Performance Improvement Measures in Achieving Glycemic Control in the Acute Brain Injury Population

CE

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ABSTRACT

Glycemic control is becoming a standard practice in the intensive care environment because it has been shown to produce positive patient outcomes and benefits. A 14-bed neurointensive care unit initiated a strict glycemic protocol and evaluated the results over a 1-year period through a performance improvement initiative. Results indicated that tight glycemic control could be achieved safely by adhering to an evidence-based established protocol. The average blood glucose level for all patients was between 90 and 130 mg/dl by Day 2 after the implementation of the glycemic control protocol. The purpose of this article was to explain how a strict glycemic protocol was safely implemented. Further research is necessary to determine long-term benefits of glycemic control in the population with neurocritical illness.

Glycemic control has become a growing trend in inpatient treatment and clinical research. Hyperglycemia has been identified as a frequent concurrent diagnosis in those with critical illness, even for those without a past medical history significant for diabetes mellitus. More often, hyperglycemia is being recognized as an independent risk factor potentially leading to further complications in both surgical and medical patient populations (Ellger et al., 2006). This phenomenon has evolved into a significant issue among the critical brain injury population, despite the patient's age, gender, race, past medical history, and state of health before injury. Research has shown that early intervention in glycemic control improves clinical outcome in the population with critical illness in both medically and surgically treated patients by reducing morbidity and mortality rates, infection rates, critical illness polyneuropathy, myopathy, the amount of time spent on mechanical ventilation, myocardial dysfunction, seizures, impaired recovery of organ failure, and neuromuscular dysfunction while improving wound healing (Ellger et al., 2006; Gearhart & Parbhoo, 2006; Hermans et al., 2007; Presutti & Millo, 2006).

Hepatic and peripheral insulin resistance and related insulin deficiency caused by a minute compensatory mechanism of pancreatic B cells have been shown to cause hyperglycemia in the population with critical illness, independent of the underlying disease process (Ellger et al., 2006). Glucose has been associated with brain tissue acidosis in patients who have experienced a major head injury (Zygun et al., 2004). Conditions such as diuresis, dehydration, ketonemia, electrolyte imbalance, and changes in mental status have been associated with acute hyperglycemia. Impaired immune responses to injuries and infections, impaired gastrointestinal motility, high cardiovascular tonus, impaired wound healing, and higher mortality rates are some of the pathologies that have been reported as consequences of hyperglycemia (Khoury, Klausner, Ben-Abraham, & Szold, 2004).

Furthermore, in patients who have sustained a traumatic brain injury, transient hyperglycemia has been shown to adversely affect cerebral energy metabolism when the blood glucose level is greater than 15 mmol/L. This increase is associated with a moderate increase in cerebral lactate levels (Diaz-Parejo et al., 2003). Diaz-Parejo et al. (2003) reported that transient moderate hyperglycemia did not in fact affect cerebral energy metabolism, as defined by a blood glucose concentration of 12 to 15 mmol/L. Acute or new hyperglycemia has been believed to occur in 5% to 30% of patients with critical illness due to the hormonal response to stress (Khoury et al., 2004).

This article describes the implementation of a glycemic control protocol, predicted upon evidenced-based research in a 14-bed neuroscience trauma surgical intensive care unit (NTSICU). The protocol was designed specifically for neurocritical care patients. The patient population cared for in the 14-bed NTSICU consisted of patients with various neurological diseases, traumatic brain injuries, subarachnoid hemorrhages, cerebral aneurysms, traumatic spinal cord injuries, strokes, brain tumors, and neurosurgical procedures, both emergent and planned. The patient population consisted of a mixed medical–surgical care

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environment. After a time allotted for data collection, an advanced practice nurse (APN) evaluated the performance of the staff's adherence to the newly developed glycemic control protocol. Implications for practice and recommendations for further research are discussed as well.

Literature Review

Taylor et al. (2006) concluded that a nurse-driven protocol for glycemic control led to more effective outcomes compared with a physician-managed protocol in the surgical intensive care environment. Results of their study demonstrated that more effective outcomes could be achieved by a nurse-driven glycemic protocol without a major increase in hypoglycemia; however, the tighter glycemic control protocol led to a lengthier time spent on an insulin infusion.

Because of a landmark study conducted by Van den Berghe et al. (2001), the positive benefits of intensive insulin therapy in the patient population with critical illness were clearly defined. Van den Berghe et al. performed a large prospective, randomized, controlled trial at a single institution. The researchers theorized that hyperglycemia and/or relative insulin deficiency contributed to a cascade of negative complications for surgical intensive care patients. A total of 1,548 participants were enrolled in the study over a 12-month time period. Patients qualified for enrollment into the study if they were being treated in the intensive care unit and were receiving mechanical ventilation. Upon admission, these patients were randomly assigned to receive either conventional or intensive insulin therapy. A continuous insulin infusion was initiated within the conventional group when the blood glucose level surpassed 215 mg/dl. The infusion was then regulated to maintain a blood glucose level between 180 and 200 mg/dl. The intervention group had tighter glucose parameters, and their infusions began when blood glucose levels went above 110 mg/dl and then were maintained to sustain a blood glucose level between 80 and 110 mg/dl. Whole blood glucose levels, either obtained from an arterial line or a capillary, were monitored every 1 to 4 hours, and the insulin infusion rate was adjusted and maintained by intensive care nurses according to a strict glycemic algorithm. According to the study protocol, the maximum insulin rate was set at 50 units per hour.

Results indicated a 4.6% mortality rate of patients in the intensive insulin therapy versus an 8% mortality rate in the conventional group. Mortality was reduced by 34% in the intensive insulin therapy group. The greatest reduction in mortality was attributed to the reduction in deaths related to multisystem organ failure with a confirmed septic focus. Those patients who were hospitalized in the intensive care unit for greater than 5 days seemed to benefit the most from the intensive insulin therapy. Multiple other advantages of intensive insulin therapy were identified through this groundbreaking trial. The intensive insulin therapy group inpatient mortality was reduced by 34%, blood stream infections were reduced by 46%, acute renal failure requiring dialysis or hemofiltration was reduced by 41%, the median number of red cell infusions was reduced by 50%, critical illness polyneuropathy was reduced by 44%, and the rate of prolonged mechanical ventilation was less likely to occur in those treated with the intensive insulin therapy.

The positive benefits of intensive insulin therapy in the patient population with critical illness have been clearly identified.

In the study conducted by Van den Berghe et al. (2001), the benefits of normoglycemia were inferred from the research conducted in the surgical intensive care unit. Recommendations were to research the benefits of normoglycemia in the medical intensive care setting as well. Van den Berghe, Wilmer, Hermans, et al. (2006) conducted another randomized controlled study at the same single-center site where 1,200 patients were randomly assigned to either a conventional or an intensive insulin therapy group in the medical intensive care unit. The study design and methods of data collection were the same as those described in the research study of Van den Berghe et al. (2001). Results indicated that inpatient mortality was not reduced in the intensive insulin therapy group, but blood glucose level was lowered. Yet, the reduction of newly acquired kidney injury, the accelerated weaning from mechanical ventilation, and the accelerated discharge from the intensive care unit and the hospital in general were achieved in the group randomized into receiving the intensive insulin therapy. The length of stay in the intensive care unit related to insulin therapy did not correlate. Those treated with intensive insulin therapy who stayed in the intensive care unit less than 3 days had a higher mortality rate versus that of the conventional therapy group. When the length of stay in the intensive care unit was greater than 3 days, inpatient mortality was reduced dramatically from 52.5% to 43% ($p = 0.009$). The significance of this study is related to the benefits of reduction of morbidity

versus that of mortality for those who received intensive insulin therapy.

Achieving euglycemia without becoming hypoglycemic has been the challenge to most clinical research studies. Van den Berghe, Wilmer, Milants, et al. (2006) performed an analysis of two randomized clinical research trials, those of Van den Berghe et al. (2001) and Van den Berghe, Wilmer, Hermans, et al. (2006), that evaluated and compared effective glucose control in both medical and surgical intensive care units. Van den Berghe, Wilmer, Milants, et al. (2006) established an acceptable glucose level for patients being treated in both medical and surgical intensive care units. Upon evaluation of all of the data, the researchers concluded that the optimal target glucose of less than 110 mg/dl was more beneficial than was the range of 110–150 mg/dl. However, the target glucose of less than 110 mg/dl also carried the greatest risk for hypoglycemia (10.7%) versus that of the 110–150 mg/dl range (4.3%) and greater than 150 mg/dl (2.9%). Within the conventional therapy group, hypoglycemia defined as a blood glucose level less than or equal to 40 mg/dl occurred in 1.8% of patients and in 11.3% of patients randomized to the intensive insulin therapy group ($p < .0001$). Patients who received more caloric intake had a higher occurrence of hypoglycemia than those who received fewer calories. Hypoglycemia was not found to have been responsible for any early deaths, rather abrupt and temporary morbidity in a small number of patients. Among the patients with documented hypoglycemia, immediate symptoms occurred in 5% of patients studied. Immediate consequences related to hypoglycemia were considered to be sweating, hemodynamic collapse, arrhythmia, decreased consciousness, epilepsy, or coma within 8 hours. Potential late sequelae of hypoglycemia included altered neurological status, epilepsy, coma, or death before hospital discharge. Three patients in the conventional therapy group and six patients in the intensive insulin therapy group displayed immediate transient symptoms of hypoglycemia, all of which fully recovered within 8 hours. There were also no permanent neurological sequelae among hospital survivors related to hypoglycemia from the intensive insulin therapy. Deaths that occurred within 24 hours of the first hypoglycemic event included three patients (12%) in the conventional therapy group and one patient (0.6%) in the intensive insulin therapy group. Overall, hospital mortality among patients who experienced a hypoglycemic event was similar in the conventional (52%) and intensive insulin therapy (50.6%) groups. According to Van den Berghe, Wilmer, Milants, et al. (2006), intensive insulin therapy causes minimal harm and reduces morbidity and mortality mutually in medical and surgical intensive unit patients. Despite these results, research from this study inferred that patients with diabetes did not significantly benefit from the intensive insulin therapy.

In a study attempting to identify the importance of achieving and maintaining normoglycemia in the population with critical illness, Ellger et al. (2006) conducted an animal research study. Ellger et al. induced critical illnesses to 47 rabbits and randomized them into four groups, including normal insulin/normoglycemia, high insulin/normoglycemia, normal insulin/hyperglycemia, and high insulin/hyperglycemia. The range of 80–110 mg/dl was used as the set target for normoglycemia. The hyperglycemic range was defined as 250–350 mg/dl. Over a 7-day period after randomization was determined, plasma insulin was sustained either at the normoglycemic range or the hyperglycemic range. Mortality rates were similar in both normoglycemia groups independent of insulin levels. However, the mortality rates in the hyperglycemic groups were higher by 35.7% in the normal insulin/hyperglycemia group and higher by 46.7% in the high insulin/hyperglycemia group, respectively. In addition, normoglycemia contributed to the prevention of liver, kidney, and endothelial dysfunction.

Method

Setting and Participants

A 14-bed NTSICU at a 772-bed quaternary care academic medical center located in a large metropolitan area performed a performance improvement evaluation to demonstrate whether tight glycemic control in the critical traumatic brain injury population could be safely achieved, the time frame in which it could be achieved, and the recognition of critical values and appropriate interventions taken by the bedside nurse in the neurocritical care patient. The NTSICU functions with an interdisciplinary team that consists of full-time coverage with neurointensivists, critical care fellows, neurosurgical residents, neurology residents, medical students, acute care nurse practitioners, pharmacists, nutritionist, respiratory therapists, and registered nurses. Daily morning neurocritical care rounds take place on the unit, and the intensive care nurse reports all subjective and objective data to the neurocritical care team from the past 24 hours. Included in the data reported is a summary of endocrine data reporting the past 24-hour blood glucose range, the amount of sliding scale regular insulin coverage the patient required, or the range of the insulin infusion administered. From the data discussed, the neurocritical care team developed a daily assessment and plan for each individual patient. Daily afternoon rounds were briefer and consisted of updating the neurointensivists and

acute care nurse practitioner of any changes or response to therapy.

Definition of Terms

For this performance improvement evaluation, hyperglycemia is defined as whole blood glucose level greater than 130 mg/dl. Tight glucose control is defined as a whole blood glucose level range of 90–130 mg/dl. Dangerously low hypoglycemia is defined as whole blood glucose level less than the 41–70 mg/dl range.

Purpose

The purposes of the performance improvement measure were to determine if nurses at the bedside could manage glycemic control safely and effectively for the brain injury population, recognize critical values, and take appropriate actions by adhering to a newly established tight glycemic control protocol. Signs and symptoms of hypoglycemia such as decreased level of consciousness are often masked in the brain injury population due to their pathology and clinical course of injury. A major concern for the performance improvement measure was that staff would not be able to recognize hypoglycemia with the initiation of the protocol and that using the protocol would increase the frequency of these events. The protocol comparison focused on whether nurses effectively lowered the incidence of hypoglycemia while patients were on a continuous insulin infusion, whether nurses appropriately recognized critical values, and whether appropriate interventions were taken by the neurocritical care nurse. A practice team consisting of neurointensivists, critical care neuroscience nurses, a clinical nurse specialist, acute care nurse practitioners, and pharmacists collaboratively developed the protocol. The goal of the performance improvement measure was to provide glycemic control to brain injury patients by safely maintaining a blood glucose level range of 90–130 mg/dl.

Performance Improvement

Standards of clinical practice were developed based upon evidence and research. As the trend in intensive care medicine moves toward achieving glycemic control, performance evaluation is necessary to monitor the progress and reflect upon the challenges. The review of this performance improvement initiative of glycemic control in the NTSICU served to incorporate all facets of the nursing process: assessment, planning, implementation, and evaluation.

The mutual goal setting between nurses, patients, and their family members in the intensive care unit aimed at healing and achieving a state of health. The purpose of this clinical practice performance improvement initiative was to evaluate the effectiveness of a nursing-centered glycemic control protocol and determine if nurses could change their practice patterns and standards with education and monitoring. Based upon the blood glucose level results, nurses followed the glycemic protocol and made adjustments accordingly. Nurses were actively involved in the development, implementation, and evaluation of the protocol. Achieving glycemic control in the NTSICU required continuous adjustment and titration of insulin according to the glycemic protocol. This protocol was developed based upon evidence-based research demonstrating that achieving glycemic control decreased morbidity and mortality rates and produced other positive patient outcomes. Implementing this evidence-based research into the NTSICU allowed nurses to help patients in the intensive care environment achieve more positive outcomes.

Performance improvement evaluations were conducted continually on this unit for the ongoing evaluation and validation of evidence-based nursing practice. Other performance evaluations that are currently being conducted specifically in the NTSICU include collecting data on total enteral nutrition guidelines to measure the incidence of aspiration with gastric feeding and evaluating a newly developed osmotherapy protocol. The hospital is mandated by the state to monitor and report nosocomial infections, including blood stream infections, urinary tract infections, ventilator-associated pneumonia, and surgical site infections. These data are benchmarked both nationally and internally and reported to the staff. Internally, the data are compared with the five other intensive care units in the hospital so that the staff members can see how their unit's performance compares with that of their peers. Through each of these quality indicators, performance improvement initiatives, and national benchmarks, the staff in the NTSICU can be confident that they are working together in an attempt to improve patient outcomes.

Data Collection

On the basis of hospital protocols, it was determined that the institution required no institutional review board approval because the researchers were conducting a performance improvement evaluation rather than a research study and the treatment was not experimental. This performance improvement evaluation utilized existing treatment methods to determine if one produced improved outcomes. The clinical effectiveness and quality improvement (CEQI) department at the hospital collected the data as per performance improvement policies. The APN in the NTSICU received the data from the CEQI department and

removed glucose data from any offservice patients such as surgical critical care and transplant patients. Therefore, the data included in the performance improvement measure are solely reflective of glucose results from patients in the intended sample group: patients on the neurocritical care service.

Once the APN filtered the data, a daily average of all blood glucose levels from day of admission to Day 30 of hospitalization was compiled. The CEQI department retrieved laboratory results and results from point of care testing (POCT) from the patient's electronic data files, including POCT results and laboratory values. In evaluating the safety of the protocol, the CEQI department gathered all POCT results that were less than 40 mg/dl, considered dangerously low, and presented them to the APN. For the duration of the evaluation, the neurocritical care team considered POCT results less than 41–70 mg/dl dangerously low because results less than this range required repeat monitoring and follow-up treatment. The APN audited every medical record to verify the low results because the glucometer can register false lows from inadequate blood samples or alterations in hematocrit concentrations. The APN confirmed if staff followed the protocol guidelines and appropriately repeated the glucose test. Only after obtaining a low value on the repeated test and verification by the APN was a true dangerously low value reported in the performance improvement collection of data. Before the APN examining the data and auditing the medical records, there were 35 low glucose level results reported that would have required treatment. However, after verifying true low values, only two patients were judged to have experienced dangerously low values based on repeated test results.

Competency Testing

All staff members on the unit including the staff clinical nurses and certified nursing assistants assisted in the monitoring and recording of blood glucose values on the unit. Proficiency in performing this task is validated annually through mandatory competencies for both the nursing assistants and staff nurses. Whole blood glucose level results, either obtained from an arterial line or capillary, were documented on the patient's bedside flow sheet and automatically downloaded to the hospital's computerized laboratory network when the glucometer was docked in its home station at the nurse's station. The glucometer was calibrated every 24 hours to ensure accuracy of results. The clinical nursing staff was responsible for adhering to the guidelines recommended in the glycemic control protocol and making appropriate autonomous interventions based upon the glucose results. Staff members were educated by inservice to the protocol, and newly hired staff nurses completed a self-learning packet on the protocol during their orientation period.

Design and Procedure

Data were collected and evaluated over a 12-month period, July 2005 through June 2006. Glucose control in the NTSICU was evaluated before the initiation of the tight glycemic protocol from July 2005 until December 2005. The intensive insulin policy was implemented in January 2006, and the evaluation of adherence to the policy and the frequency of critically low blood glucose level were measured through June 2006. The APN collected data over the second 6-month period on whether the protocol was followed appropriately and also measured the frequency of critically low blood glucose level results that were less than 40 mg/dl. Table 1 represents the progression of events that led to glycemic control in the NTSICU.

One of the factors used in evaluating adherence to the protocol was staff's compliance in responding to hypoglycemia. Hospital nursing protocol requires immediate response to a very low (<40 mg/dl) or very high (>50 mg/dl) POCT result. The protocol directs the staff nurse to immediately confirm the result by retesting the glucose by simultaneously using a glucometer and by drawing a venous sample and sending it to the laboratory. If results correlate, the staff nurse should administer 25 g of dextrose 50% in water (D50W) to the patient. Finally, the staff nurse restarts the insulin infusion when the blood sugar level is greater than 90 mg/dl at an insulin infusion rate of 50% less than the drip running before discontinuing for hypoglycemia.

Intensive Insulin Therapy Protocol

The rationale for the NTSICU glycemic control protocol was to achieve normoglycemia because of the overwhelming amount of evidenced-based research published in favor of achieving glycemic control in the intensive care unit environment. Glycemic control in the intensive care unit environment is critical to medical management. Hyperglycemia has been linked to poor patient outcomes and increased mortality rates. For example, Kinsley (2003) performed a retrospective medical record review of 1,826 patients with critical illness and comparatively analyzed hospital mortality rates associated with mean serum glycemic values. Mortality rates increased as the mean serum glucose value rose. The mean serum glucose range of 80–99 mg/dl had a mortality rate of 9.6%, the range 100–119 mg/dl had a mortality rate of 12.2%, the range 200–249 mg/dl had a mortality rate of 37.5%, and mean serum glucose greater than 300 mg/dl had the highest mortality rate of 42.5%.

As per the protocol developed by the collaborative team, the NTSICU staff members were instructed to

TABLE 1. Glycemic Control Performance Improvement Timeline and Protocol Steps

1. Development of protocol by interdisciplinary team
2. Retrieved data of blood glucose control before glycemic protocol initiated; data reviewed from a 6-month period (July to December 2005)
3. Staff training for the new protocol conducted over 1 month (December 2005)
4. Protocol implementation (6-month period of initial trial: January to June 2006)
5. Hospital CEQI department collected data from patients' electronic file, gathered data, and submitted blood glucose data to NTSICU APN.
6. NTSICU APN received data from CEQI, filtered the data, recorded the average daily blood glucose level, and audited charts of patients with critically low values.
7. Reviewed results with staff and interdisciplinary team.

Note. CEQI = clinical effectiveness and quality improvement; NTSICU = neuroscience trauma surgical intensive care unit; APN = advanced practice nurse.

start with a regular insulin sliding scale for all patients admitted to the NTSICU. If the staff members were unable to control the blood sugar level within the specified range for two consecutive fingersticks, the staff members were to start a continuous insulin infusion at a rate specified in the protocol based upon the most recent elevated blood sugar level. Some high-acuity patients required starting the continuous insulin infusion immediately upon admission. The NTSICU protocol development committee decided that the patients in the NTSICU would initially begin with blood glucose level monitoring every 4 hours starting with admission. If the patient subsequently had two consecutive blood glucose levels greater than 130 mg/dl while receiving regular insulin subcutaneously as per the sliding scale guidelines, then the patient should be initiated on the continuous insulin infusion. A patient also qualified for the continuous insulin infusion if his or her expected time on mechanical ventilation was expected to last greater than 48 hours, if the patient had increased intracranial pressures which required management, or at the discretion of the critical care team.

Tables 2 and 3, Figure 1, and Table 4 outline the NTSICU glycemic control protocol, the hypoglycemia protocol, insulin drip guideline, and adjusting the insulin drip guideline used in the performance improvement measure, respectively.

Results

Four hundred twenty patients were evaluated from admission through their length of stay in the NTSICU from January through June 2006. On average, glycemic control was achieved as per protocol by Day 2 of the protocol initiation. Results indicated that glycemic control was maintained during patient stay in the NTSICU. These results demonstrate that nurses in the intensive care setting can effectively manage patients on insulin infusions by adhering to protocol guidelines and quickly responding to critical values as defined by the protocol. The glycemic protocol initiated and monitored in the NTSICU was retrospectively proven to be effective and safe for use in the brain injury population, as evidenced by fewer incidences of critical values after the implementation of the glycemic protocol. Overall, the glycemic protocol, managed by the NTSICU-trained nurses, adequately, consistently, and safely maintained blood glucose level in the neurocritical population.

A significant difference in hypoglycemic events was noted between the POCT sample of patients and the group treated as per the glycemic control protocol. These data indicate that the frequency of critically low blood glucose level in all NTSICU patients decreased after the implementation of the glycemic control protocol. Data from the POCT glucometer were downloaded directly; all results are recorded. In this sample, the frequency of samples with false low glucose did not change; however, the number of samples with actual low blood glucose level requiring treatment with D50W decreased significantly. Refer to Figure 2 for further details.

Before the initiation of the strict glycemic protocol in the NTSICU, treatment of hypoglycemia was a standard order of 25 g of D50W for all blood glucose levels less than 70 mg/dl. After the implementation of the glycemic protocol, treatment parameters for hypoglycemia differed and are described in Table 3.

Figure 3 represents NTSICU protocol outcomes from the time period of January through March 2006 when 420 patients were as treated per the glycemic protocol guidelines. The average blood glucose level for all patients was between 90 and 130 mg/dl by Day 2 after the implementation of the glycemic control protocol.

TABLE 2. Glycemic Control for the NTSICU Patient

NTSICU guidelines

Glycemic control between 90 and 130 mg/dl will be the goal for all neurosurgery and neurology service patients in the NTSICU.

All neurosurgery and neurology service patients with critical illness will have BG monitoring every 4 hours starting on admission.

Glycemic control will first be attempted with regular human insulin subcutaneous injections per sliding scale (see below).

Continuous insulin infusion will be initiated per protocol when

- Patient has two consecutive BG levels greater than 130 mg/dl while receiving insulin subcutaneously per sliding scale.
- AND
- Patient meets criteria for insulin infusion:
  - Ventilator dependent and expected to be on ventilator for more than 48 hours, OR
  - Increased intracranial pressure requiring intracranial hypertension management, OR
  - At the discretion of the neurocritical care team managing patient

Continuous insulin infusion will be discontinued and transitioned to insulin sliding scale per protocol when:

- Patient is transferring to a non-ICU area, OR
- Hemodynamically stable—able to maintain glycemic control without insulin infusion
- If patient is transitioning to insulin subcutaneous injection:
  - Administer ordered Lantus insulin dose at noon, and stop insulin infusion at 2 p.m.
  - Start regular human Insulin as ordered with each meal (prandial dose) if appropriate.
  - Continue checking BG level before each meal and bedtime. Combine prandial dose with correctional scale insulin as indicated.
  - Insulin sliding scale: regular human insulin subcutaneous injection every 4 hours as needed
    - 3 units if BG level is 131–200 mg/dl
    - 6 units if BG level is 201–250 mg/dl
    - 9 units if BG level is 251–300 mg/dl
    - 12 units if BG level is 301–350 mg/dl
    - 15 units if BG level is 351–400 mg/dl
    - 18 units if BG level is >400 mg/dl
    - Call physician/certified registered nurse practitioner if BG level is >400 mg/dl

Note. ICU = intensive care unit; NTSICU = neuroscience trauma surgical intensive care unit; BG = blood glucose.

Discussion

Practice Implications

It is reasonable to maintain tight glycemic control based on current evidence by following a protocol; this practice is achievable and safe.

As many of the patients in this 14-bed NTSICU have brain injury and meet the protocol for continuous insulin infusion, the amount of glucometers properly functioning in the unit poses a dilemma. As the continuous insulin infusion is being titrated, the patient's blood sugar level is required to be checked on an hourly basis. At the time of the study, the NTSICU had only four functioning glucometers. As the plethora of benefits of strict glycemic control is continuing to surface through research trials, perhaps each intensive care room should have its own glucometer docked in its room because cardiac monitoring and thermometers are already located in each room.

In addition, it is not documented in the medical record if the frequent serum glucose samples are drawn arterially from an arterial line, collected via a venous

TABLE 3. Hypoglycemia Protocol

Blood glucose level (mg/dl)	Action
≤40	If patient is unable to eat and swallow or is NPO (nothing by mouth): Administer 25 g (50 ml) D50W by intravenous push. Recheck glucose level within 15 minutes. Repeat treatment until glucose level is >70 mg/dl. If patient is able to eat and swallow safely: Give 15 g of glucose gel. Recheck glucose in 15 minutes. Repeat treatment until glucose level is >70 mg/dl.
41–70	If patient is unable to eat and swallow or is NPO: Administer 12.5 g (25 ml) D50W by intravenous push. Recheck glucose level within 15 minutes. Repeat treatment until glucose level is >70 mg/dl. If patient is able to eat and swallow safely or has nasogastric tube: Give 15 g of glucose gel. Recheck glucose in 15 minutes. Repeat treatment until glucose level is >70 mg/dl.

Note. D50W = dextrose 50% in water.

FIGURE 1 Insulin Drip Guideline

Insulin Drip Guideline

- Regular Human Insulin Infusion 100units in 100mL of Normal Saline
- Test BG by finger stick method or arterial line sample, using the glucose meter.

INITIATING INSULIN DRIP

Blood Glucose	IV Insulin Bolus	IV Insulin Rate
90 – 130mg/dL	0	1Unit/hour
131 – 180mg/dL	0	2Units/hour
181 – 240mg/dL	4Units	3.5Units/hour
241 – 300mg/dL	8Units	5Units/hour
301 – 359mg/dL	12Units	6.5Units/hour
≥ 360mg/dL	16Units	8Units/hour

Frequency of Blood Glucose (BG) testing while on an Insulin drip

- Check BG every 1 hour until Stable
- Check BG every 2 hours if a patient is at a "Stable Infusion Rate." This is achieved when:
  - BG remains between 90 to130mg/dL.
  - Insulin rate remains unchanged times 4hours.

If BG is out of "Target Range" (90 to130mg/dL) resume hourly testing.

laboratory draw or a capillary stick via a lancet stick while the patient is receiving intensive insulin therapy. The glucometers used recognized a blood sample, but there was no setting to record whether the blood sample is arterial or capillary. This method of serum glucose collection is not uniform. The arterial line tubing currently used at the institution requires 5 ml of blood to be wasted before each collection, thus leading to unnecessary overphlebotomy if used solely for collecting blood glucose values. Frequent hourly lancet sticks have often led to bruising, calloused capillaries, and bleeding in patients with thrombocytopenia. A standard-size lancet is used throughout the institution.

Further education needs to be conducted for the nurses on the appropriate time to discontinue the insulin infusion and when they can attempt to change back to the sliding scale coverage. In some instances, patients remain on a low dose, for example, 2 to 4 units of insulin per hour, of continuous insulin for days at a time, without the neurocritical care team attempting to change over to sliding scale coverage or preprandial insulin dosing. Most likely this has to do with the staff nurses' knowledge and comfort level in feeling confident enough to discontinue the insulin drip and convert to subcutaneous insulin coverage. Continuing education provided by APNs on the unit should be coordinated through staff inservices, power points, and bulletin boards. The dissemination of this information would potentially aid in improving patient care and outcome, which is the overall end goal.

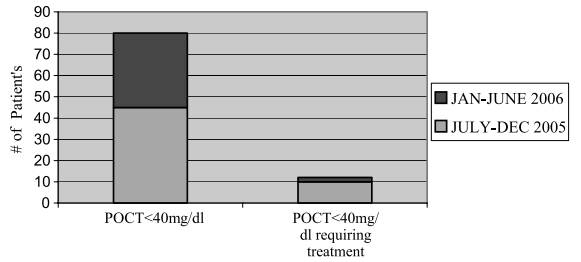
The major barrier to strict glycemic control protocols, especially in the critical brain injury population, continues to be hypoglycemia. Ongoing quarterly performance evaluations of the glycemic protocol are recommended. Staff nurses should be encouraged to report each occurrence of hypoglycemia, defined as blood sugar levels less than 40 mg/dl, in a standardized fashion. A uniform policy for event reporting should be established on the unit, and the APN should track these results and infer why complications took place. A task force composed of clinical nursing staff, nursing assistants, and APNs should be developed to

TABLE 4. Adjusting Insulin Drip

Blood glucose level (mg/dl)	Action
<40	Stop infusion.
	Give 50 ml of D50W or 15 g of glucose gel (if able to eat and swallow safely).
	Recheck BG level in 15 minutes. Repeat treatment until BG level is greater than 70 mg/dl.
	Alert physician/CRNP.
	When BG level is greater than 90 mg/dl, restart drip at 50% of prior rate. Check BG level in 1 hour.
41–75	Stop infusion.
	Give 25 ml of D50W or 15 g of glucose gel (if able to eat and swallow safely).
	Recheck BG level in 15 minutes. Repeat treatment until BG level is greater than 70 mg/dl.
	When BG level is greater than 90 mg/dl, restart drip at 50% of prior rate. Check BG level in 1 hour.
76–90	Lower: If BG level is lower by less than 10 mg/dl from the last BG level, reduce infusion by 0.5 unit/hr.
	Lower: If BG level is lower by 10 mg/dl or more from the last BG level, reduce infusion by 50% of current rate.
	Higher or equal: If BG level is higher or equal to the last BG level, there should be no change in rate.
90–130 (target range)	Lower: If BG level drops by 20 mg/dl or more from the last reading, reduce infusion by 50%.
	If BG level drops by less than 20 mg/dl or is higher than the last BG level, there should be no change in rate.
	When BG level is greater than 90 mg/dl and drip was stopped for a low BG level, restart drip at 50% of previous rate.
131–160	Lower: If BG level is lower by 20 mg/dl or more from the last BG level, there should be no change in rate.
	Lower: If BG level is lower by less than 20 mg/dl from the last BG level, increase infusion by 0.5 unit/hr.
	Higher: If BG level is higher than the last BG level, increase infusion by 0.5 unit/hr.
161–200	Lower: If BG level is lower by 20 mg/dl or more from the last BG level, there should be no change in rate.
	Lower: If BG level is lower by less than 20 mg/dl from the last BG level, increase infusion by 0.8 units/hr.
	Higher: If BG level is higher than the last BG level, increase infusion by 0.8 units/hr.
>200	Lower: If BG level is lower by 30 mg/dl or more from the last BG level, there should be no change in rate.
	Lower: If BG level is lower by less than 30 mg/dl from the last BG level, increase infusion rate by 1 unit/hr.
	Higher: If BG level is higher than the last BG level, increase infusion rate by 1 unit/hr.
After three consecutive increases in insulin drip and BG greater than 240 mg/dl	Bolus per ''initial iv insulin bolus'' dosage scale above and double the insulin infusion rate. Recheck BG in 30 minutes.
After two consecutive BG readings greater than 300 mg/dl	Call physician/CRNP for additional orders.

Note. Caution: Confirm BG value from point of care testing if a ''high/low'' reading or results <40 and >500 mg/dl. With prolonged hypoglycemia, do not exceed four ampules of D50W in 2 hours and confirm value by drawing venous sample with simultaneous point of care testing. D50W = dextrose 50% in water; BG = blood glucose.

FIGURE 2 Hypoglycemic Events Requiring Treatment



review these situations and barriers to adhering to the strict glycemic protocol.

Implications for Future Research

At the time of this performance improvement measure, the hospital staff members where this protocol was observed used regular insulin as their formulary drug for their sliding scale. However, beginning in April 2007, the hospital staff members have changed their sliding scale formulary from regular human insulin to Aspart injection insulin (NovoLog), which has a much different pharmacology profile. NovoLog has a more rapid onset and shorter duration of action than that of regular human insulin. The hospital staff members have chosen to continue using regular insulin as their intensive insulin infusion. Further research will need to be done to compare results of the glycemic protocol with regular human insulin versus the results of sliding scale coverage with NovoLog insulin.

Long-term follow-up should also be conducted to determine more information on the exact mechanisms of actions and pathophysiology of how strict glycemic control improves patient outcome in the brain injury population. Large multicenter research studies sponsored through government funding would aid in inferring these data. However, data published thus far have overwhelmingly indicated how strict glycemic control reduces overall morbidity and mortality rates in the intensive care unit. This alone should encourage funding that would potentially improve the quality of healthcare that is supported through evidenced-based research. Healthcare dollars saved through reducing complications that are lessened by strict glycemic control in the intensive care unit should encourage support of this endeavor. The next level of study should evaluate the cost associated with training, protocol implementation, and glucometers stationed in every room versus the time saved related to fingerstick/sliding scale processes to continuous infusions, medical waste produced from fingerstick injections, reduced ventilator utilizations, and reduced time spent in the intensive care unit. If it can be demonstrated that, because of improved patient care, cost reductions or cost savings occur as well, then the implementation of aggressive protocols could be more consistently accepted.

Limitations

Due to interdisciplinary planning, many factors that could have limited the success of the performance improvement analysis were avoided. For example, the clinical nursing staff was educated by an inservice before the implementation of the protocol. Protocols were laminated on bright-colored paper and placed in each of the patient's bedside medical record.

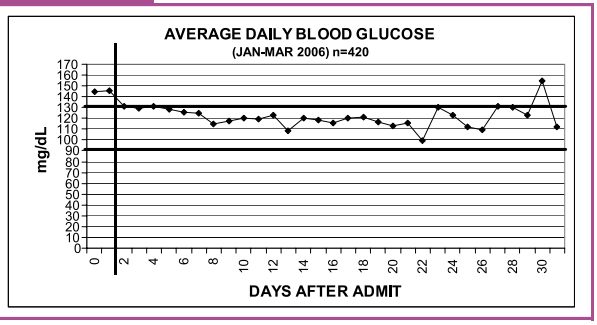
Limitations of this study included the retrospective nature of this study through electronic medical record auditing and the need for individualized care that occurs in the intensive care unit. One APN conducted the retrospective data collection of hypoglycemic events; a collaborative nursing research team involving clinical nurses may have interpreted, collected, or followed up on data differently.

Although glucose monitoring equipment and related data collection was readily available for traditional glycemic management, the clinical staff needed to have access to glucometers more frequently with the patients receiving aggressive glycemic management. This created down time while the staff waited to access equipment, which at times caused frustration and delayed treatment interventions.

Although a majority of the patients in the NTSICU were placed on intensive insulin therapy according to the practice protocol, insulin drips were not stocked in the unit's pyxis. Insulin infusions had to be ordered by the physician or nurse practitioner once the patient qualified for an insulin infusion and then prepared by the pharmacists and delivered to the unit. There was a lag time between a hyperglycemic result and the actual initiation of the continuous insulin infusion.

Often, most patients on the 14-bed NTSICU were on continuous insulin infusions and required hourly

FIGURE 3 Neuroscience Trauma Surgical Intensive Care Unit Protocol Outcomes



blood glucose level testing. Also, it was difficult for the clinical staff nurse and/or nursing assistant to obtain a blood glucose sample hourly on all of the patients in the unit receiving continuous insulin infusions. Some results were documented or reported at lengthier intervals than hourly. Using various methods of serum collection such as arterial draws, venous sticks, or capillary lancet sticks prevented uniformity in the collection of serum blood glucose.

Another limitation was patients might have unknowingly been treated with the same tight glycemic control that was implemented in January 2006 before the development of the protocol. Perhaps patients who were in the sample population that was reviewed before January 2006 may have received the same tight glycemic control regimen as the individuals treated after the protocol implementation. Without a prior protocol, it is difficult to determine which treatment methods were used by practitioners at the time.

Summary

Through retrospective data analysis, the strict glycemic control protocol developed collaboratively by the neurocritical care team proved to be both safe and achievable. The nursing staff recognized the defined critical levels and appropriately followed the established interventions for dangerously low hypoglycemic values. The findings from this retrospective analysis of data demonstrate that a strict glycemic control protocol can be safely integrated into neurocritical care practice. Further research is needed to determine how beneficial strict glycemic control is in the neurocritical care environment and the long-term effects on patient outcomes.

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