Effective Glycemic Management in Hospitalized Patients: A Multidisciplinary Approach

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ABSTRACT

The dual purpose of this process paper is to describe the implementation of an intensive insulin infusion program against multiple barriers, despite the increasing evidence in the literature supporting glycemic control, and to report the glucose outcomes. Traditional hyperglycemic management has been done either by subcutaneous sliding scale or intravenous insulin infusions based on absolute glucose numbers. A review of the literature, with particular evidence within the cardiothoracic surgical (CTS) population, has shown significant deleterious effects of even mild hyperglycemia.

Increasing evidence supporting prevention of hyperglycemia, along with an unsatisfactory review of current methods used in-house, prompted the initiation of a pilot program to improve current methods utilizing insulin therapy. A multidisciplinary committee was formed consisting of the director of the intensive care unit, a dietician, a nursing unit director, a charge nurse, an endocrinologist, and two endocrinology nurse practitioners with extensive experience in intensive insulin therapy, including continuous subcutaneous insulin infusion. A review of literature was performed to evaluate available data and intravenous insulin infusion algorithms used by published authors. The CTS population was chosen as well as the intensive care unit. Nursing barriers in particular were extensive, and the use of a velocity driven insulin protocol required didactic instruction as well as individual reinforcement. All education, algorithm development, and oversight of patients were primarily performed by the nurse practitioners with immediate endocrinologist availability if needed. A review of glucose results indicated a significant reduction in hyperglycemia with a decrease in hypoglycemia and facilitated transition to subcutaneous therapy when necessary.

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INTRODUCTION

Hyperglycemia in critically ill patients has historically been viewed as an adaptive response to stress and an incidental marker of illness severity (1). Current research has challenged this notion and heightened the awareness of the detrimental effects of hyperglycemia in critically ill patients both with and without a previous diagnosis of diabetes (2-4). The stress of an acute illness is associated with the overproduction of counter-regulatory hormones (epinephrine, glucagon, cortisol, and growth hormones) that contribute to insulin resistance and decreased peripheral glucose uptake (5).

The mechanisms of harm from hyperglycemia include impairment of immune function, increased coagulopathy and inflammation, oxidative stress, and endothelial dysfunction (6). Increased incidence of nosocomial and surgical infections, sepsis, arrythmias, congestive heart failure, reinfarction, and decreased functional recovery in stroke survivors (7,8) are among the reported adverse clinical outcomes.

A large, randomized, prospective, controlled trial in a surgical intensive care unit in Leuven, Belgium, made a significant contribution to the emerging clinical evidence in support of strict glycemic control in critically ill patients (9). This study reported a substantial reduction in one-year mortality (42%), as well as statistically significant decreases in other short-term outcomes, including infections, acute renal failure and dialysis, critical illness polyneuropathy, need for mechanical ventilation, and length of intensive care unit (ICU) stay (9). Subsequent analysis of the data from the Leuven study identified maintenance of normoglycemia, rather than the amount of infused insulin, to be most closely correlated to the beneficial effects of intensive insulin therapy (10).

The control of hyperglycemia is now recognized as an important treatment goal in critically ill patients. The American College of Endocrinology (ACE) Task Force on Inpatient Diabetes and Metabolic Control issued a position statement that describes specific patient populations reported to show the greatest benefit

from intravenous insulin therapy along with specific recommendations for glycemic target guidelines. The position statement recommends the use of standardized protocols developed by multidisciplinary teams that have been shown to improve glycemic control with low rates of hypoglycemia (11).

The purpose of this review is to describe the interdisciplinary process used by Ochsner Medical Center (OMC) to develop an intravenous insulin infusion protocol for treatment of hyperglycemia in critically ill patients. The work specifically describes a pilot program to improve glycemic control in 105 patients undergoing cardiothoracic surgery with postoperative admission to the mixed 20-bed medical/surgical ICU.

INSULIN INFUSION PROTOCOL DEVELOPMENT, IMPLEMENTATION, AND OUTCOMES

Phase One: Development

Development of the OMC Endocrine Insulin Infusion Protocol (EIIP) began as a quality improvement initiative spearheaded by the hospital Pharmacy and Therapeutics (P&T) committee. An in-house P&T-led retrospective review of glycemic control in 28 cardiac surgery patients who were postoperatively admitted to the ICU revealed inconsistent management of hyperglycemia. Treatment included capillary blood glucose monitoring every 6 hours with use of sliding scale regular insulin or use of a standard insulin infusion protocol. Of this group, 82% never achieved a desired glycemic goal of 75-110 mg/dL, with 27.6% exhibiting blood glucose readings >180 mg/dL. In addition, 1.5% of patients experienced hypoglycemia, defined as blood glucose readings <70 mg/dL.

The P&T committee appointed a multidisciplinary committee to address the need for performance improvement in the area of glycemic management in critically ill patients. The committee was chaired by the medical director of the ICU. Committee members included the pharmacy director, ICU doctor of pharmacy, ICU nursing director, critical care dietician, director of nursing education, and two nurse practitioners (NPs) to represent the Department of Endocrinology, both of whom had specialized training in subcutaneous intensive insulin management and continuous subcutaneous insulin infusions.

The first step was to develop a protocol or modify an existing protocol for use at our institution. The committee reviewed the current available literature and, as recommended by ACE (11), all "traditional" insulin infusion protocols (where infusion rate changes were based only on the absolute blood glucose value) were discarded. More recent protocols were considered that incorporate both the level of glycemia and change in glycemia over time as a surrogate for insulin sensitivity (or resistance) to guide infusion rate changes.

Protocols reviewed included those of the Diabetes Insulin-Glucose in Acute Myocardial Infarction (DIGAMI) Study Group (12), Van den Berghe et al (10), and investigators from Portland (8) and Yale (13). The efficacy of each of these protocols is well established in the literature. However, careful scrutiny revealed significant differences in required calculations, time expenditure, and other determinants of ease of use, as well as training necessary for safe implementation and utilization by the nursing staff. The published Yale protocol with blood glucose target of 100–139 mg/dL was ultimately felt to be more user-friendly. Modifications were made under the direction of the OMC Endocrine Department to reflect blood glucose targets that were closer to those recommended by ACE and the American Diabetes Association. In addition, a pocket-sized slide rule version was developed for use at the bedside.

At this juncture, there was considerable debate among the committee members about oversight of the fledgling intensive insulin program. The chair of the OMC Endocrine Department strongly lobbied for a consult service to be staffed mainly by NPs, with endocrine fellow and staff involvement as needed. The ICU director felt that a consult service would result in inadequate training in insulin management for house staff. All parties agreed that initiation of this program would constitute a substantial culture change in the institution, and ultimately decided to move forward as a consult service, with agreement to revisit this issue after the pilot program was completed.

The final decision left to the committee was the choice of patient population in which to pilot the program. Guided by the obvious need for improvement in our current glycemic management approach in cardiac patients as evidenced by the chart review initiated by P&T, as well as strong literature support for the benefit of intensive insulin in cardiothoracic surgery patients (8,14), the committee decided to focus the pilot program on this group.

A cardiothoracic surgeon was asked to join the committee to ensure that the goals were consistent, to provide input from the cardiothoracic surgery perspective, and to serve as an advocate within the cardiothoracic surgery department. The protocol was to be implemented on all post-surgical cardiac patients with an initial blood glucose reading of >180

mg/dL or two blood glucose readings >150 mg/dL. The initial target blood glucose goal was a range of 80–120 mg/dl. This was later changed to 75–110 mg/dL after the results of the first 25 patients were evaluated. Approval for the study was obtained from the Ochsner Health System (OHS) institutional review board.

Phase Two: Implementation

The intensive insulin order set was labeled Endocrine Intensive Insulin Protocol (EIIP) to differentiate it from the "best practice" insulin infusion orders used as current standard of care. The pharmacy director and ICU doctor of pharmacy facilitated the placement of the EIIP order sets on the OHS intranet and hospital pharmacy computer order system. The inpatient pharmacists were also trained by the pharmacy director to prevent inappropriate utilization of the EIIP in unapproved locations or patient populations.

Nursing education was coordinated by the ICU nursing director and the nursing education department. Traditional didactic methods were used to introduce the EIIP and ensure that both the concepts and the details of the protocol were understood. Early educational efforts focused on the deleterious effects of hyperglycemia in an effort to get "buy-in" from the ICU nurses. Fear of hypoglycemia was acknowledged to be an appropriate concern and avoidance of hypoglycemia was considered an important goal. The value of velocity of change to the interpretation of individual blood glucose values was highlighted. For example, a blood glucose level of 82 mg/dL should not be cause for undue alarm if the blood glucose value the previous hour was 87 mg/dL. On the other hand, if the blood glucose reading the hour before was 190 mg/dL, fear of a precipitous drop in glucose over the next hour would be warranted.

In our experience, didactic training sessions were poorly attended and attention spans very short. This was particularly true when nurses had just completed a 12-hour night shift. A decision was made to proceed with the pilot program and focus on one-on-one training for both introduction (in some cases) and reinforcement of protocol operation. The NPs assigned to the consult service provided start-up infusion rate and bolus orders. They remained available throughout the day to assist nurses with details of the protocol and to provide additional teaching. The day shift nurses were responsible for review of protocol operations with the evening/night nurses during shift report.

During daily rounds, NPs reviewed the insulin rate changes made by the nurses and the resultant glycemic control of the patients. This provided direct feedback, constructive criticism, and support to the nurses. Moreover, this review process provided information about the performance of the protocol, which was used to make needed modifications or clarifications in both the order set and operational details in the initial stages of protocol implementation.

Specifics of the Endocrine Insulin Infusion Protocol

Upon admission to ICU, each cardiothoracic surgery patient's blood glucose was monitored every 2 hours for 6 hours. Endocrine was consulted if blood glucose results met criteria for initiating the EIIP. A variety of factors that influence insulin sensitivity, such as weight, body mass index, renal function, medications, and prior diagnosis of diabetes, were used to determine the initial infusion rate and the need for an insulin bolus.

The majority of patients were started on an intravenous insulin infusion (100 units of regular insulin in 100 cc of normal saline) at a dose of 0.8 units/kg. This rate equaled the anticipated total daily insulin dose divided by 24. Patients with body mass indexes <25 or with marked renal insufficiency were started at 0.5 units/kg. Patients with a previous diagnosis of diabetes were started at their current total daily doses of insulin if that exceeded the 0.8 units/kg calculations. Most patients received an initial bolus to attempt to correct their blood glucose level to 100 mg/dL. A target blood glucose of 150 mg/dL was used for patients with renal insufficiency, defined as serum creatinine >1.5 mg/dL. The protocol called for hourly monitoring of blood glucose levels after the initial start-up. The endocrine NPs or on-call physicians were to be notified if there were three consecutive blood glucoses >180 mg/dL to determine if additional intervention was warranted.

Phase Three: Outcomes

To date, the EIIP has been used 107 times in 105 patients in the surgical intensive care unit who have undergone cardiac surgery. Of these patients, 47% had a previous diagnosis of diabetes. The mean age was 67 years; 71% were males and 29% females. Mean and median ± SD (standard deviation) glucose values at EIIP initiation were 179.85, 178 ±39.70 mg/dL. Mean ± SD time to reach glucose levels of <140 mg/DL = 4.6 ± 3.8 hours; <110 = 8.1 ± 4.6 hours. Mean ± SD for the duration of the infusion was 31.7 ± 23.4 hours. Mean ± SD of blood glucose levels during the EIIP was 121.5 ± 35.0 mg/dL. After the first 5 hours, 42.3% of subsequent values were in the goal range and 80.6% of the values were between 70 and 140 mg/dL.

Hypoglycemia, as defined by blood glucose <70 mg/dL, was experienced by 26 patients, with 12 readings <60 mg/dL. There were no glucose values <40 mg/dL and no clinically significant adverse events related to hypoglycemia. Only 1.4% of all glucose values were <70 mg/dL. Furthermore, although not statistically significant due to insufficient numbers, the rate of deep sternal wound infections was decreased by 50% at our institution since the intensive insulin protocol was initiated.

Insulin infusion protocols designed to promote tight glycemic control have been reported to meet with resistance from nurses (15). Newer protocols that incorporate rate of change are complex and time-consuming, and successful implementation depends on nurse "buy in." We were unable to find any literature that describes nurse acceptance of clinical practice initiatives specifically facilitated by NPs. A Likert scale survey was developed to determine the perception of the OMC ICU nurses as to:

- the effectiveness of the EIIP,
- the value of the role of the Endocrine NPs in EIIP education, management and oversight, and
- the utility of a slide rule designed to assist nurses at the bedside.

Demographics of the ICU nurses who responded to the survey are shown in Table 1. The results of the survey (Table 2) revealed an improved understanding of the role of tight glycemic control, with nurses favoring the EIIP over both the standard insulin infusion protocol and the use of sliding scale insulin. Nurses expressed overall satisfaction with the NPs' educational and support roles, with the majority of less-favorable responses coming from the night shift nurses. This information offered an opportunity to address the difficulty of training night shift nurses on new and complex clinical practice initiatives.

The nurses felt that the slide rule accurately represented the EIIP order set. The majority of nurses found the tool to be time-saving and easy to use. Since we were not sure how well-accepted or helpful the slide rules would be, we printed only a limited number. Response to this survey identified the need to print more slide rules to ensure easy accessibility to nurses who prefer this method of insulin adjustment. Results from this survey suggest that the endocrine NPs have been well accepted by ICU nurses in both their educational and management roles.

Table 1. Demographics of ICU nurses who responded to survey.

Usual Work Schedule	63% days 37% nights
Length of Employment	3% < 6 months 34% 6 months–2 years 63% > 2 years
Year of Graduation	16% < 1995 57% from 1995-2003 27% after 2003
Gender	22% male 78% female

Surveys were sent by e-mail to all nurses on the ICU e-mail list: 69 full-time and 15 agency or part-time. Thirty-eight nurses responded to the survey, 34 of whom were full-time and four of whom were agency or part-time.

Likert scale questions were compiled by the Endocrine NPs and distributed to six experts in the field to rank questions in order of importance.

DISCUSSION

Historically, OMC physicians and nurses have depended on sliding scale insulin orders and were accustomed to and satisfied with blood glucose values far higher than the glycemic goals of an intensive insulin protocol. Many seasoned ICU nurses were resistant to a change in their current practice, with legitimate concerns about the potential for additional workload as well as fear of the negative consequences for patients who develop acute hypoglycemia. We found the learning curve required for use of a velocity-sensitive protocol to be steep, and repetition and follow-up teaching have been extremely important to the success of the program. As the pilot program neared completion, the safety and effectiveness of the protocol became evident, and, thus, the willingness to take on this extra burden increased.

The decision to use a consult service staffed primarily by specially trained NPs may not be feasible for all institutions. As a combined hospital/clinic, the Endocrine Department NPs at OMC have ready access to consultation with endocrine staff physicians with whom they are engaged in a collaborative practice. NP practice privileges differ from state to state. In Louisiana, it is within the scope of practice for NPs to provide care, write hospital orders, and bill for services without the requirement of a co-signature from a physician. The NPs' schedules allow for approximately 60% of their time in the hospital and 40% in the endocrine clinic. This helps to provide more seamless continuity of care and improved outpatient access for patients in need of ongoing follow-up.

Table 2. Results of the Likert scale survey completed by Ochsner ICU nurses who followed the Endocrine Intensive Insulin Protocol (EIIP).

The EIIP improved my feelings of competency to administer intravenous insulin.
- Strongly disagree: 2.5%
- Disagree: 29%
- Agree: 53%
- Strongly agree: 16%

The EIIP is a valuable method for maintaining tight blood glucose control.
- Strongly disagree: 5%
- Disagree: 3%
- Agree: 71%
- Strongly agree: 21%

The EIIP provides improved blood sugar control compared to the standard insulin infusion protocol.
- Strongly disagree: 2.5%
- Disagree: 10.5%
- Agree: 63%
- Strongly agree: 24%

The EIIP provides improved blood sugar control compared to the use of sliding scale insulin.
- Strongly disagree: 2.5%
- Disagree: 13%
- Agree: 60.5%
- Strongly agree: 24%

The EIIP is difficult to understand.
- Strongly disagree: 13%
- Disagree: 63%
- Agree: 18.5%
- Strongly agree: 2.5%

The NPs are effective in training nurses to use the EIIP.
- Strongly disagree: 2.5%
- Disagree: 8%
- Agree: 58%
- Strongly agree: 31.5%

I understand why tight blood glucose control is important in critically ill patients.
- Strongly disagree: 0%
- Disagree: 0%
- Agree: 45%
- Strongly agree: 55%

The availability of the Endocrine NPs to do "on the job" training has been valuable.
- Strongly disagree: 8%
- Disagree: 11%
- Agree: 54%
- Strongly agree: 27%

The time requirements for use of the EIIP are reasonable.
- Strongly disagree: 13.5%
- Disagree: 11%
- Agree: 70%
- Strongly agree: 5.5%

The EIIP is well designed to guard against hypoglycemia.
- Strongly disagree: 5%
- Disagree: 29%
- Agree: 58%
- Strongly agree: 8%

I have felt comfortable to make suggestions about ways to improve the EIIP.
- Strongly disagree: 8%
- Disagree: 10.5%
- Agree: 71%
- Strongly agree: 10.5%

I have felt comfortable asking questions about the EIIP.
- Strongly disagree: 3%
- Disagree: 3%
- Agree: 61%
- Strongly agree: 33%

The EIIP slide rule is a valuable tool for making adjustments to the insulin infusion rate.
- Strongly disagree: 3%
- Disagree: 13%
- Agree: 66%
- Strongly agree: 18%

The directions for operating the EIIP slide rule are clear.
- Strongly disagree: 0%
- Disagree: 24%
- Agree: 54%
- Strongly agree: 22%

The EIIP slide rule saves time.
- Strongly disagree: 5%
- Disagree: 27%
- Agree: 46%
- Strongly agree: 22%

The EIIP slide rule accurately represents the EIIP order set.
- Strongly disagree: 3%
- Disagree: 13.5%
- Agree: 59.5%
- Strongly agree: 24%

The EIIP slide rule is easy to use.
- Strongly disagree: 5.5%
- Disagree: 16%
- Agree: 59.5%
- Strongly agree: 19%

I routinely use the EIIP slide rule rather than the order set to make insulin rate changes.
- Strongly disagree: 19.5%
- Disagree: 14%
- Agree: 47%
- Strongly agree: 19.5%

As reported in the outcomes section, the majority of patients responded very well to the insulin protocol. However, some patients, due to various pathophysiological processes, proved to be more difficult to manage with prolonged hyperglycemia or persistent or intermittent hypoglycemia. Patterns emerged that were useful in directing and individualizing treatment. This information was subsequently used to develop a set of step-down orders for safe conversion of patients from the EIIP to subcutaneous insulin if necessary.

FUTURE PLANS

Results of the pilot program were presented and reviewed by the hospital P&T committee. The EIIP was approved for use as a consult service in all critical care areas including the operating room, recovery room, surgical and medical intensive care units, and the cardiac and transplant step-down units. The Endocrine Department has been given the responsibility to provide education, training, and support on a unit-by-unit basis.

A second version of the protocol has been developed for use on medical/surgical floors with target blood glucose values of 80-140 mg/dL. Other than the difference in the goal blood glucose, the order set and slide rule operate in an identical fashion to the critical care protocol. This allows nurses to use the EIIP safely as they migrate between critical care and general units. A second successful pilot program was conducted for the medical/surgical protocol on a single floor with patients receiving total parenteral nutrition. The staffing issues and time requirements for nurses on the general floor remain difficult barriers; for this reason, only two floors have been designated as “insulin friendly” and the protocol is used only on a very select patient population.

CONCLUSION

Hyperglycemic management in hospitalized patients presents significant challenges as a growing body of literature correlates aggressive management of glucose with improved patient outcomes. The Joint Commission on Hospital Accreditation is actively working on guidelines for attainment of certification for institutions that demonstrate expertise in this area. OMC has recently formed a committee to address the future of overall management of hyperglycemia throughout the hospital. The committee is coordinated by the Performance Improvement Department, enjoys the full support of the administration, and is inclusive of all stakeholders.

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