

# Implementing an intravenous insulin infusion protocol in the intensive care unit

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**H**yperglycemia, a condition that is associated with substantial complications,<sup>1</sup> is a common occurrence in the intensive care unit (ICU).<sup>2</sup> Studies show that maintaining glycemic control in a variety of ICU patient populations, with and without a prior history of diabetes, reduces morbidity and mortality.<sup>3-6</sup> Surgical ICU patients on mechanical ventilation (MV),<sup>3</sup> medical ICU patients receiving MV,<sup>4</sup> and coronary care unit patients after acute myocardial infarction<sup>5,6</sup> who are treated with i.v. insulin infusion therapy have improved outcomes. Decreases in the rates of infections, acute renal failure, and mortality have also been observed in a randomized controlled trial of ICU patients using i.v. insulin infusions to achieve desired levels of glucose control.<sup>3</sup>

As demonstrated by randomized controlled trials of spontaneous

**Purpose.** The implementation of three different insulin protocols in intensive care unit (ICU) settings in two community hospitals and one academic hospital is described.

**Summary.** Each institution possessed a commitment to improve the existing insulin protocols in order to achieve tighter glycemic control for ICU patients. Studies have shown that the maintenance of tight glycemic control provides improved patient outcomes. Obstacles to implementation of the insulin protocols at the institutions were increased staff workload, difficulties in interpreting algorithms, and lack of perceived benefit. In comparing details of the insulin protocols at the academic and community hospitals, it was found that differences were influenced by the type of institution. The differences among the institutions in the implementation of the protocols included the initial physician response to the protocol, the details of each protocol, nursing staff autonomy, and the involvement of the nursing staff in early protocol development. All three institu-

tions had a dedicated pharmacist in the ICU who committed time toward insulin protocol implementation. For an increased likelihood of successful insulin protocol implementation, a full-time dedicated ICU pharmacist should be assigned to participate on multidisciplinary rounds, provide nursing support and education, and collect process measures to monitor and improve the protocol.

**Conclusion.** The i.v. insulin infusion protocols developed and implemented in the ICUs at three institutions successfully achieved acceptance and compliance by physicians and nurses. The factors attributed to the success were multidisciplinary involvement, the continuous education of nursing staff, the vigilant involvement of a pharmacist, and flexibility in revising the protocol.

**Index terms:** Hospitals; Injections; Insulin; Insulins; Pharmacists, hospital; Physicians; Protocols; Workload

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breathing in patients on MV, protocols that facilitate appropriate clinical decision-making by staff involved in the care of a patient improve outcomes, enhance efficacy, and decrease potentially harmful variations in care.<sup>7</sup> Protocol-driven care that provides a vigilant system for both treatment and monitoring of hypoglycemia is beneficial to patients.<sup>8</sup>

Numerous examples of i.v. insulin infusion protocols are available for health care professionals attempting to standardize patient care in this area.<sup>9-15</sup> Most protocols have reported efficacy in maintaining the blood glucose (BG) level within a prespecified goal, while ensuring safety through a low rate of hypoglycemia.<sup>9-12</sup>

The method of developing and introducing an insulin protocol targeting hyperglycemia can play an important role in staff acceptance, especially in an ICU setting where more urgent conditions demand attention. Addressing obstacles to protocol implementation early in the development phase helps to facilitate the process. This article describes the implementation of insulin protocols in ICU settings of three different institutions, including one academic and two community hospitals. The general impetus for development of an insulin protocol in three institutions came from the Van den Berghe et al.<sup>3</sup> study, which provided clear evidence for improved patient outcomes through maintenance of tight glycemic control. Multidisciplinary involvement was instrumental in developing these protocols, which were promoted by pharmacists in each of these institutions.

### Description of implementation process

**Academic medical center—medical ICU.** The University of Pittsburgh Medical Center, Presbyterian (UPMC-P) is a 647-bed tertiary care academic medical center with a level 1 regional resource trauma center. UPMC-P has more than 120 des-

ignated adult ICU beds. The medical ICU (MICU) is a 24-bed unit staffed by attending and fellow physicians in the division of pulmonary, allergy, and critical care medicine and internal medicine house staff. The patient-to-nurse ratio is either 1:1 or 2:1, depending on patient acuity. The mean  $\pm$  S.D. ICU length of stay (LOS) for patients in this unit is  $6.2 \pm 9.5$  days. A clinical pharmacist performs rounds daily as part of the MICU patient care team and is available by pager at all times.

Before implementing the insulin protocol, there was no standard procedure for controlling hyperglycemia. Most patients admitted to the ICU were started on regular insulin i.v. with a sliding scale, monitoring of BG every six hours. Treatment was often reserved for a BG concentration of  $>200$  mg/dL. The administration of regular insulin via continuous i.v. infusion or subcutaneous administration of isophane insulin human (NPH) insulin, as well as selection of the target BG, was at the physician's discretion.

In an effort to optimize glycemic control in the MICU, the medical director, nursing director, and clinical pharmacist of the MICU teamed up with members of the UPMC-P multidisciplinary diabetes patient safety committee to design an intensive i.v. insulin protocol (IIP). The concept of tighter glycemic control was introduced to the MICU nursing staff in small group staff meetings for both night and day shifts. The nursing director and critical care pharmacist presented the insulin protocol as a way for nurses to give better care to their patients, with the potential of improving overall mortality. This protocol was also designed to give nursing staff more autonomy in their professional practice. About 75% of the MICU nursing staff volunteered to participate in the initial implementation of the protocol. These participants became the insulin protocol volunteer group (IPVG), and

they were given the opportunity to make recommendations to improve the protocol based on their observations and experience.

To gain experience under controlled conditions, the protocol was initially used in only one patient in the entire MICU at a time, with an IPVG nurse providing care. Nurses, a critical care pharmacist, a diabetes clinical pharmacist, and the MICU physician director met weekly to discuss patients on the protocol, process measures, and operational issues. Process measures<sup>16</sup> were (1) the nurses' ability to follow protocol instructions, (2) the time (hours) to achieve the BG goal range, and (3) the number of BG measurements in the target range during protocol use.

At first glance, the IIP appeared complicated; however, the majority of nurses using the protocol (Figure 1) agreed that it was easy to follow and instructions were clear. A clinical pharmacist interacted daily with the IPVG nurses for the first 10 patients to ensure that instructions were understood. Nurses were encouraged to page pharmacists, who were available around the clock to answer questions regarding the application of the protocol. In the first few weeks, the pharmacists received many calls, mostly from nurses who required assurance that they were following the protocol correctly. Calls that verified problems with the IIP resulted in protocol adjustments. By the fifth patient, the calls became rare, since most nurses had become comfortable with the protocol.

Every nurse in the MICU was educated on the IIP, and it was fully implemented within six months after the first patient was treated. For the first 25 patients started on the protocol, the time to achieve the BG goal averaged less than six hours, the rate of severe hypoglycemia (BG concentration of  $<40$  mg/dL) was less than 0.5%, and protocol instructions were followed for 94% of all BG samples that were drawn.<sup>17</sup>

As the number of patients concurrently on the IIP increased, a major operational obstacle was the low number of glucose meters in the unit. The model in use at UPMC-P is costly, since it links with the institution's laboratory and financial computer systems. The supply of glucose meters was insufficient for the increased demand. The director of nursing viewed this as a priority item in the MICU nursing budget, and subse-

quently more glucose meters were purchased.

As the IIP became the standard of care, nurses who were less experienced with the protocol seemed to disregard an important built-in safety feature. Precarious drops in BG levels (>25 mg/dL), even when both the previous and current BG levels are within the goal range, require additional action according to the IIP. To ensure that the protocol

is followed correctly, the critical care pharmacist designed a website that automates the IIP (Figure 2). Data are being collected to determine if this automation will increase compliance with the IIP instructions and improve patient safety while decreasing the nursing workload.

**Community teaching hospital—cardiothoracic surgery ICU.** Located in Wilmington, North Carolina, the New Hanover Regional Medi-

**Figure 1.** University of Pittsburgh Medical Center insulin protocol: academic medical center. Subsequent insulin adjustment is not included in this figure. ARDS = acute respiratory distress syndrome, BG = blood glucose, CBG = concentration of blood glucose, CVVHD = continuous venovenous hemodialysis, D5 = 5% dextrose solution, HCT = hematocrit, RN = registered nurse, 1/2 sodium chloride = 0.45% sodium chloride solution, TPN = total parenteral nutrition.

**REGULAR INSULIN IV INFUSION PROTOCOL: GOAL BLOOD GLUCOSE 80–150 mg/dL**

- Start IV Insulin infusion (1 unit/mL). Waste 15 mL of infusion through new tubing and every time tubing is changed.

<b>Initial CBG (mg/dL):</b>	<b>100-150</b>	Start IV insulin infusion at 1 unit/h
	<b>151 - 200</b>	Start IV insulin infusion at 2 units/h
	<b>201 - 250</b>	Give 2 units insulin IV push and start IV insulin infusion at 2 units/h
	<b>251 - 300</b>	Give 4 units insulin IV push and start IV insulin infusion at 2 units/h
	<b>&gt;300</b>	Give 4 units insulin IV push and start IV insulin infusion at 4 units/h

- Hold all previous insulin orders and oral hypoglycemic medication orders
- Follow insulin adjustment protocol. Notify MD if BG not at goal by 6 hours or if the rate exceeds 10 units/h.
- If vasopressors (epinephrine, norepinephrine, vasopressin, phenylephrine, dopamine), corticosteroids, or CVVHD are discontinued, decrease infusion to 1/2 previous rate and recheck BG in 1 h

**FOR PATIENTS ON NUTRITIONAL SUPPORT:**

- If the rate of dextrose, enteral or parenteral feeding is decreased (or TPN is being transitioned to enteral feeding), decrease insulin infusion by 50%
- If nutritional support is interrupted (held for any reason including "off-unit" trips), initiate D5 1/2 Sodium Chloride at 85 ml/h, decrease insulin infusion rate by 50%, resume q 1 h BG checks, and notify MD.

**IF PATIENT NOT ON NUTRITIONAL SUPPORT:**

- When BG is < 200 mg/dL, initiate Dextrose 5 1/2 Sodium Chloride IV at 85 mL/h

**CORTICOSTEROID THERAPY:** (Consider dividing the total daily dose of hydrocortisone when treating ARDS, adrenal insufficiency, etc. by 24 h and give as a continuous IV infusion. Note to RN: hydrocortisone is compatible with regular insulin at the Y-site.)

- Discontinue current order for hydrocortisone and give hydrocortisone IV continuous infusion at \_\_\_\_\_ mg/h

**MONITORING:**

- Check BG Q1 h until stable (at least 2 values between 80-150 mg/dL). BG checks can then be reduced to Q2 h. Once BGs are within goal range for 12 hours, reduce BG checks to Q4 h.
- Restart Q1 h BG checks if any change in insulin infusion rate occurs **OR** if there is significant change in clinical condition, vasopressor therapy, CVVHD, nutritional support, or glucocorticoid therapy.
- The site for BG checks should remain consistent. It is preferred to use either an arterial line or "VAMP" on a central line. Only values obtained **on the bedside glucose meter should be used to adjust the insulin drip.**
- Confirm BG via lab STAT if BG>500, HCT <20 or if clinical judgement indicates.
- Confirm BG with meter if BG<60 or if BG changes more than 100 mg/dL on a stable IV infusion.
- Check serum potassium at least Q12 h x 2 then Q24 h. Replace potassium within IV fluids or per protocol as needed.

Figure 1 (continued)

**Abbreviated MICU IV Insulin Protocol Adjustment Instructions:**

CBG (mg/dL)	Current rate 0.1-3.9 units/h	Current rate 4-6.9 units/h	Current rate 7-10 units/h	Current rate >10 units/h
<50	(1) D/C insulin. Give 50mL (1 amp) D50 IV. Recheck CBG in 15 min. Repeat as necessary. (Do not restart insulin until at least 1h after D50.) Notify MD. If no continuous nutrition, initiate D5 ½ Sodium Chloride at 85 ml/h. Restart insulin at 50% (half) previous rate when CBG >100 AND it is at least 1h after D50. Recheck CBG in 1h.			
50-69	(2) D/C insulin. Give 20mL D50 IV. Recheck CBG in 15 min. Repeat as necessary. (Do not restart insulin until at least 1h after D50.) Notify MD. If no continuous nutrition initiate D5 ½ Sodium Chloride at 85 ml/h. Restart insulin at 50% (half) previous rate when CBG >100 AND it is at least 1h after D50. Recheck CBG in 1h.			
70-79	(3) D/C insulin. Recheck CBG in 1h. When CBG >100, restart insulin but decrease rate by 50% (half) and recheck CBG in 1h.	(4) D/C insulin. Recheck CBG in 1h. When CBG >100, restart insulin but decrease rate by 2 units/h and recheck CBG in 1h.	(5) D/C insulin. Recheck CBG in 1h. When CBG >100, restart insulin but decrease rate by 3 units/h and recheck CBG in 1h.	(6) D/C insulin. Recheck CBG in 1h. When CBG >100, restart insulin but decrease rate by 4 units/h and recheck CBG in 1h.
80-150	(7.1) If CBG drop >50 mg/dl from last check, D/C insulin for 30 minutes and then recheck CBG. Restart insulin (as long as CBG>80), but decrease by 50% (half) and recheck CBG in 1h. (7.2) If CBG drop 25-50 mg/dl from last check, decrease infusion by 50% (half) and recheck CBG in 1h. (7.3) Otherwise, make no changes. If CBGs remain 80-150 for 2 consecutive hours, recheck q2h.	(8.1) If CBG drop >50 mg/dl from last check, D/C insulin for 30 minutes and then recheck CBG. Restart insulin (as long as CBG>80), but decrease rate by 2 units/h and recheck CBG in 1h. (8.2) If CBG drop 25-50 mg/dl from last check, decrease by 2 units/h and recheck CBG in 1h. (8.3) Otherwise, make no changes. If CBGs remain 80-150 for 2 consecutive hours, recheck q2h.	(9.1) If CBG drop >50 mg/dl from last check, D/C insulin for 30 minutes and then recheck CCBG. Restart insulin (as long as CBG>80), but decrease rate by 3 units/h and recheck CBG in 1h. (9.2) If CBG drop 25-50 mg/dl from last check, decrease by 3 units/h and recheck CBG in 1h. (9.3) Otherwise, make no changes. If CBGs remain 80-150 for 2 consecutive hours, recheck q2h.	(10.1) If CBG drop >50 mg/dl from last check, D/C insulin for 30 minutes and then recheck CBG. Restart insulin (as long as CBG>80), but decrease rate by 4 units/h and recheck CBG in 1h. (10.2) If CBG drop 25-50 mg/dl from last check, decrease by 4 units/h and recheck CBG in 1h. (10.3) Otherwise, make no changes. If CBGs remain 80-150 for 2 consecutive hours, recheck q2h.

cal Center (NHRMC) is a 500-bed community teaching hospital with a 14-bed cardiothoracic (CT) ICU. In the department of cardiac services, three cardiothoracic surgeons manage and admit all patients to this unit. Physician residents do not care for patients in this unit, and traditional daily multidisciplinary rounds are not scheduled. The patient-to-nurse ratio is 1:1 postoperatively and 2:1 postextubation.

The standard of treatment for hyperglycemia was that diabetic postoperative patients have BG levels checked every six hours. Sliding-scale insulin treatment was reserved for a BG concentration of >200 mg/dL, and insulin drips were instituted at the physician's discretion, with 150–200 mg/dL as the target BG range.

At this institution, acceptance by both nurses and physicians was perceived as critical to the success of any protocol. Before presenting the issue to the surgeons, the nursing manager and clinical pharmacist involved as many nurses as possible in designing a hyperglycemia management protocol for every postoperative cardiac

surgery patient upon admission to the CTICU.

Permission to implement the hyperglycemia management protocol was obtained from all the surgeons. The initial plan (goal BG concentration of 90–119 mg/dL) was considered to be too aggressive, so a BG goal range of 100–149 mg/dL was accepted. The protocol was implemented as a pilot protocol over the course of one month to allow ongoing modifications based on feedback from nursing staff and patient outcomes.

Nurses were educated about the benefit of tight glycemic control by the ICU nursing manager and the clinical pharmacist during staff meetings. Preoperatively, patients were also educated that they might receive insulin during their hospital stay even if they did not have diabetes. This helped to allay patient fears of being harmed by treatment with an unnecessary pharmacologic agent. A copy of the protocol was placed in patient medication charts so that detailed instructions were readily available. The clinical pharmacist monitored patients two or three

times weekly, and nursing feedback was elicited regularly during nursing staff meetings. The surgeons were updated on the protocol and rate of hypoglycemia during multidisciplinary meetings.

The first step toward implementation of the insulin protocol was obtaining physician acceptance of 90–119 mg/dL as the goal BG concentration. Since this goal was not initially accepted for the pilot protocol, the solution was to target a higher BG concentration range (100–149 mg/dL) and then reduce the BG range in a stepwise fashion over time. After six months of experience with the pilot, surgeons agreed to the next phase: decreasing the goal BG concentration range to 90–119 mg/dL. Figure 3 depicts the i.v. insulin infusion portion of the revised hyperglycemia management protocol. The rate of hypoglycemia (BG concentration of <40 mg/dL) was monitored for a three-month period for the protocol (Figure 3) and was found to be only 0.04%.

Implementation of the revised protocol (BG concentration range,

Figure 2. University of Pittsburgh Medical Center, Presbyterian insulin protocol website. BG = blood glucose, CVVHD = continuous venovenous hemodialysis, TPN = total parenteral nutrition.

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**REGULAR INSULIN IV INFUSION PROTOCOL: GOAL BLOOD GLUCOSE 80-150 MG/DL**

**Nursing Inputs:**

Is this a new start?:  Yes  No

Enter the previous blood glucose level:  mg/dL

Enter the current blood glucose level:  mg/dL

Enter the current infusion rate:  units/hour

Enter the last non-zero infusion rate:  units/hour

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**REGULAR INSULIN IV INFUSION PROTOCOL: GOAL BLOOD GLUCOSE 80-150 MG/DL**

**Nursing Inputs:**

New start: **No**

Previous blood glucose level: **100** mg/dL

Current blood glucose level: **170** mg/dL

Current infusion rate: **2** units/hour

**Recommendations:**

Set IV insulin infusion rate at **3** units/hour.  
Recheck BG in 1 hour.

*If vasopressors (epinephrine, norepinephrine, vasopressin, phenylephrine, dopamine), corticosteroids, or CVVHD are discontinued, decrease infusion to 1/2 previous rate and recheck BG in 1 hour.*

*If the rate of dextrose, tube feeding, or TPN is decreased (or TPN is being transitioned to tube feeds), decrease insulin infusion by 50%.*

*If nutritional support (tube feeding, or TPN) is interrupted (held for any reason, including "off-unit" trips), initiate D5 1/2 NS IV at 85 mL/hour.*

90–119 mg/dL) initially met with resistance from the nurses. This problem was eased by using nursing staff feedback to further change the details of protocol performance. An aggressive i.v. insulin bolus infusion protocol was instituted every two hours for a BG concentration of  $\geq 120$  mg/dL. If two consecutive BG concentrations were  $\geq 200$  mg/dL,

then an i.v. insulin drip was initiated. This aggressive bolus infusion approach was the same method used to control hyperglycemia in the operating room by the anesthesiologists. Postoperative coronary artery bypass graft (CABG) patients at NHRMC have a mean  $\pm$  S.D. ICU LOS of  $73.9 \pm 69.4$  hours. Insulin infusions were not started initially on all patients

with BG concentrations of  $\geq 120$  mg/dL because of the potential for a significant increase in nursing workload associated with rapid and continuous ICU patient turnover due to the short ICU LOS. Discharge from the ICU would also be delayed because insulin i.v. infusions are not allowed to be administered outside of the ICU at this institution.

Figure 3. New Hanover Regional Medical Center insulin protocol: community/teaching hospital (blood glucose [BG] goal, 90–119 mg/dL).

**Aggressive IV Insulin Bolus and Infusion Protocol**

BG (mg/dL)	Instructions
≤59	50 mL D50 IV <sup>1</sup>
64–60	25 mL D50 IV <sup>1</sup>
65–79	Recheck BG in 1 h
80–119	Recheck BG in 4 h
120–149	2 units IV push <sup>2</sup> <ul style="list-style-type: none"> <li>• If previous BG ≥150, give previous dose plus 2 units<sup>2</sup></li> <li>• If repeat BG is 120–149, give previous dose plus 2 units<sup>2</sup></li> </ul>
150–199	4 units IV push <sup>2</sup> <ul style="list-style-type: none"> <li>• If previous BG ≥120, give previous dose plus 2 units<sup>2</sup></li> <li>• If repeat BG is 150–199, give previous dose plus 2 units<sup>2</sup></li> </ul>
200–250	8 units IV push <sup>2</sup> <ul style="list-style-type: none"> <li>• If two consecutive BG are ≥200, start IV Insulin Infusion. Give 8 units IV push then start 8 units/h infusion<sup>2</sup></li> <li>• If previous BG 120–199, give previous dose plus 4 units<sup>2</sup></li> <li>• If repeat BG 200–250, give previous dose plus 4 units<sup>2</sup></li> </ul>
251–300	12 units IV push then start 12 units/h infusion <sup>1</sup>
301–350	15 units IV push then start 15 units/h infusion <sup>1</sup>
351–400	20 units IV push then start 20 units/h infusion <sup>1</sup>
>401	25 units IV push then start 25 units/h infusion <sup>1</sup>

<sup>1</sup>Recheck BG in 1 hour

<sup>2</sup>Recheck BG in 2 hours

Insulin Infusion Titration Guidelines:

1. BG should be checked Q 1h unless 2 consecutive BG are between 90–119 mg/dL then you have the option to change BG monitoring to Q2h
2. Do **not increase** infusion greater than 5 units/h unless BG is > 300 mg/dL
3. Do **not increase** infusion if BG decreases > 30 mg/dL
4. BG 90 to 200 mg/dL: **Decrease** infusion rate if BG decreases > 30 mg/dL
5. At 90–119 mg/dL: Consider a **decrease** infusion rate if BG decreases > 10 mg/dL
6. BG < 90 mg/dL then d/c infusion; check BG in 1 h and continue protocol; restart infusion when BG > 120 mg/dL if diabetic
7. While weaning vasopressor agents, begin BG monitoring Q1 h
8. Resume home diabetic medications if insulin infusion rate is less than 5 units/h; D/C IV insulin infusion
9. Nurses may ask for the diluent in intermittent IV medication infusions to be changed from dextrose to 0.9% sodium chloride, if compatible

Protocol deviations by the nursing staff were identified in two areas: BG monitoring every two hours and the initiation of continuous infusions. Discussions at the nursing staff meetings produced two major revisions. First, patients who were extubated and tolerated oral feedings or patients on continuous enteral nutrition would be automatically switched to subcutaneous NPH insulin and BG checks would be reduced to every

four hours. Second, a regular insulin i.v. bolus infusion protocol for BG concentrations of 200–250 mg/dL was introduced. If the level of BG was not reduced after two attempts, an insulin infusion would be started. These changes were approved by the CT surgeons; protocol deviations were reduced once the changes were initiated.

**Community teaching hospital—medical, surgical, and cardiac ICUs.**

Gundersen Lutheran Medical Center (GLMC) is a 325-bed community teaching hospital and tertiary referral center located in La Crosse, Wisconsin. It is a level II trauma center and emergency department with 16 medical and surgical and 24 cardiac ICU beds. The patient-to-nurse ratio is 1:1 or 2:1 depending on admission type and acuity.

As standard practice, only patients with CABG and patients on

parenteral nutrition received attention to BG control according to an established protocol. The BG goal was 150–200 mg/dL for CABG<sup>18</sup> and 120–220 mg/dL for patients receiving parenteral nutrition. Adherence to the former protocol was inconsistent because (1) the nurse was required to calculate the new rate of insulin infusion according to a percentage change from the previous rate (e.g., if BG level decreases by 25%, then decrease the rate of insulin infusion by 10%), (2) adjustment was not clearly specified (e.g., increase insulin by 1–2 units/hr), and (3) adjustment of i.v. insulin was limited by the available i.v. infusion pumps (0.5 mL/hr was the lowest rate). Efficacy of the protocols was perceived to be poor since severe hyperglycemia was rarely controlled.

The ICU medical director, CT surgery physicians, nurse practitioners, staff nurses, and a clinical pharmacist developed the insulin protocol with a goal BG range of 80–120 mg/dL and met monthly during the implementation and development period to monitor safety and efficacy. A concentration of 0.5 unit/mL regular insulin was selected so that adjustments could be handled in lower increments.

The keys to successful implementation were nursing education and efforts to increase the comfort level with this earlier and more aggressive treatment of hyperglycemia. Educational presentations detailing the benefit of intensive insulin therapy were valuable, but providing bedside information and support was priceless. The critical care department met as a group to monitor safety and efficacy during the initial implementation period. Nursing comments, questions, and suggestions on how to improve the protocol were also discussed at the meetings. After two months of training and following the pilot protocol, a month of data collection began in order to compare BG control in prepilot and postpilot

protocol patients. The pilot protocol was then finalized and approved by the pharmacy and therapeutics committee (Figure 4).

The increase in nursing workload required to achieve this level of patient glucose control became an obstacle. As a solution, nurses were educated in the importance of BG monitoring and insulin rate adjustments in achieving improved patient outcomes. In addition, patient care technicians were trained to draw blood from arterial lines, perform finger sticks, use bedside glucose meters, and enter data into the bedside electronic flow sheets in order to provide assistance in obtaining the hourly BG measurements.

Intensive BG monitoring significantly increased the use of meters and test strips. Consequently, the yearly allotted budget for point-of-care monitoring equipment was depleted within seven months. The mechanism for BG monitoring was changed as a result of this problem. First, hourly glucose monitoring was only required during the initial adjustment period. Subsequently, an arterial BG sample was sent to the laboratory every two hours. A laboratory technician analyzed patient samples on an immediate basis, batching them together to minimize analytical variability. If 30-minute or one-hour follow-up BG levels were needed, they were performed with BG meters in the ICU.

The more aggressive adjustment schedule required slightly more time to reach the tighter goal (7.5 hours for standard goal versus 9.2 hours for intensive goal). Stressing the importance of administering the initial i.v. bolus infusion of insulin and increasing the initial infusion rate for higher BG allowed the time to achieve the goal BG level to be shortened.

Initially, compliance with the protocol corresponded with adherence to previous protocols, but gradually improved as the comfort level of the staff increased. During the initial

implementation phase, the nurse adherence rate with the protocol was 72%. The highest rate of noncompliance was when BG concentrations were in the 121–160-mg/dL range (40.7% of total compliance errors [the errors made when nurses did not follow the specific instructions in the insulin protocol]) versus a 21% noncompliance rate for BG in the other BG ranges. Nurses did not follow the protocol when they were instructed to increase the rate of insulin infusion. The major fear among the nurses was that the protocol would create hypoglycemia and related adverse events in the patient. This problem was corrected by more intensive education and nursing support. However, follow-up data are not available at this time. The rate of hypoglycemia (BG concentration of <40 mg/dL) was 0.14%, which comprised only two BG concentrations of the 1381 that were evaluated. Both events were attributed to a decrease or discontinuation of concomitantly administered epinephrine infusion, without a subsequent decrease in the insulin infusion.

### Practical issues for protocol implementation

Introducing protocols directed at improving patient outcomes provides a learning opportunity for all clinical personnel involved in administering this care. As problems were encountered in these three institutions, solutions were found and protocols were revised. Details described below are clarifications that arose from experiences during implementation which are applicable to any hospital desiring to implement an insulin protocol.

**Blood sampling issues.** BG results vary when the blood sample is obtained from a different site.<sup>19</sup> To illustrate this point, at UPMC-P blood samples were obtained at the same time period in three patients from different sites. BG results from capillary (i.e., fingerstick), venous,

■ PRACTICE REPORTS Intravenous insulin infusion protocol

Figure 4. Gundersen Lutheran Medical Center insulin protocol: community/teaching hospital. BG = blood glucose, ICU = intensive care unit, IVP = intravenous push, NPO = nothing by mouth.

Goal blood glucose [BG], 80–120 mg/dL

Inclusion:

- Critically ill patients with BG > 120 mg/dL
- Actual or predicted ICU length of stay with mechanical ventilation > 24 h
- NPO or continuous feeding via parenteral or enteral nutrition

Exclusion:

- Diagnosis of diabetic ketoacidosis/non-ketotic hyperglycemia
- Regular diet

1. D/C previous insulin orders
2. Insulin preparation: Mix 50 units Regular insulin in 100 mL D5W (0.5 units/mL)
3. All other infusions in 5% dextrose solution (with or without sodium chloride or lactated ringers) if possible for total of 83 mL/h or more of dextrose containing fluids

**Initial Insulin IV Bolus and Infusion Rate**

BG (MG/DL)	120–180	181–240	241–300	301–360	>360
Bolus (IVP)	2 units	4 units	6 units	8 units	10 units
Infusion rate	1 unit/h	2 units/h	3 units/h	4 units/h	5 units/h

*This IV bolus protocol is to only be used for the first BG value and when insulin infusion rate is at 24 units/h.*

4. Infusion Titration (target level 80–120 mg/dL)

BG (MG/DL)	CURRENT INFUSION 0–10 UNITS/H	CURRENT INFUSION >10 UNITS/H (MAXIMUM RATE 24 UNITS/H)
<50	D/C infusion, give 25 mL D50 IVP and recheck BG in 30 min: <ul style="list-style-type: none"> <li>• If BG &lt; 50 mg/dL repeat 25 mL D50 IVP q 30 min until BG &gt; 80 mg/dL</li> <li>• If BG &gt; 80 mg/dL restart infusion at 50% previous rate</li> </ul>	
50–80	D/C infusion. Recheck BG in 1 h. If >80 mg/dL, restart infusion but decrease rate by 1 unit/h.	D/C infusion. Recheck BG in 1 hour. If >80 mg/dL, restart infusion but decrease rate by 50%
81–120	Continue at same rate. If BG continues to decrease over 3 consecutive hours, decrease rate by 0.5 units/h Increase rate by 0.5 units/h*	Continue at same rate. If BG continues to decrease over 3 consecutive hours, decrease rate by 2 units/h
121–160	Increase infusion by 1 units/h*	Increase rate by 1.5 units/h*
161–200	Increase infusion by 2 units/h*	Increase infusion by 3 units/h*
>200		Increase infusion by 4 units/h.* <i>Give an additional IV bolus (per above bolus scale) if infusion rate is at 24 units/h, but do not increase rate.</i>
<p><b>If there is a &gt;50% decrease in BG from previous value, decrease rate by 50% and recheck BG in 1 hour.</b></p> <p><b>*If there is a ≥30 mg/dL decrease from the previous value do not increase infusion rate.</b></p>		

Figure 4 (continued on next page)

Figure 4 (continued)

5. If **vasopressors, enteral or parenteral nutrition discontinued, stop insulin infusion.**  
Recheck BG in 1 h and restart protocol per above
6. For BG that remains elevated > 200 mg/dL despite maximal insulin infusion (24 units/h) give IV bolus per above scale recheck BG in 1 hour. If BG continues to remain elevated, pharmacy may change IV medications to normal saline, but maintain baseline of 83 mL/h or more IV dextrose infusion
7. Hang new insulin bag every 24 h
8. Monitoring: Arterial line or fingerstick BG by chemstrip Q1 h until 3 consecutive values within goal range, then change to Q2 h monitoring via stat BG levels. Reduce BG monitoring to Q4 h if goal range is maintained over 3 consecutive BG. If insulin infusion rate changes are made for BG concentrations greater than the goal range (80–120 mg/dL), resume Q2 h BG monitoring. May use fingerstick BG if arterial line is not present
9. Discontinue protocol when a regular diet has been ordered or patient has been moved to a non-critical care area. Obtain new sliding scale or infusion range orders from primary service

or arterial samples differed by as much as 34%, with no consistent trend among different patients, site of blood samples, or method used to analyze blood (i.e., bedside glucose meter versus central hospital laboratory). In a larger study, values from arterial lines correlated with central laboratory values better than capillary samples.<sup>20</sup> This emphasizes the importance of consistency of site used to obtain the BG sample and method for analysis for accurate interpretation of results.

**Nutritional issues.** A continuous dextrose source, in the form of i.v. fluid, either as enteral or parenteral nutrition, should be started at the initiation of any insulin protocol to avoid hypoglycemia that may occur with an improvement in insulin sensitivity over time.<sup>15</sup> If the rate of continuous nutrition is decreased or interrupted, dextrose-containing i.v. fluids should be initiated to avoid hypoglycemia.<sup>1,3</sup>

Transitioning from parenteral to enteral nutrition or to a regular diet can produce either hyperglycemia or hypoglycemia if not handled appropriately. Even when a regular diet excludes use of the insulin protocol, as in some institutions, it is important to adjust insulin therapy accordingly for any change in diet.

Similarly, stopping enteral feedings for baths and other short procedures can cause hypoglycemia if feeding is discontinued while the insulin rate is constant. There is no literature to support brief enteral feeding interruptions, so it may be preferable to keep enteral nutrition constant during short procedures. In addition, it may be beneficial for a protocol to include a contingency that if the rate of any glucose source (i.e., enteral feedings, total parenteral nutrition, any dextrose-containing i.v. fluid) is decreased, the rate of insulin infusion should decrease by as much as 50%.

Unexplained hyperglycemia has been observed following changes of insulin i.v. tubing in the literature.<sup>21</sup> A study at UPMC-P found that the concentration of insulin in the first 15 mL of the 1 unit regular insulin/1 mL solution from the i.v. tubing was variable, contributing to hyperglycemia in some patients despite previously stable glycemic control. Therefore, flushing new i.v. tubing with 10–30 mL of 1 unit regular insulin /1 mL 0.9% sodium chloride should be considered before initiation of the insulin infusion.

**Medications and dialysate.** Medications such as corticosteroids and vasopressor agents and procedures such as continuous venovenous

hemodialysis (CVVHD) are known to cause or exacerbate hyperglycemia.<sup>1</sup> If these therapies are either introduced or discontinued for any reason during continuous i.v. insulin treatment, either hyperglycemia or hypoglycemia may occur. In order to maintain BG goal ranges, protocols can be modified to adjust the insulin rate if those medications or CVVHD are initiated or discontinued.

Patients on intermittent doses of corticosteroids such as hydrocortisone and methylprednisolone can experience variations in BG. To avoid this, the total daily dose of either hydrocortisone or methylprednisolone can be divided over 24 hours and administered as a continuous i.v. infusion.<sup>3</sup> Hydrocortisone, but not methylprednisolone, is compatible at the Y-site with regular insulin, simplifying nursing administration in a patient with limited i.v. access.<sup>22</sup>

Intermittent i.v. medications (e.g., premixed i.v. bags of vancomycin, clindamycin, levofloxacin, and ciprofloxacin) administered in dextrose solutions may cause elevations in BG, directing the nurse to increase the rate of insulin infusion. Once the infusion of a medication in dextrose-containing fluids is completed, hypoglycemia may result. One solution to

this problem is to mix medications in 0.9% sodium chloride, if compatible. Both UPMC-P and NHRMC allow changes in the diluent of the intermittent i.v. medication based on either a written physician order or a phone call from the nurse to the dispensing pharmacy, respectively. GLMC instructs nurses to temporarily hold continuous postoperative i.v. fluid infusions during the administration of intermittent i.v. medications containing dextrose. As institutions become more familiar with causes of hyperglycemia and hypoglycemia, data for different solutions to this challenge should be collected and compared.

### Discussion

In comparing the details of the insulin protocols at the academic and community hospitals, we found that some differences were influenced by the type of institution. The decision to use a detailed protocol versus one allowing more nurse clinical judgment is complicated by the fact that many experienced nurses prefer the autonomy, while newer nurses desire more guidance.

The Van den Berghe<sup>23</sup> insulin infusion protocol provides guidelines for glycemic management but allows a greater degree of freedom for nurses to initiate insulin therapy than is considered part of their practice at many institutions. While it has been shown that tight glycemic control has a positive effect on patient mortality and outcomes, the details of the insulin protocol must be tailored for each institution. There must be a balance between the amount of glucose monitoring and the autonomy of the nursing staff for maintaining glucose in the proper goal range. Some areas where differences exist are glucose goals and aggressiveness of therapy. More aggressive therapy may incur an increased risk of hypoglycemia and requires more stringent BG monitoring, which significantly affects staff workload.

Another difference in the three protocols was the level of nursing involvement in protocol development. At NHRMC, nurses were actively involved in initial protocol development and gave feedback that caused changes. In the other two centers, the protocol was designed by the multidisciplinary team with the bulk of nursing input solicited during protocol implementation and evaluation.

In the protocol used at GLMC (Figure 4), the method and site for obtaining blood samples were not consistent. Arterial line and fingerstick samples were allowed, and both the central laboratory and the bedside glucose meter were used to assess BG concentration. This is different from the other two institutions that used consistent methods and sites. As mentioned previously, the use of more than one site or method to determine BG may result in clinical disagreements.<sup>20</sup>

In the Van den Berghe et al.<sup>3</sup> study, blood samples were taken from arterial lines and BG was measured with a bedside meter. This is usually preferable to sampling from a central line since less blood is wasted. Any insulin protocol should include instructions for nurses to be consistent with the site used for BG monitoring. If an arterial line is not available, a central venous catheter with a Venous Arterial Blood Management Protection System (VAMP) offers an alternative. VAMP is a sterile closed system that connects to the central venous catheter and allows blood to be drawn back into a reservoir. Once a sample is obtained, the blood remaining in the reservoir is returned to the patient.<sup>24</sup> This method prevents blood loss by avoiding discard waste in obtaining a sample. Fingerstick samples are used only if other access is unavailable; however, caution is urged since testing may be inaccurate in conditions such as hypotension, dehydration, anemia, shock, or abnormal blood pH.<sup>1,25,26</sup>

Although it was not the goal of this article to evaluate outcome mea-

asures (e.g., mortality and morbidity) with each of the different insulin protocols, evaluation of outcomes according to different levels of nursing autonomy and targeted BG ranges is important. The outcomes between BG concentrations of 80–110 and 80–150 mg/dL are potentially tremendous in terms of nursing workload and the rate of hypoglycemia. Additional insight into implementing and sustaining a general quality assurance program in the ICU was offered by Curtis and colleagues.<sup>27</sup>

All three institutions in this report had a dedicated pharmacist in the ICU who committed time toward insulin protocol implementation. At NHRMC, the ICU pharmacist was only able to devote two to three days per week in the ICU versus ICU coverage of five days per week from pharmacists at the other two institutions. Pharmacists at UPMC-P are also available by a pager 24 hours a day. Pharmacist workload during the initial implementation period was significantly increased with monitoring of patients, data collection, and nursing support. For an increased likelihood of successful insulin protocol implementation, a full-time dedicated ICU pharmacist should be assigned to participate on multidisciplinary rounds, provide intense around-the-clock nursing support and education, and collect process measures to monitor and improve the protocol.

Another important area is the development of a protocol to transition patients leaving the ICU from insulin infusions to scheduled subcutaneous insulin therapy, continuing goal-directed BG management.<sup>28–30</sup> The use of long-acting insulin in this transition needs further investigation. Safe and efficacious conversion rules continue to be studied and are necessary to improve clinical outcomes and safety.

Adopting strategies to reduce medication errors in the ICU may be necessary, since medication errors are

known to occur with insulin infusion protocols in the ICU. An electronic version of an insulin protocol has been used to assist nurses in calculating the dose of insulin needed to treat a patient with a certain BG level.<sup>31</sup> A web-based insulin protocol taking into account the previous and current BG levels and the current rate of the infusion is currently being tested at UPMC-P with the goal of improving baseline medication error rates with the insulin protocol (Figure 2).

### Conclusion

The i.v. insulin infusion protocols developed and implemented in the ICUs at three institutions successfully achieved acceptance and compliance by physicians and nurses. The factors attributed to the success were multidisciplinary involvement, the continuous education of nursing staff, the vigilant involvement of a pharmacist, and flexibility in revising the protocol.

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