

Hospital Management of Hyperglycemia

Kristen B. Campbell, PharmD, and Susan S. Braithwaite, MD

For decades, a precept was passed down by academic physicians to trainees and staff as a guideline for inpatient care of patients with diabetes. That bit of wisdom held that it is best to “keep the patient a little sweet.” The Diabetes Control and Complications Trial¹ and the U.K. Prospective Diabetes Study² showed the ability of intensified control to reduce microvascular complications of diabetes. Despite the increased risk of hypoglycemia, these trials changed practice patterns in ambulatory settings in favor of intensification of diabetes therapy. Among hospitalized patients, a relationship of adverse outcomes to hyperglycemia was suggested by many observational studies that reported on mortality,³⁻⁷ infectious complications,⁸⁻¹¹ length of stay,¹² and other findings. Nevertheless, hospitalization continued to be seen by many practitioners as just a brief interlude during which tight glycemic control was risky and also irrelevant to the long-term well-being of patients with diabetes.

Two randomized, prospective trials using intravenous insulin therapy now have revolutionized our thinking about inpatient care of diabetes and hyperglycemia by showing the ability of intensive insulin treatment of critically ill hospitalized patients to reduce mortality without increasing morbidity due to hypoglycemia.^{13,14} The first study called for initiation of an infusion of glucose and insulin in the setting of myocardial infarction and aimed at a target glucose of 126–180 mg/dl.^{13,15,16} The second used intravenous insulin infusion in the surgical intensive care unit to achieve a target

glucose of 80–110 mg/dl.^{14,17} Control of hyperglycemia or insulin therapy per se hypothetically might reduce risks for hospitalized patients by correcting mechanisms of injury such as neutrophil dysfunction, abnormal activation of cytokines and the inflammatory pathway, cardiac reperfusion injury, endothelial dysfunction, thrombotic tendency, catabolism, and hyperglycemia-induced oxidative stress with resultant tissue injury.¹⁸ Although the findings of the inpatient trials cannot be extended confidently beyond the populations that were studied, practitioners and professional organizations now have embraced a position in favor of hospital normoglycemia.^{18,19}

The target ranges for plasma glucose in the hospital are:

- Preprandial: < 110 mg/dl
- Peak postprandial: < 180 mg/dl
- Critically ill surgical patients: 80–110 mg/dl

Deciding Whether to Maintain the Outpatient Treatment Plan

Deciding whether to maintain a patient’s ambulatory treatment plan while the patient is in the hospital usually is not difficult. In general, metformin will be contraindicated. Changes in renal function put patients at risk for hypoglycemia during glyburide therapy. All oral agents require prolonged observation between dose adjustments. Insulin provides the greatest flexibility to meet rapidly changing requirements. Therefore, most patients, if they need antihyperglycemic therapy to maintain target-range control, are best served by temporary conversion to subcutaneous or intravenous insulin therapy or by

addition of insulin to those oral agents that are safe to use under conditions of hospitalization.

The Physiological Requirement for Insulin

In normal physiology, the pancreatic output of insulin is divided approximately equally into basal and prandial components. The basal component can be thought of as the amount of insulin necessary to prevent excessive or inappropriately timed conversion of storage forms of energy into fuels (i.e., the amount of insulin necessary to prevent unchecked postprandial or fasting gluconeogenesis and ketogenesis and the amount necessary to prevent fasting hyperglycemia). The prandial component is the amount needed in relation to normal meals to promote conversion of digested nutrients into storage forms of energy (i.e., the amount of insulin necessary to cover meals without development of postprandial hyperglycemia).

Patients with type 2 diabetes sometimes can meet the physiological needs for insulin through the endogenous production of insulin. If they once required exogenous insulin, the dose requirement may change depending on caloric intake and body weight, or it may disappear entirely. Patients with type 1 diabetes, in contrast, have an absolute requirement for exogenous insulin, and, in the absence of medical stress or major lifestyle changes, the requirement is remarkably stable over time.

Intravenous Infusion of Insulin

Intravenous infusion of insulin is the only insulin treatment strategy specifi-

cally developed for use in the hospital. Indications for intravenous insulin infusion include diabetic ketoacidosis; non-ketotic hyperosmolar state; critical care illness; myocardial infarction or cardiogenic shock; the post-operative period following heart surgery; patients on NPO status in type 1 diabetes; general pre-, intra- and postoperative care; organ transplantation; stroke (possibly); exacerbated hyperglycemia during high-dose glucocorticoid therapy; use as a dose-finding strategy anticipatory to initiation or reinitiation of subcutaneous insulin in type 1 or type 2 diabetes; labor and delivery; and other acute illness for which prompt glycemic control is judged important to recovery, such as prevention or treatment of infection.

A number of protocols have been published describing the conduct of intravenous insulin infusion.^{6,17,20-23} Glucose monitoring by nursing staff initially must be provided on an hourly basis. After stabilization of glycemic control, some protocols permit the frequency of glucose monitoring to decrease to every 2 hours or every 4 hours. Computerization of an algorithm for determination of the needed rate of insulin infusion, engineering of the delivery system, and future developments in glucose monitoring are likely to simplify therapy for the staff.²⁴

Outside of the critical care or step-down unit, most hospitalized patients requiring insulin receive subcutaneous therapy. Before an intravenous infusion of insulin is stopped, subcutaneous therapy should be started and enough time passed for the patient to experience onset of action.

Subcutaneous Insulin Therapy

Assuming a patient requires exogenous insulin, a regimen of subcutaneous insulin therapy must meet basal requirements (basal insulin). Above the basal requirement, insulin therapy sufficient to meet caloric exposure must be prescribed (nutritional insulin), either to cover discrete meals (prandial insulin) or to cover sustained caloric exposure. By

providing in advance for insulin administration sufficient in amount to cover both basal and nutritional requirements and appropriate in timing (scheduled insulin, programmed insulin), the goal of subcutaneous insulin therapy (i.e., the prevention of hyperglycemia) can be met.^{25,26}

Small supplementary doses of regular insulin or rapid-acting analog responsive to hyperglycemia also can be prescribed (correction dose therapy).²³ For acutely ill patients, correction doses of regular insulin or rapid-acting analog may be given every 4 or 2 hours, respectively. The amount used as correction dose therapy may be a guide to needed changes of scheduled insulin. Correction dose therapy differs from sliding scale monotherapy in that correction doses are proportionate to daily requirement and are offered as a supplement to, not a replacement for, scheduled therapy.

The use of sliding scale as monotherapy is ineffective.^{27,28} All too often, patients carry a sliding scale with them, inscribed on their medication administration record (MAR), and borne throughout the hospital from general ward to preoperative holding areas, briefly replaced with intravenous bolus therapy in the operating room, and then carried to the postoperative recovery area and back again to the general ward. Ward transfer orders may simply state, "Resume sliding scale."

For patients possibly having type 1 diabetes, by far the more pressing need is that, wherever such patients go, their MAR should carry a basal insulin regimen, the component of their insulin therapy that must never be stopped. What is basal insulin? Once in the blood, of course, insulin is insulin. Assuming the absence of insulin allergy, it is not the choice of pharmacological preparation that counts, but instead the amount and the schedule for administration, which must be designed to maintain continuously and uninterrupted the needed blood levels of insulin to meet the physiological basal requirement.

Basal, prandial, and correction insulin therapy for patients who are eating

For patients in the hospital who eat discrete meals and do not receive carbohydrate between meals, it is easy and effective to prescribe scheduled insulin as separate basal and prandial components. Many patients with type 2 diabetes do well with premixed or split-mixed NPH and regular insulin used to cover both basal and prandial needs. However, in both type 1 and type 2 diabetes, insulin therapy is easiest to apply effectively, and the risk of hypoglycemia generally is lowest, with treatment plans that utilize intermediate or long-acting peakless insulin for the basal component of therapy and a rapid-acting analog matched to the carbohydrate content of meals for prandial therapy.²⁹⁻³² Correction doses then are given as small doses of a rapid-acting analog when hyperglycemia occurs.

Many patients previously treated with mixed NPH and regular insulin are grateful to go home on such a regimen, with the hope of hypoglycemia reduction and the potential that the treatment regimen offers for freedom in the timing and composition of meals. Outpatient follow-up about advanced carbohydrate counting is desirable.

For patients who are not familiar with the use of an insulin-to-carbohydrate ratio and who are not practicing self-management in the hospital, physicians should prescribe a consistent carbohydrate diet.³³ Carbohydrate may be prescribed in increments of about 15 g, the amount historically considered to be "one serving." Typical orders would provide for 45, 60, or 75 g (3-5 servings) of carbohydrate at each major meal and 15-30 g (1-2 servings) at snacks, plus any other diet specifications, such as "soft diet," salt restriction, or low phosphorus. The nutrition or dietary service of the hospital should implement the consistent-carbohydrate order and sometimes should be asked to assess patients' actual intake.

Fine-tuning through modification of the scheduled insulin regimen is appro-

appropriate when glucose results are close to target range control. However, when starting, it is appropriate to divide the basal and prandial components of daily therapy approximately equally. The total daily dose of insulin (TDDI) is estimated. About 50% of the TDDI is given as basal therapy, and the remaining 50% is divided among the major meals to match the carbohydrate content of the meals.

Following is a sample consistent-carbohydrate meal plan order with basal, prandial, and correction insulin orders for a patient who does not yet count carbohydrate:

- Capillary blood glucose daily before meals and at bedtime
- Consistent carbohydrate diet: 60 g at breakfast, lunch, and supper and 30 g at bedtime
- Lispro insulin, 6 units, before breakfast, lunch, and supper
- Glargine insulin, 18 units, at bedtime.

For patients receiving corticosteroids, the proportion may approach 30% basal and 70% prandial. If prednisone is given only in the morning, the prandial requirements may be greatest at lunch and supper.

Scheduled and correction insulin therapy for patients not eating

Many patients in the hospital do not eat discrete meals or do receive caloric exposure between meals. Patients may “graze” on transitional meal plans, or they may receive between-meal nutritional supplements, intravenous dextrose, enteral feedings, total parenteral nutrition, continuous renal replacement therapy, or other exposures to dextrose. There may be planned interruptions of caloric exposure as with overnight cycling of enteral feedings, or interruptions of enteral feedings for delivery of drugs such as phenytoin. There may be unplanned interruptions, as with obstruction of the enteral feeding tube or clotting of venous access for continuous renal replacement therapy. Using creativity coupled with a knowledge of the onset and duration of action of available

insulin products, the caregiver should devise a treatment plan that will provide continuous scheduled insulin coverage to meet the nutritional needs during the hours of the day when continuous caloric exposure is occurring.³⁴

Often it is not desirable to identify the physiological requirements for basal and nutritional insulin therapy uniquely with specific pharmacological preparations of insulin. For continuous nutritional coverage, rapid-acting analogs are less effective than longer-acting insulins, including mixtures, such as regular and NPH insulin given at 6-, 8- or 12-hour intervals. Basal needs can be met with the same preparations or with long-acting or peakless insulin.

As a safety precaution against unforeseen interruptions of nutritional intake or caloric exposure, the amount of long-acting insulin or peakless insulin should not exceed the basal requirements of the patient. For the same reason, to minimize risks in the event of sudden interruption of caloric exposure, to cover the nutritional needs it may be better to prescribe frequent small doses of intermediate-acting or regular insulin than infrequent larger doses of insulin. For example, to cover the nutritional needs of a patient receiving continuous enteral feedings, an initial plan for small doses of mixed NPH and regular insulin, given every 6–8 hours, may be safer than a plan for larger doses of NPH given every 12 hours.

Physicians also can write “hold” orders for the regular insulin component of therapy below a given threshold, such as 100 mg/dl.

“Alert” and “hold” parameters

The intent of a “hold” order is to provide a buffer against hypoglycemia in case of initial overestimation or downward trending of the insulin requirement and to protect against continued insulin administration when nutritional intake might suddenly change. “Alert” or “call” parameters are intended to prompt consideration of a revision of standing orders. For example, orders for a patient

receiving continuous enteral feedings might be:

- Capillary blood glucose every 6 hours
- NPH insulin, 8 units, every 6 hours
- Regular insulin, 4 units, every 6 hours
- Hold regular insulin if glucose is < 100 mg/dl
- Hold regular insulin if tube feeds are interrupted
- Call me for glucose < 80 mg/dl or > 240 mg/dl or interruption of tube feeds.

Today’s insulin dose

One of the most challenging questions about insulin therapy is, quite simply: “How much?” Or, to be more exact, the question is initially, “How much to start with?” and later, “How much for today?”

Having a clear record of the pre-admission treatment plan, such as that shown in Figure 1, is always helpful to admitting providers. For type 2 diabetes treated with insulin monotherapy, assuming there is no evidence for obvious over-treatment or under-treatment and assuming the patient will be eating, an appropriate starting estimate is often the TDDI before admission. As an alternative, one can estimate TDDI based on a patient’s body weight by starting with about 0.3 units/kg body weight, of which about 0.15 units/kg would provide basal coverage.^{35–38} Such an estimate usually must quickly be revised upward, however.

If nutritional intake is severely reduced, the requirement for exogenous insulin may disappear for a patient with type 2 diabetes. When caregivers are uncertain whether hyperglycemia will persist in a patient with type 2 diabetes, it may be safest to withhold scheduled insulin to see what pattern emerges.

For type 1 diabetes, the needed TDDI usually is already known. In type 1 diabetes, the needed amount of basal insulin is about 40–50% of the TDDI, as determined during normal health when the patient is eating normal meals. If a revision is required and the caregiver wishes to “start over,” a reasonable place

INFORMATION FOR THE PROVIDER ADMITTING MY PATIENT:
 This careplan (adapted to a consistent carbohydrate mealplan and fixed prandial doses of insulin), describes the outpatient diabetes treatment plan of my patient. It is understood that conditions of hospitalization may require treatment revision.

_____ (patient name) _____ (date of birth)

CONSISTENT CARBOHYDRATE DIET ORDERS:
 Carbohydrate content (suggested amounts are approximately 45–75 g for meals and 15–30 g for snacks, in increments of 15 g):
 Breakfast _____g Lunch _____g Supper _____g
 Mid-AM snack _____g Mid-PM snack _____g HS snack _____g
 Additional specifications to diet: _____

SCHEDULED DIABETES MEDICATIONS WHILE EATING USUAL DIET:
 Oral diabetic agents: _____

Subcutaneous scheduled daily insulin	<input type="checkbox"/> Breakfast	<input type="checkbox"/> Lunch	<input type="checkbox"/> Supper	<input type="checkbox"/> Bedtime
Rapid-acting insulin Lispro (Humalog®)	_____ units	_____ units	_____ units	_____ units
Rapid-acting insulin Aspart (Novolog®)	_____ units	_____ units	_____ units	_____ units
Short-acting insulin Regular	_____ units	_____ units	_____ units	_____ units
Intermediate-acting insulin NPH	_____ units	_____ units	_____ units	_____ units
Long-acting insulin Glargine (Lantus®)	_____ units	_____ units	_____ units	_____ units
Other insulin: _____	_____ units	_____ units	_____ units	_____ units

"Hold" parameters or comments _____

CAPILLARY GLUCOSE MONITORING (select one or more):
 QAC and QHS Q6h (6-12-18-24) Q4h (2-6-10-14-18-22)
 QAC and 2400 BID (8-17) _____h after each meal 0300

CORRECTION DOSE ALGORITHMS FOR SUBCUTANEOUS INSULIN
 Select insulin: Lispro (Humalog®) Aspart (Novolog®) insulin Regular insulin

For ALGORITHM assignment, preferred criterion = total daily dose of insulin (TDDI), adding all scheduled components. Alternative criterion = body weight. Algorithm may be selected or revised according to clinical judgement and response to previous therapy.
 Use of rapid-acting analog (Lispro or Aspart) should be repeated no more often than every 2 hours.
 Use of short-acting regular insulin should be repeated no more often than every 4 hours.

<input type="checkbox"/> ALGORITHM 1 Lispro / Aspart [TDDI <input type="checkbox"/> 24 (< 28) units, or wt < 56 kg] Regular [TDDI <input type="checkbox"/> 20 (< 23) units, or wt < 46 kg]	<input type="checkbox"/> ALGORITHM 2 Lispro / Aspart [TDDI <input type="checkbox"/> 30 (28–36) units, or wt 56–73.9 kg] Regular [TDDI <input type="checkbox"/> 25 (23–30) units, or wt 46–61.9 kg]	<input type="checkbox"/> ALGORITHM 3 Lispro / Aspart [TDDI <input type="checkbox"/> 45 (37–55) units, or wt 74–111.9 kg] Regular [TDDI <input type="checkbox"/> 37½ (31–46) units, or wt 62–93.9 kg]	<input type="checkbox"/> ALGORITHM 4 Lispro / Aspart [TDDI <input type="checkbox"/> 72 (56–90) units, or wt 112–181.9 kg] Regular [TDDI <input type="checkbox"/> 60 (47–75) units, or wt 94–151.9 kg]	<input type="checkbox"/> ALGORITHM 5 Lispro / Aspart [TDDI <input type="checkbox"/> 120 (91–144) units, or wt ≥ 182 kg] Regular [TDDI <input type="checkbox"/> 100 (76–120) units, or wt ≥ 152 kg]	<input type="checkbox"/> ALGORITHM 6 Lispro / Aspart [TDDI <input type="checkbox"/> 180 (> 144) units] Regular [TDDI <input type="checkbox"/> 150 (> 120) units]	<input type="checkbox"/> ALGORITHM 7
BG units	BG units	BG units	BG units	BG units	BG units	BG units
150–224 1	150–209 1	150–189 1	150–199 2	150–209 4	150–199 5	
225–299 2	210–269 2	190–229 2	200–249 4	210–269 8	200–249 10	
300–374 3	270–329 3	230–269 3	250–299 3	270–329 12	250–299 15	
375–449 4	330–389 4	270–309 4	300–349 4	330–389 16	300–349 20	
≥ 450 5	≥ 390 5	310–349 5	350–399 10	≥ 390 20	≥ 350 25	
		≥ 450 6	≥ 450 12			

Signed: _____ Printed Name: _____ Date: _____

Figure 1. Sample pre-admission treatment plan.

to start is with a TDDI of about 0.5 units/kg body weight, estimating the basal requirement to be about 0.25 units/kg/day.

If patients who were treated with insulin monotherapy before admission are assumed potentially to have type 1 diabetes and are maintained on basal insulin in appropriate dosage throughout their hospitalization, there is little likelihood of harm. When the diagnosis of type 2 diabetes is suspected in a heavy-set patient but classification is uncertain and a decision is made to treat as if the patient might have type 1 diabetes, the initial calculation for basal insulin may be as little as 0.15 units/kg.

Estimates of insulin requirement may prove to be excessive for patients who have a condition predisposing to hypoglycemia, such as renal failure, or if the estimated insulin dose was derived from observations made during periods of overnutrition. If medical stress is severe, on the other hand, or during corticosteroid therapy for patients with either type 1 or type 2 diabetes, the preadmission dose of insulin is likely to be too low. In such cases, there is likely to be an increase in scheduled insulin requirement that may be apportioned, for patients who are eating, between the basal and prandial components of therapy.

Some patients are newly treated with insulin as an intravenous infusion in the critical care setting. At the time of interruption of intravenous insulin infusion, for reasonably stable patients not receiving pressors and not exposed to dextrose, the hourly insulin infusion rate necessary to achieve overnight fasting glucose control during intravenous insulin therapy can be used to estimate the basal insulin requirements during subcutaneous therapy. Based on patient response to subcutaneous therapy, any estimate of basal insulin requirement should be reassessed 12–24 hours after discontinuation of intravenous insulin therapy and daily thereafter.

At the time of transfer from a critical care unit, as after heart surgery, or at oth-

er times during hospitalization, the basal insulin requirements may be high, and the food intake may be doubtful. The prandial insulin then can be estimated as just 1–2 units of rapid-acting analog per 15 g of carbohydrate at meals, starting with 1 unit per 15 g or 3–5 units at each meal, with instructions to nursing staff to deliver the insulin only if the patient has eaten at least half of the tray. Over several days during recovery, the basal requirement often falls, and the prandial requirement rises. If the patient will not receive discrete meals, but rather receives intravenous dextrose or continuous nutritional support, about 1 unit of insulin for every 10 g of carbohydrate is a reasonable initial estimate of daily requirement for nutritional insulin coverage.³⁹ For example, D5-containing fluids administered at 83 cc/hour would deliver 2 liters or 100 g of dextrose daily and might initially be covered by about 10 units of scheduled subcutaneous insulin above basal requirements. The initial dose often greatly underestimates the need that eventually will be demonstrated during nutritional support.^{40–43}

To maintain glucose levels in the target range, the amount of scheduled subcutaneous insulin should be revised once or twice daily. There should be a review of the total amount of insulin actually administered over the preceding 24 hours, including supplements and decrements, and the results of glucose monitoring. It is also important to look back over several days to note any upward or downward trending of glucose results and insulin requirements and to assess for presence of conditions that might affect insulin requirements. A reasonable dose-finding strategy for the next 24 hours is:

- Determine yesterday's total insulin dose actually administered
- Review yesterday's glycemic control
- Calculate today's scheduled insulin dose, as follows:
 - If some glucoses were < 80 mg/dl, use 80% of yesterday's total
 - If glucoses were 80–179 mg/dl, use 100% of yesterday's total

- If some glucoses were \geq 180 mg/dl, and none were < 80 mg/dl, use 110% of yesterday's total.

Basal insulin requirement among patients who might have type 1 diabetes

Unlike the situation for many patients having type 2 diabetes, interruption of nutritional intake does not have a significant impact on the basal insulin requirement for patients having type 1 diabetes. The need to estimate and continue providing the basal insulin requirement is a matter of life-saving importance in type 1 diabetes. Luckily, it is not difficult.

The total daily basal insulin can be delivered in one of the following ways: glargine given once daily; equally divided amounts of NPH given every 6–12 hours, mixtures of NPH and regular insulin given every 6–8 hours, or regular insulin given subcutaneously every 4 hours (for patients with renal failure, every 6 hours may work); continuous subcutaneous infusions of rapid-acting analog by pump; or intravenous regular insulin.

For example, a patient with type 1 diabetes who has mild chronic renal failure may have taken 70/30 insulin before admission, 20 units in the morning and 10 units at supper. In the hospital, if there will be interruption of normal meals, it would be prudent to devise a new plan. Using 12 units, or 40% of the outpatient TDDI, as the estimated basal requirement, it would be acceptable to begin one of the following schedules for basal insulin, or another alternative, not to be withheld for normoglycemia:

- 12 units glargine, once daily
- 6 units NPH every 12 hours
- 4 units of 70/30 NPH/regular premixed insulin every 8 hours
- 3 units of regular insulin every 6 hours

When the basal component of therapy is implicated as the cause of hypoglycemia or as the cause of downward trending of glucose creating a risk for hypoglycemia, then the hypoglycemia is treated, and basal therapy is rewritten to

deliver a lower amount over 24 hours. The dose reductions are seldom > 20% at a time. In type 1 diabetes, adjustments are made without abrupt interruption of basal insulin.

Prevention of Hospital Hypoglycemia

Fear of hypoglycemia is probably the principal barrier to attainment of normoglycemia. Most cases of severe insulin-induced hypoglycemia probably happen on general wards, not in the intensive care unit. On general wards, glucose monitoring is less intense, and the route of insulin administration provides longer duration of action.⁴⁴

Most episodes of hospital hypoglycemia among insulin-treated patients are predictable and therefore should be preventable. Although abundant literature about treatment of hypoglycemia exists,⁴⁵ there is little published information about prevention. A proactive strategy of prevention requires that physicians in their order-writing must be aware of the development or presence of renal insufficiency, malnutrition, liver disease, sepsis, shock, malignancy, dementia, congestive heart failure, stroke, alteration of patients' ability to self-report symptoms, tapering of glucocorticoids, withholding of scheduled doses of insulin, episodes of hypoglycemia that have already occurred, or other predisposing conditions that suggest the need for cautious prescribing.⁴⁶

Many cases of hypoglycemia among hospitalized insulin-treated patients result from a mismatch between administered caloric intake and nutritional insulin therapy.⁴⁷ If nutrition ceases to be provided, nutritional insulin coverage should be interrupted. If nutritional insulin already has been given, prevention usually consists of 1) recognizing a triggering event for hypoglycemia, 2) increasing the intensity of glucose monitoring for the duration of action of previously administered insulin (for example to every 2 hours), and 3) administering carbohydrate by an alternative route before the plasma glucose becomes low (for example, in this set-

ting, 50% dextrose for glucose < 120 mg/dl).⁴⁸

There should be ward-based protocols or hospital policies that permit appropriate nursing responses to triggering events. Triggering events include transportation off ward causing meal delay, new NPO status, interruption of intravenous dextrose, interruption of total parenteral nutrition, interruption of enteral feedings, or interruption of continuous renal replacement therapy.

Diabetes Patient Self-Management

Patients who are competent to continue self-management in the hospital deserve every effort by their caregivers and the hospital to accommodate their wish and to recognize their superior ability to do so. To meet internal and external regulatory requirements that are binding on the hospital pharmacy, the point-of-care testing program, nursing standards, and the medical devices oversight committee of the hospital, it is helpful to establish a multidisciplinary committee that can work together with the hospital quality assurance program to establish an enabling policy. First and foremost, the safety of patients must be assured. This outcome is often best achieved, after assessment of competency, by allowing appropriate patients to continue self-management.

Moving Toward Discharge

Patients are often discharged on a new diabetes treatment regimen, sometimes also with altered organ function, body weight, or nutritional intake compared to their preadmission status. Hypoglycemia sometimes occurs shortly after discharge.⁴⁹ The discharge plans should include call parameters that would intercept a downward or upward trend of blood glucose. A return visit shortly after discharge to discuss diabetes control and ongoing outpatient education is appropriate.

Managing Complexity

When excessive numbers of alert parameters and conditional statements are con-

tained in physician orders, and when there is variability among prescribers, then the risk of misunderstanding and error increases.

In general, the safe and effective care of hospitalized patients having hyperglycemia requires institutional and physician commitment to quality control and a multidisciplinary team effort in devising hospital procedures.⁵⁰ Ward-based protocols or hospital-wide policies can eliminate the need for making special provisions in each set of doctors' orders, such as might be required for the treatment or prevention of hypoglycemia. Well-designed protocols, as for intravenous insulin infusion or correction of hyperglycemia, can contain the necessary complexity and yet be ordered with a single signature.⁵¹ The best protocols can be executed by nursing staff without requiring nurses to make mathematical calculations or to analyze sequential events. Standardized order sets, with blanks for specific patient variables, can familiarize the staff with the actions of insulin and with common treatment plans.⁵² Direct physician order entry by computer further reduces error.⁵³

Summary

Not only hypoglycemia, but also hyperglycemia is a patient safety factor. Target range glucose is 80–110 mg/dl during critical care in a surgical intensive care unit, < 110 mg/dl before meals (if eating), and < 180 mg/dl peak postprandial (or if receiving continuous intravenous dextrose or nutritional support). Good care involves discovery and ongoing revision of daily insulin dose to replace correction therapy with scheduled insulin.

Fear of hypoglycemia is the principal barrier to normoglycemia. Hypoglycemia in the hospital is mostly preventable (by means other than undertreatment of diabetes). Patients who are competent, eating, and experienced in self-management should continue self-management in the hospital.

Nationwide opportunities for improvement include facilitation of insulin drip therapy, standardization of diabetes order sets and correction dose algorithms, protocols for prevention of hypoglycemia, patient education and discharge planning, and hospital policies on patient self-management.

REFERENCES

- 1^{The DCCT Research Group: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 329:977-986, 1993}
- 2^{U.K. Prospective Diabetes Study Group: Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* 352:837-853, 1998}
- 3^{Stagnaro-Green A, Barton MK, Linekin PL, Corkery E, deBeer K, Roman SH: Mortality in hospitalized patients with hypoglycemia and severe hyperglycemia. *Mount Sinai J Med* 62:422-426, 1995}
- 4^{Capes S, Hunt D, Malmberg K, Gerstein H: Stress hyperglycaemia and increased risk of death after myocardial infarction in patients with and without diabetes: a systematic overview. *Lancet* 355:773-778, 2000}
- 5^{Umpierrez GE, Isaacs SD, Bazargan N, You X, Thaler LM, Kitabchi AE: Hyperglycemia: an independent marker of in-hospital mortality in patients with undiagnosed diabetes. *J Clin Endocrinol Metab* 87:978-982, 2002}
- 6^{Furnary AP, Gao G, Grunkemeier GL, Wu Y, Zerr KJ, Bookin SO, Floten HS, Starr A: Continuous insulin infusion reduces mortality in patients with diabetes undergoing coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 125:1007-1021, 2003}
- 7^{Finney SJ, Zekveld C, Elia A, Evans TW: Glucose control and mortality in critically ill patients. *JAMA* 290:2041-2047, 2003}
- 8^{Golden SH, Peart-Vigilance C, Kao WHL, Brancati F: Perioperative glycemic control and the risk of infectious complications in a cohort of adults with diabetes. *Diabetes Care* 22:1408-1414, 1999}
- 9^{Pomposelli JJ, Baxter JK, Babineau TJ, Pomfret EA, Driscoll DF, Forse RA, Bistran BR: Early postoperative glucose control predicts nosocomial infection rate in diabetic patients. *J Parenter Enteral Nutr* 22:77-81, 1998}
- 10^{Zerr KJ, Furnary AP, Grunkemeier GL: Glucose control lowers the risk of wound infection in diabetics after open heart operations. *Ann Thorac Surg* 63:356-361, 1997}
- 11^{Furnary AP, Zerr KJ, Grunkemeier GL, Starr A: Continuous intravenous insulin infusion reduces the incidence of deep sternal wound infection in diabetic patients after cardiac surgical procedures. *Ann Thorac Surg* 67:352-362, 1999}
- 12^{Furnary AP, Chaugle H, Zerr K, Grunkemeier GL: Postoperative hyperglycemia prolongs length of stay in diabetic CABG patients [Abstract]. *Circulation* 102 (Suppl. II):556, 2000}
- 13^{Malmberg K, Rydén L, Efendic S, Herlitz J, Nicol P, Waldenström A, Wedel H, Welin L: Randomized trial of insulin-glucose infusion followed by subcutaneous insulin treatment in diabetic patients with acute myocardial infarction (DIGAMI study): effects on mortality at 1 year. *J Am Coll Cardiol* 26:57-65, 1995}
- 14^{Van den Berghe G, Wouters P, Weekers F, Verwaest C, Bruyninckx F, Shetz M, Vlasselaers D, Ferdinande P, Lauwers P, Bouillon R: Intensive insulin therapy in critically ill patients. *N Engl J Med* 19:1359-1367, 2001}
- 15^{Malmberg K, for the DIGAMI Study Group: Prospective randomised study of intensive insulin treatment on long term survival after acute myocardial infarction in patients with diabetes mellitus. *BMJ* 314:1512-1515, 1997}
- 16^{Malmberg K, Norhammar A, Wedel H, Ryden L: Glycometabolic state at admission: important risk marker of mortality in conventionally treated patients with diabetes mellitus and acute myocardial infarction: long-term results from the diabetes and insulin-glucose infusion in acute myocardial infarction (DIGAMI) study. *Circulation* 99:2626-2632, 1999}
- 17^{Van den Berghe G, Wouters PJ, Bouillon R, Weekers F, Verwaest C, Schetz M, Vlasselaers D, Ferdinande P, Lauwers P: Outcome benefit of intensive insulin therapy in the critically ill: insulin dose versus glycemic control. *Crit Care Med* 31:359-366, 2003}
- 18^{Clement S, Braithwaite SS, Magee MF, Ahmann A, Smith EP, Schafer RG, Hirsh IB, American Diabetes Association Diabetes in Hospitals Writing Committee: Management of diabetes and hyperglycemia in hospitals (Technical Review). *Diabetes Care* 27:553-597, 2004}
- 19^{American College of Endocrinology Task Force on Inpatient Diabetes and Metabolic Control: Position statement on inpatient diabetes and metabolic control. *Endocrine Pract* In press}
- 20^{Hawkins JB, Jr, Morales CM, Shipp JC: Insulin requirement in 242 patients with type II diabetes mellitus. *Endocrine Pract* 1:385-389, 1995}
- 21^{Brown G, Dodek P: Intravenous insulin nomogram improves blood glucose control in the critically ill. *Crit Care Med* 29:1714-1719, 2001}
- 22^{Markovitz LJ, Wiechmann RJ, Harris N, Hayden V, Cooper J, Johnson G, Harelstad R, Calkins L, Braithwaite SS: Description and evaluation of a glycemic management protocol for diabetic patients undergoing heart surgery. *Endocrine Pract* 8:10-18, 2002}
- 23^{Trence DL, Kelly JL, Hirsch IB: The rationale and management of hyperglycemia for inpatients with cardiovascular disease: time for change. *J Clin Endocrinol Metab* 88:2430-2437, 2003}
- 24^{Bode BW, Davidson GG, Mather SR, O'Malley BC, Sainz M, Gross T, Jeng L, Miller E, Weinert S: Evaluation of the Glucose Management System (GMS) for administering IV insulin therapy to hospitalized patients with diabetes (Abstract). *Diabetes* 48 (Suppl. 1):A120, 1999}
- 25^{Herbst KL, Hirsch IB: Insulin strategies for primary care providers. *Clin Diabetes* 20:11-17, 2002}
- 26^{DeWitt DE, Hirsch IB: Outpatient insulin therapy in type 1 and type 2 diabetes mellitus: scientific review. *JAMA* 289:2254-2264, 2003}
- 27^{Gearhart JG, Duncan JL, Replogle WH, Forbes RC, Walley EJ: Efficacy of sliding-scale insulin therapy: a comparison with prospective regimens. *Fam Pract Res J* 14:313-322, 1994}
- 28^{Queale WS, Seidler AJ, Brancati FL: Glycemic control and sliding scale insulin in medical inpatients with diabetes mellitus. *Arch Intern Med* 157:545-552, 1997}
- 29^{Anderson JH, Brunelle RL, Koivisto VA, Pfützer A, Trautmann ME, Vignati L, DiMarchi R: Reduction of postprandial hyperglycemia and frequency of hypoglycemia in IDDM patients on insulin-analog treatment. *Diabetes* 46:265-270, 1997}
- 30^{Anderson JH, Brunelle RL, Keohane P, Koivisto VA, Trautmann ME, Vignati L, DiMarchi R: Mealtime treatment with insulin analog improves postprandial hyperglycemia and hypoglycemia in patients with non-insulin-dependent diabetes mellitus. *Arch Intern Med* 157:1249-1255, 1997}
- 31^{Lalli C, Ciofetta M, Del Sindaco P, Torlone E, Pampanelli S, Compagnucci P, Cartechini MG, Bartocci L, Brunetti P, Bolli GB: Long-term intensive treatment of type 1 diabetes with the short-acting insulin analog lispro in variable combination with NPH insulin at mealtime. *Diabetes Care* 22:468-477, 1999}
- 32^{Heller S, Amiel S, Mansell P: Effect of the fast-acting insulin analog lispro on the risk of nocturnal hypoglycemia during intensified insulin therapy. *Diabetes Care* 22:1607-1611, 1999}
- 33^{American Diabetes Association: Diabetes nutrition recommendations for health care institutions (Position Statement). *Diabetes Care* 27 (Suppl. 1):S55-S57, 2004}
- 34^{Hirsch IB, Paauw DS, Brunzell J: Inpatient management of adults with diabetes. *Diabetes Care* 18:870-878, 1995}
- 35^{Henry R, Gumbiner B, Ditzler T, Wallace P, Lyon R, Glauber H: Intensive conventional insulin therapy for type II diabetes: metabolic effects during a 6-mo outpatient trial. *Diabetes Care* 16:21-31, 1993}
- 36^{Abraira C, Colwell J, Nuttall F, Sawin C, Nagel N, Comstock J, Emanuele N, Levin S, Henderson W, Lee H: Veterans Affairs Cooperative Study on glycemic control and complications in type II diabetes (VA CSDM): results of the feasibility trial. *Diabetes Care* 18:1113-1123, 1995}
- 37^{Abraira C, Henderson W, Colwell J, Nuttall F, Comstock J, Emanuele N, Levin S, Sawin C, Silbert C: Response to intensive therapy steps and to glipizide dose in combination with insulin in type 2 diabetes. *Diabetes Care* 21:574-579, 1998}
- 38^{Turner RC, Cull CA, Frighi V, Holman RR, for the UK Prospective Diabetes Study Group: Glycemic control with diet, sulfonylurea, metformin, or insulin in patients with type 2 diabetes mellitus: progressive requirement for multiple therapies (UKPDS 49). *JAMA* 281:2005-2012, 1999}

- ³⁹Pitts DM, Kilo KA, Pontious SL: Nutritional support for the patient with diabetes. *Crit Care Nurs Clin North Am* 5:47-56, 1993
- ⁴⁰Woolfson AM: Control of blood glucose during nutritional support in ill patients. *Intens Care Med* 7:11-14, 1980
- ⁴¹Woolfson AM: An improved method for blood glucose control during nutritional support. *J Parenter Enteral Nutr* 5:436-440, 1981
- ⁴²Park RH, Hansell DT, Davidson LE, Henderson G, Legge V, Gray GR: Management of diabetic patients requiring nutritional support. *Nutrition* 8:316-320, 1992
- ⁴³Kerr D, Hamilton P, Cavan DA: Preventing glycaemic excursions in diabetic patients requiring percutaneous endoscopic gastrostomy (PEG) feeding after a stroke. *Diabet Med* 19:1006-1008, 2002
- ⁴⁴Montori VM, Bistrrian BR, McMahon MM: Hyperglycemia in acutely ill patients. *JAMA* 288:2167-2169, 2002
- ⁴⁵McMahon MM, Rizza RA: Nutrition support in hospitalized patients with diabetes mellitus. *Mayo Clin Proc* 71:587-594, 1996
- ⁴⁶Kagansky N, Levy S, Rimon E, Cojocaru L, Fridman A, Ozer Z, Knobler H: Hypoglycemia as a predictor of mortality in hospitalized elderly patients. *Arch Intern Med* 163:1825-1829, 2003
- ⁴⁷Fischer KF, Lees JA, Newman JH: Hypoglycemia in hospitalized patients. *N Engl J Med* 315:1245-1250, 1986
- ⁴⁸Knapke CM, Owens JP, Mirtallo JM: Management of glucose abnormalities in patients receiving total parenteral nutrition. *Clin Pharmacol* 8:136-144, 1989
- ⁴⁹Shorr RI, Ray WA, Daugherty JR, Griffin MR: Incidence and risk factors for serious hypoglycemia in older persons using insulin or sulfonylureas. *Arch Intern Med* 157:1681-1686, 1997
- ⁵⁰Roman SH, Linekin PL, Stagnaro-Green A: An inpatient diabetes QI program. *Jt Comm J Qual Improv* 21:693-699, 1995
- ⁵¹Raforth RJ: Standardizing sliding scale insulin orders. *Am J Med Qual* 17:169-170, 2002
- ⁵²Quevedo SF, Sullivan E, Kington R, Rogers W: Improving diabetes care in the hospital using guideline-directed orders. *Diabetes Spectrum* 14:226-233, 2001
- ⁵³Achtmeyer CE, Payne TH, Anawalt BD: Computer order entry system decreased use of sliding scale insulin regimens. *Methods Inf Med* 41:277-281, 2002

Kristen B. Campbell, PharmD, is a cardiology specialty resident in the Department of Pharmacy at the University of North Carolina—Chapel Hill. Susan S. Braithwaite, MD, is a clinical professor of medicine at the University of North Carolina—Chapel Hill with faculty practice location at the Diabetes Care Center of the University of North Carolina—Chapel Hill in Durham, N.C.

Note of disclosure: Dr. Braithwaite has received honoraria for speaking engagements from Aventis and research support from Bristol-Myers Squibb. These companies manufacture pharmaceutical products for the treatment of diabetes.