surgery. Patients were randomized to intensive insulin therapy, where IV insulin was used to maintain BG levels between 90 and 110 mg/dL, or standard treatment, where IV insulin was used if BG levels exceeded 215 mg/dL, with a target of 180 to 200 mg/dL. The intensively treated group benefited from a dramatic reduction in ICU and in-hospital mortality and morbidity, had shorter periods of ventilatory support, less critical illness polyneuropathy, and shorter lengths of stay [14]. The patients who stayed longer in the ICU—more than 3 to 5 days—experienced the most benefit. A subset of these patients, those who had undergone cardiac surgery, was analyzed 4 years postoperatively. Intensively treated patients maintained the reduced mortality benefit observed initially, but there was no additional benefit following discharge [15]. Patients who suffered a stroke perioperatively were noted to have better functional status 12 months later [16]. Tight glycemic control in surgical patients reduced immediate complications that were maintained on long-term follow-up.

These findings were not reproduced when the Van den Berghe group studied medical ICU patients [17]. Drawing from their experience in the surgical ICU, the group tried to select patients who would need ICU care for at least 3 days. Of the 2110 patients considered for the study, 1200 patients were enrolled; only 760 ended up staying in the ICU for 3 days or more. In the intention-to-treat analysis of 1200 patients, no mortality benefit for intensive treatment was seen, but there was a small benefit in terms of morbidity. However, patients in the intensive treatment group experienced more hypoglycemia, defined as BG less than 40 mg/dL (mean, 31–32 mg/dL), and hypoglycemia was an independent risk factor for mortality [9,14,17].

Consensus Statement Recommendations

In light of the evidence highlighting the need for attention to glucose management in the acute care setting, in 2004 the American College of Endocrinology and American Association of Clinical Endocrinologists issued a position statement on the management of glucose in hospitalized patients [11]. The statement recommends a target BG level for ICU patients of less than 110 mg/dL, and target levels of less than 110 mg/dL preprandial and 180 mg/dL maximal for patients in step-down units. These recommendations have been controversial, with critics holding that the efficacy, safety, and practicality of these targets are not supported by the evidence. In our view, while available evidence may support the benefits of maintaining BG under 140 or 150 mg/dL, there remains insufficient evidence to maintain BG under 110 mg/dL. The tighter the BG goals, the greater the risk of hypoglycemia, which was noted to be associated with adverse outcomes in both Van den Berghe studies [14,17]. The benefits of tight glycemic control are influenced by baseline patient characteristics. A recent study comparing tight control to more liberal control intraoperatively in cardiac surgery patients demonstrated an increase in both...
mortality and stroke for the tight control group [18]. An analysis of cardiac surgery patients in selected Australian hospitals suggests that over 100 patients need to be treated with tight glycemic control to prevent 1 death and that this is likely to cause approximately 10 episodes of significant hypoglycemia [19]. Tight glycemic control imposes a significant burden on hospital resources (at our institution it would increase the number of patients initially treated with insulin infusions from approximately 30% to 100%) and is unattainable outside of the ICU. Further studies to define the optimal level of glycemic control are needed before generalized guidelines can be adopted. Some of these studies are underway (Table 1).

**Development of the Diabetes Management Service**

The BWH is a 750-bed teaching hospital with medical care provided by housestaff and overseen by attending staff. BWH serves as a tertiary referral center as well as a primary care center for the local community. There are distinct ICUs for cardiac surgery, thoracic surgery, burn and trauma, general surgery, cardiac care, neurology, and medicine. Many of these services also have step-down units. All floors are high acuity, with telemetry capabilities.

In 1996 we began studying the effects of diabetes on hospital costs and length of stay. Approximately 5000 patients with the diagnosis of diabetes were admitted annually between 1996 and 1999, representing 13% to 14% of total admissions. The average length of stay for patients with diabetes was 1.6 days (33%) longer than for comparable patients without known diabetes. This translated in total charges for patients with diabetes of approximately $110 million annually, representing an excess charge rate of 36%. The discrepancy between the costs of caring for patients with diabetes versus those without diabetes became even more dramatic when the data were analyzed by service. Approximately one third of the patients admitted to cardiac surgery had diabetes.

Convinced by compelling cost data as well as emerging evidence in medical literature about the benefits of an organized clinical diabetes program, hospital administrators strongly endorsed establishment of a multidisciplinary Diabetes Management Service (DMS). The mission of this new service was to intensify the care of patients with hyperglycemia and improve clinical outcomes, including reducing infection rates, readmission rates, and length of stay. It was anticipated that the cost of the program would exceed the revenues generated from direct billing; however, it was anticipated that the excess cost would be offset by savings from decreased length of stay and improved medical billing and coding practices. The DMS was initially introduced on the cardiovascular and vascular services, which had a disproportionately higher incidence of diabetes and higher costs. The plan was to expand the DMS to other surgical and medical services as the value and safety of improving glycemic control became evident.

The DMS team is made up of endocrinologists and nurse practitioners. The nurse practitioners are able to direct patient care autonomously, provide support to nursing, and bill independently. Dietitians, pharmacists, and staff nurses and physician leaders on patient care units were included in key phases of planning the program. Endocrine fellows also participate in the DMS in a limited role. They rotate on the service for 2 months of their first year and then perform selected consultations throughout the year.

**Culture Change**

In the late 1990s, the hospital’s diabetes program was a sparsely utilized consult service that was mainly employed for very difficult to treat cases. Inpatient diabetes care was managed by housestaff and consisted almost exclusively of using sliding scale insulin in hopes of avoiding hypoglycemia and severe hyperglycemia. The sliding scale that was used was a standardized scale that failed take into account differences in insulin resistance among patients [20]. Most hospital providers feared the consequences of severe hypoglycemia in their patients and did not recognize the potential adverse effects of hyperglycemia.

**Table 1. Ongoing Studies Investigating Inpatient Glycemic Control**

<table>
<thead>
<tr>
<th>Study Name</th>
<th>Description</th>
<th>Patients Randomized</th>
<th>Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Glucontrol</strong></td>
<td>(A Multi-center Study Comparing the Effects of Two Glucose Control Regimens by Insulin in Intensive Care Unit Patients) Belgium</td>
<td>3500 MICU and SICU patients randomized to tight or modest glucose control</td>
<td><a href="http://www.clinicaltrials.gov/ct/show/NCT00107601?order=1">www.clinicaltrials.gov/ct/show/NCT00107601?order=1</a></td>
</tr>
<tr>
<td><strong>NICE-SUGAR</strong></td>
<td>(Normoglycemia in Intensive Care Evaluation and Survival Using Glucose Algorithm Regulation) Australia, New Zealand, and Canada</td>
<td>4500 MICU and SICU patients randomized to tight or traditional glucose control</td>
<td><a href="http://www.clinicaltrials.gov/ct/show/NCT00220987?order=1">www.clinicaltrials.gov/ct/show/NCT00220987?order=1</a></td>
</tr>
<tr>
<td><strong>VISEP</strong></td>
<td>(Prospective Randomized Multicenter Study on the Influence of Colloid vs. Crystalloid Volume Resuscitation and of Intensive vs. Conventional Insulin Therapy on Outcome in Patients With Severe Sepsis and Septic Shock) Germany</td>
<td>600 patients with sepsis, crystalloid vs. colloid + glucose control</td>
<td>MICU = medical intensive care unit; SICU = surgical intensive care unit.</td>
</tr>
</tbody>
</table>
GLYCEMIC CONTROL

There was a clear need for the DMS to educate staff about the dangers of hyperglycemia and to develop approaches to improving glycemic control. Everyone involved in patient care, from department chiefs to staff at the bedside, would need to embrace new glycemic goals for their patients and understand some of the nuances in achieving these goals.

Meetings were held with the chiefs of surgical services where the DMS efforts were to be initially targeted. Appropriate data were reviewed and consideration given to the best approaches for the patient populations on each service. This then determined the nature of DMS involvement with the service. For example, on cardiac surgery, where 30% of the patients had diabetes or hyperglycemia, consultation was provided to all patients who had preexisting diabetes, elevated preoperative hemoglobin A1c, or required IV insulin to maintain BG under 150 mg/dL for greater than 24 hours. Vascular surgery identified patients preoperatively and asked for assistance in management if they had a hemoglobin A1c over 7% or were not responding to the team’s efforts. The renal and bariatric surgery teams identified patients with hyperglycemia or those at high risk for hyperglycemia preoperatively and automatically notified the DMS team on the day of admission. All chiefs embraced the concept of more aggressive diabetes management and fully supported the efforts that were outlined for DMS collaboration with their services.

Education

An ongoing education program that addressed the rationale and implementation of the intensified inpatient diabetes management program was developed. Physician education was aimed at all levels of care providers, from attending staff to housestaff. All new residents were given an overview of glycemic control during orientation. Consults on individual patients are used as opportunities to teach the housestaff and nurses about the importance of glycemic control and strategies to achieve it. Members of the DMS participate in departmental meetings, housestaff rounds, and morbidity and mortality conferences.

In collaboration with nurse educators and nurse managers, programs were initially developed for the nursing staff of the cardiac surgery and vascular surgery services. Nursing staff were educated about glycemic targets, insulin and oral agent action, carbohydrate counting, and effects of exercise and illness on glycemic control. The programs were offered on a very flexible schedule, including shift overlaps, lunch hours, evenings, and early morning (to capture the nursing staff on the night shift). For all programs, continuing education credit was given and meals were served. In addition to providing didactic talks and at meetings, members of the DMS are available to the nursing staff at all times to answer questions regarding protocols and individual patient care.

Hospital Systems Changes

Systems changes were implemented hospital-wide to support tighter glycemic control throughout the hospital. This required the collaboration of many hospital departments, including information services, dietary, physical therapy, and pharmacy.

IV Insulin Protocol

The Portland Protocol had been introduced for use in the cardiac surgery ICU just prior to the formation of the DMS. The Portland Protocol [5,21] has been proven to be safe and effective in this patient population. It served as the basis for the development of our current BWH insulin drip protocol shown in Figure 1. The BWH protocol requires frequent monitoring for hyperglycemia and the use of IV insulin for BG levels outside prescribed parameters. The current BG target on the cardiac surgery unit is less than 150 mg/dL. As with the Portland Protocol, a key component of the BWH protocol is the maintenance of adequate glucose control until the third postoperative day, which requires tight glucose control even after patients are taking food by mouth and after transfer to the step-down unit.

DMS evaluated the efficacy of the initial Portland Protocol, monitoring for correction of hyperglycemia, frequency of hypoglycemia, and errors in administration. The protocol was found to be safe and effective. The protocol was modified by simplifying the wording and calculations to minimize errors and adjusting glycemic targets from less than 200 mg/dL, to less than 175 mg/dL, and eventually to less than 150 mg/dL. Initially, continuous IV insulin infusion was initiated following surgery, but now the protocol is initiated in the operating room, which has led to significantly improved glucose control and a corresponding positive impact on outcomes. An order set for the entire protocol is now available in the computerized order entry system and is accessible to all hospital units. Nurses are provided with a bedside chart for easy reference.

Transition from IV Insulin and Management of Non–ICU Patients

Once a patient starts taking nutrition, rapid-acting subcutaneous insulin needs to be initiated; otherwise any significant nutrition intake will result in postprandial hyperglycemia. This forms the basis for a basal-bolus insulin regimen, which provides both basal and nutritional insulin coverage. About 50% of the anticipated total daily insulin needs is given as basal insulin, and the other 50% is given before meals as rapid-acting insulin. It is usually necessary for the IV insulin to overlap the subcutaneous regimen. As the IV is self-adjusting, it will be automatically weaned when it is no longer necessary.

For patient transitioning from IV insulin, the estimation of subcutaneous insulin doses can be based on the IV doses
START INSULIN DRIP AS FOLLOWS

Step 1: If lab blood glucose > 150, confirm blood glucose by fingerstick method, central or arterial line sample (BBG = bedside blood glucose)

Step 2: Mix drip and flush tubing with 10 cc of solution and discard. This is necessary to coat the tubing.

Step 3: Piggyback insulin drip (1 unit/cc) in to a maintenance line running at least 10 cc/hr

Step 4: Start insulin drip when BBG is over 150 and confirmed

FREQUENCY OF BEDSIDE BLOOD GLUCOSE TESTING

Every 1 hour until glucose is between 100–150

If insulin rate has remained unchanged for 4 hrs, then test q 2–4 hrs

Check q 30 minutes (until stable) while

- titrating pressors
- BBGs over 350 or under 75

INSULIN DRIP TITRATION (BBG = BEDSIDE BLOOD GLUCOSE)

<table>
<thead>
<tr>
<th>BBG</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 75</td>
<td>Stop insulin*&lt;br&gt;    If patient symptomatic or BBG less than 60, give 25 cc D50W&lt;br&gt;    If neither, call MD about need for D50W&lt;br&gt;    Recheck BBG every 30 minutes until over 75 × 4, then resume hourly BBGs&lt;br&gt;    <strong>When BBG is over 125, restart at 50% of previous rate</strong>&lt;br&gt;    if insulin drip stopped for 6 or more hours, and restart with <strong>Table 1</strong> above</td>
</tr>
<tr>
<td>76–100</td>
<td>Stop insulin*&lt;br&gt;    Recheck BBG every 30 minutes × 2, then resume hourly BBGs&lt;br&gt;    <strong>When BBG is over 125, restart at 50% of previous rate</strong>&lt;br&gt;    if insulin drip stopped for 6 or more hours, and restart with <strong>Table 1</strong> above</td>
</tr>
<tr>
<td>101–125</td>
<td>If lower than previous test&lt;br&gt;    • change of 10 mg/dL or more then decrease rate by 50%&lt;br&gt;    • change less than 10 mg/dL then decrease rate by 0.5 units/hr&lt;br&gt;    Otherwise continue current rate</td>
</tr>
<tr>
<td>126–150</td>
<td>Same rate</td>
</tr>
<tr>
<td>151–200</td>
<td>If lower than previous test then continue same rate&lt;br&gt;    If higher than previous test then increase rate by 0.5 units/hr</td>
</tr>
<tr>
<td>Over 200</td>
<td>If BBG is dropping&lt;br&gt;    • change of 20 mg/dL or more then continue same rate&lt;br&gt;    • change of less than 20 mg/dL then increase rate by 1 unit/hr&lt;br&gt;    If BBG is rising then increase rate by 1 unit/hr&lt;br&gt;    If BBG is over 200 and has not decreased after 3 hours, then double insulin rate and <strong>recheck BBG in 30 minutes</strong>&lt;br&gt;    If insulin drip rate has been doubled, increase by 1 unit increments q 1 hour × 3 before doubling again</td>
</tr>
</tbody>
</table>

*For patients with type 1 or insulin-dependent diabetes, never turn insulin drip off; continue at 0.5 units/hour and add D5 or D10W if needed to prevent hypoglycemia until patient is on SC insulin.

PROTOCOL GUIDELINES

- Use regular human insulin (CZI)
- Final dilution is 1 unit of insulin to 1 cc solution<br>    100 units insulin (1.0 cc of insulin)/100 cc bag of NS<br>    250 units insulin (2.5 cc of insulin)/250 cc bag of NS
- BWH insulin drip protocol is started during surgery or in the ICU and includes:<br>    Q 1–2 hr BBGs<br>    Use of IV insulin to maintain BBGs 100 to 150
- ADA diabetic diet starts with any PO intake including liquids
- If resuming SC insulin, discontinue insulin drip:<br>    30 minutes after administering fast-acting insulin (Humalog, Novolog, or Regular) OR<br>    2–3 hours after administering delayed-action insulin (NPH, Lente, Ultralente, or Lantus)

Table 1. Initiating Insulin Drip

<table>
<thead>
<tr>
<th>Blood Glucose</th>
<th>Insulin, units/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 150</td>
<td>0</td>
</tr>
<tr>
<td>150–175</td>
<td>1</td>
</tr>
<tr>
<td>176–225</td>
<td>2</td>
</tr>
<tr>
<td>Over 225</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 1. BWH insulin drip protocol.
needed over the previous 6 to 24 hours, giving about 50% of that amount in basal insulin, or based on the patient’s home regimen. Guidelines for glycemic management in all patients who do not require IV insulin were developed (Figure 2). These were reviewed with the housestaff and made available online, but were not implemented as an order set due to the varying needs of individual patients. These guidelines call for oral agents to be discontinued in hospital and hyperglycemia to be managed with insulin until the patient is getting ready for discharge. A strategy for estimating insulin doses based on the patient’s home doses and preadmission hemoglobin A1c or by the patient’s weight is outlined. The safety and flexibility of a basal-bolus regimen is highlighted, using long-acting insulin such as NPH or glargine to meet the basal needs only, and a rapid-acting insulin analogue (Lispro, Aspart, or Glulisine) to meet all nutritional needs. Nutritional insulin can be held if a patient will not be eating due to a procedure or poor appetite and can be given when the patient is ready to take oral nutrition. While a proactive insulin regimen is the mainstay of in-hospital glycemic control, an insulin sliding scale (Table 2) may be necessary to correct for possible underdosing. We redesigned the sliding scales at BWH to prevent glucose levels from rising to toxic levels and to allow for differences in insulin sensitivity in different patients.

Diet
DMS collaborated with nutritionists to develop a menu for diabetes patients that offered food choices with appropriate carbohydrate content and adequate nutrition for a patient healing from major surgery. A dietitian is available on each unit to review each patient’s selection and to ensure that these nutritional goals are met.

An interesting observation led to a change in beverage offerings. Previously, the only sugar-free beverages were diet ginger ale and water. Neither of these was appropriate for administering some medications or supplements, notably fast-acting potassium. Patients who received potassium received it with juice to make it palatable, and these patients had reproducibly elevated BG at lunch. In a tasting session, potassium was added to various diet beverages as well as juice. The best tasting beverage was red raspberry sugar-free beverage, even when compared with juice. Red raspberry sugar-free beverage is now stocked on all floors, with better BG levels before lunch.

Patient Education
Hospitalized patients are receptive to learning about their disease and adopting strategies for improving their health. Patients are taught about their diet by meeting with a nutritionist, using a carbohydrate-controlled menu, and getting feedback on their meal selections. Glucose values obtained in the hospital are reviewed with the patients and are used to assess the current regimen and analyze how the glucose reading resulted from the preceding insulin or medication doses, activity, and food intake. Patients’ home glucose monitoring is reinforced and insulin administration skills fortified. Diabetes education materials, home glucose monitors, and insulin starter kits are made available to the nursing floors and patients.

Patient Consults
Complex patients frequently defy protocols and require individualized regimens for glucose control. Thus, the majority of the DMS efforts are spent in direct patient care, consulting on patients and guiding their diabetes management. New consults are initially seen by one of the team’s physicians. The therapeutic plan is outlined and parameters for revision specified. The majority of follow-up is done by a nurse practitioner. The nurse practitioners also play a key role in discharge planning, ensuring that patients leave the hospital with the skills needed to care for their diabetes and follow-up if needed. This involves collaboration with the floor nursing staff and case management staff. The DMS team meets 2 to 3 times per week to review all the patients, evaluate practice guidelines and protocols, and identify any problems that may need to be addressed. One team member is on call during the week to answer questions during off hours and a team physician or nurse practitioner makes rounds over weekends and holidays, focusing on established patients with unstable glycemia and new consultations. Individual patient consultation helps the DMS team to identify systematic problems that need to be addressed and help target educational efforts more effectively. During the first year of the insulin drip protocol, the DMS team was alerted to the use of the protocol on some services via e-mail, which often led to a formal consultation for help with transitioning the patient from IV to subcutaneous insulin.

Program Assessment
We retrospectively reviewed the postoperative BG control in 5183 consecutive adult patients admitted to the cardiac surgery ICU between January 2002 and March 2006. Patient characteristics are given in Table 3. Glycemic control was assessed by calculating mean BG from blood draw samples during the first 72 hours of the postoperative period. Blood draws were obtained approximately every 2 hours in the ICU and recorded electronically. In order to minimize the weighting effect of increased blood testing during periods of rapid change, individual patient BG measures occurring within 30 minutes of each other were averaged, and the mean BG was calculated as the mean of these remaining measures.

Between January 2002 and March 2006, tighter glycemic control was achieved for both diabetic and nondiabetic
Determine Type of DM
Type 1 – insulin requiring at all times
Type 2 – may be on insulin or oral agents
If on insulin, should continue in hospital. Consider anyone
who requires 2 or more shots at home as “insulin requir-
ing” (needing long-acting and short-acting insulin)
If on oral agents, and anticipated hospital stay is > 36 hrs,
change to insulin

Glycemic Targets
Premeal, 80–110; postmeal, up to 180

Assess Admission Control
Glycemia: HbA1c 7.0 represents average BG of 170, each
1% change reflects change in average BG of 35 mg/dL or
home BGs
Home regimen: adherence to meds and diet, anticipated
changes in hospital

Basal/bolus regimens are most physiologic and are easily adapted and modified in the hospitalized patient with variable
nutritional intake

<table>
<thead>
<tr>
<th>Physiologic Need</th>
<th>Insulin Dosing</th>
<th>Point of Emphasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal</td>
<td>NPH in AM and HS or Lantus daily</td>
<td></td>
</tr>
</tbody>
</table>
| | Starting dose of 0.1 units/lb per day (0.25 units/kg/day) | Must provide basal insulin at all times for patients with type 1 DM
Do not hold if patient is NPO, see below |
| Prandial or Nutritional | Pt eating |
| | Starting dose of 0.1 units/lb per day divided among 3 meals |
| | (0.25 units/kg/day) |
| | Tube feeds or TPN |
| | Starting dose 0.1 units/lb per day if on full calorie replacement |
| | Add to basal or give regular insulin divided Q 4–6 hr |
| Correction | For correcting insufficiency in insulin over the past 4–12 hr. Start with default scale, adjust if total insulin needs are > 65 units per day |
| | Determine total daily dose of insulin |
| | Each unit will drop BG by 1800/total dose of insulin used per day |
| | Modify scale to correct BG to 100–125 |
| | The only appropriate use of sliding scale |

Insulin Dose Estimation
Use home doses if well controlled (A1c < 7 or BGs under 150
and above 60)
(Re)calculate if initiating insulin regimen for the first time or
home control poor
Increased insulin needs if
Pt starting or increasing steroids – increase by 40%–60%,
especially nutritional
Pt severely ill
Dialysis results in transient hyperglycemia as pt’s BG equal-
izes against the high glucose dialysis bath
Tube feeds and TPN – usually require more than the anticip-
ated nutritional insulin
Reduced insulin requirements if
Newly increased creatinine or decline in renal function
Prolonged lack of nutrition (> 48–72 hrs) results in depletion
of glycogen stores
Hepatic insult

Oral Agents (adequate endogenous insulin)
• If NPO – hold oral agents, regular scale OK
• If eating, may continue oral agents
• HOLD metformin if creatinine clearance is < 60 (serum
creatinine > 1.4 in women, > 1.5 in men) or if contrast
within past 24–48 hr, or severe CHF
• HOLD TZDs if liver dysfunction, edema, or CHF
• REDUCE sulfonylurea for renal or hepatic dysfunction

Insulin Action

<table>
<thead>
<tr>
<th>Type</th>
<th>Onset, hr</th>
<th>Peak, hr</th>
<th>Duration, hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lispro (Humalog)</td>
<td>¼</td>
<td>1</td>
<td>3–4</td>
</tr>
<tr>
<td>Aspart (Novolog)</td>
<td>½</td>
<td>2–4</td>
<td>6–8</td>
</tr>
<tr>
<td>Glulisine (Apidra)</td>
<td>None</td>
<td>12–18</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>2–12</td>
<td>12–18</td>
<td></td>
</tr>
<tr>
<td>70/30</td>
<td>1–2</td>
<td>None</td>
<td>24</td>
</tr>
<tr>
<td>Humalog</td>
<td>75/25</td>
<td>None</td>
<td>24</td>
</tr>
<tr>
<td>Humulin R</td>
<td>5/30</td>
<td>2–12</td>
<td>12–18</td>
</tr>
<tr>
<td>Novolog</td>
<td>75/25</td>
<td>None</td>
<td>24</td>
</tr>
</tbody>
</table>

Figure 2. Inpatient diabetes guidelines.
GLYCEMIC CONTROL

Table 2. Insulin Sliding Scale

<table>
<thead>
<tr>
<th>Blood Glucose, mg/dL</th>
<th>&lt; 175 lb</th>
<th>&gt; 175 lb</th>
<th>Custom</th>
</tr>
</thead>
<tbody>
<tr>
<td>80–150</td>
<td>0</td>
<td>0</td>
<td>[ ]</td>
</tr>
<tr>
<td>150–200</td>
<td>2</td>
<td>4</td>
<td>[ ]</td>
</tr>
<tr>
<td>201–250</td>
<td>4</td>
<td>6</td>
<td>[ ]</td>
</tr>
<tr>
<td>251–300</td>
<td>6</td>
<td>10</td>
<td>[ ]</td>
</tr>
<tr>
<td>301–350</td>
<td>8</td>
<td>14</td>
<td>[ ]</td>
</tr>
<tr>
<td>&gt; 350</td>
<td>10</td>
<td>18</td>
<td>[ ] and call HO</td>
</tr>
</tbody>
</table>

Note: Give rapid-acting insulin when tray is in front of patient. Doses indicated in units. Doses estimated based on insulin sensitivity estimated based on body weight. Use higher scale if patient is known to require more than 65 units insulin per day. HO = house officer.

Table 3. Patient and Treatment Characteristics (n = 5183)

<table>
<thead>
<tr>
<th>Age, yr</th>
<th>Mean ± SD</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female, % (n)</td>
<td>34.8% (1826)</td>
<td>67</td>
</tr>
<tr>
<td>Diabetes, % (n)</td>
<td>65.5 (3433)</td>
<td></td>
</tr>
<tr>
<td>Any type</td>
<td>25.9 (1357)</td>
<td>7.7 (404)</td>
</tr>
<tr>
<td>Requiring insulin</td>
<td>24.2 (1268)</td>
<td></td>
</tr>
<tr>
<td>FHCAD, % (n)</td>
<td>66.6 (3493)</td>
<td></td>
</tr>
<tr>
<td>Peripheral vascular disease, % (n)</td>
<td>19.7 (1031)</td>
<td></td>
</tr>
</tbody>
</table>

Operative characteristics

| CABG only, % (n) | 17.3 (908)   |
| CABG + valve, % (n) | 43.6 (2287)  |
| Valve only, % (n) | 32.5 (1705)  |
| Other, % (n) | 6.5 (343)     |
| Emergent, % (n) | 3.8 (199)     |

CABG = coronary artery bypass grafting; FHCAD = family history of coronary artery disease.

patients (Figure 3). During this 51-month period, the mean BG level for diabetic patients decreased from 187.4 ± 19.9 mg/dL to 142.7 ± 16.8 mg/dL. Likewise, the mean BG in nondiabetic patients decreased from 150.7 ± 19.9 mg/dL to 131.0 ± 10.2 mg/dL. Two changes to standard operating procedure occurred during this period: intraoperative IV insulin drips were initiated and a target BG of 100 to 150 mg/dL was incorporated into the ICU insulin drip protocol. By April 2006, 78% of diabetic patients and 97% of nondiabetic patients achieved a mean BG level of less than 150 mg/dL.

In order to assess the safety of tighter glucose management protocols in our patients, we identified patients experiencing hypoglycemia, defined as a BG measurement less than 60 mg/dL. During the time period from 2002 to 2006, there were 70 hypoglycemic measurements affecting a total of 67 patients out of more than 47,000 blood draws on 5183 patients. Only 3 patients had uncorrected hypoglycemic episodes that consisted of 2 consecutive BG measurements less than 60 mg/dL. This analysis only included BG measurements from blood draws since fingerstick BG values were not electronically recorded. It is possible that additional episodes of hypoglycemia occurred that were detected by bedside fingerstick testing and corrected according to the ICU protocol before the next blood draw. Nevertheless, the data suggest that tighter glycemic control did not result in significant numbers of hypoglycemia episodes nor adverse clinical outcomes in our patient population.

Summary

There is ample evidence that glycemic control is important for all patients in the acute care setting. This has been demonstrated in surgical, neurologic, cardiac, and medical patients across the acuity spectrum. Optimal glycemic goals are not well established. It is probable that safer and effective targets will vary with the patient’s acuity, diagnoses, and clinical setting. Tight control is probably most appropriate for the sickest patients in critical care settings; conversely, healthier patients in less acute settings probably have less aggressive targets that minimize the risk of hypoglycemia. Patients without diabetes likely benefit more than patients with diabetes from minimizing hyperglycemia. Achieving glycemic control in the hospital is possible with the use of IV insulin infusions guided by frequent BG monitoring and by using subcutaneous insulin and insulin analogues. An IV insulin protocol has been shown to be safer and more effective than ad-lib titration of IV insulin. Similarly, a proactive subcutaneous insulin regimen based on physiologic needs can be guided by pre- and postmeal BG monitoring. The ideal method for glucose control will depend on a particular clinical setting, anticipated nutritional intake, and the ability to monitor BG levels and adjust the insulin regimen as clinical conditions change. To achieve optimal control, all members of the health care team need to collaborate. Physicians will direct the care regimens, supported by pharmacy teams, nutritionists and nursing staff. Continued studies are needed to determine appropriate and specific glycemic control goals and the optimal protocols for achieving them.

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References

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Figure 3. Mean blood glucose levels in the first 3 postoperative days in the cardiac surgery population.

12. Rady MY, Johnson DJ, Patel BM, et al. Influence of individual characteristics on outcome of glycemic control in intensive care unit patients with or without diabetes mellitus. Mayo


