A Practical Guide to Insulin Pump Management in Adults In and Around Hospital

Jia Jia Ren MD, Robyn L. Houlden MD FRCPC

Insulin pumps have become increasingly more prevalent in the management of diabetes in recent years. Currently in North America, about 20% to 30% of patients with type 1 diabetes mellitus are pump users (1). As a result, non-diabetes specialists are encountering these patients throughout the healthcare system, including the inpatient setting. Ideally, hospital personnel knowledgeable in insulin pump therapy should be available to assist patients, and medical and nursing staff (2). However, many institutions currently lack this resource. This article is designed to help non-diabetes specialists manage patients on pump therapy in and around hospital.

THE BASICS OF INSULIN PUMP THERAPY

The insulin pump is a small, programmable, external battery-powered device that delivers rapid-acting insulin in tiny continuous amounts (basal doses) and in larger amounts for meals (bolus doses). Several different models of insulin pump are available. Most attach to the patient by an infusion set consisting of long, thin flexible tubing with a needle or catheter on the end that is inserted subcutaneously. Recently, a pump has become available where the pump with a very short infusion catheter both sit on the skin surface, held by an adhesive; this model of pump is controlled by a wireless controller.

The patient programs and operates the pump to deliver insulin doses that match their individual needs. The **total daily dose (TDD)** of insulin is typically 20% to 25% lower when taking insulin pump therapy compared with multiple daily injections. Of the reduced TDD, 40% to 50% is usually given as basal insulin and 50% to 60% as mealtime boluses. A target blood glucose range is programmed into the pump (e.g. 5.5 ± 1 mmol/L). The pump user either directly enters their current blood glucose value into the pump or has a glucose meter that remotely transmits the value into the pump.

The **basal dose** is initially developed by taking 50% of the estimated TDD divided by 24 to get an mean hourly rate, and fine tuned in response to blood glucose monitoring results. Many patients require a slightly lower basal rate in the early nocturnal period, and a slightly higher rate in the early morning due to the dawn phenomenon.

The **mealtime bolus insulin dose** is usually calculated based on the carbohydrate content of the meal and the insulin-to-carbohydrate ratio of the patient. The insulin-to-carbohydrate ratio is the amount of carbohydrate in grams that is handled by a 1-unit dose of rapid-acting insulin. A common insulin-to-carbohydrate ratio is 1:10, which means that 1 unit of insulin will cover 10 grams of ingested carbohydrate. For example, the carbohydrate content of a single slice of bread is roughly 15 g, a medium-sized apple is about 25 g, and 250 mL (1 cup) of milk is about 12 g. Thus, a lunch of a sandwich, an apple and a glass of milk would be about (15 × 2) + 25 + 12 = 67 g of carbohydrate. The insulin-to-carbohydrate ratio varies for different pump users, but is typically calculated initially as 500 divided by TDD. Ideally, blood glucose will increase by 2 to 4 mmol/L from before the meal to the postprandial peak and return to preprandial levels by 4 hours postprandial. The accuracy of the insulin-to-carbohydrate ratio can be evaluated by measuring blood glucose preprandial and at 2 and 4 hours postprandial. A person may use more than one insulin-to-carbohydrate ratio (e.g. a ratio of 1:10 for breakfast, 1:12 for lunch and 1:15 for dinner) based on physical activity and other variables.

Pump users also administer **correction doses** of insulin for blood glucose levels above their target using an insulin sensitiv-

ity factor (ISF). The ISF is the expected change in blood glucose from administering 1 unit of rapid-acting insulin. Similar to the insulin-to-carbohydrate ratio, the ISF varies for different pump users and typically ranges from 1 unit/0.5 mmol/L to 1 unit/4.0 mmol/L. The ISF can be calculated initially as 100 divided by the TDD. Once the ISF is programmed into the pump, the pump calculates the dose of insulin needed to normalize the current blood glucose level to the target range and displays the recommended correction bolus, which the patient then accepts or modifies. The accuracy of the ISF can be evaluated by tracking blood glucose 4 hours after a correction bolus, at a time during which no additional food or insulin is taken, by which time the expected blood glucose should be at the target level. In an inpatient setting, the ISF can be ordered as an insulin correction scale using the known ISF for that patient. For example, if the ISF equals 2, then for each 2 mmol/L above the target range, the patient would receive 1 extra unit of rapid-acting insulin (e.g. if the target range in hospital is 5 to 10 mmol/L and the patient's preprandial blood glucose is 14 mmol/L, they would receive an extra 2 units of insulin added to the meal bolus). Patients in hospital may frequently have greater insulin requirements due to increases in circulating concentrations of stress hormones, decreased physical activity, medications (e.g. glucocorticoids), or total or parenteral nutrition, and the ISF may have to be decreased. Table 1 summarizes the basic insulin pump settings.

SELF-MANAGEMENT

Patients on insulin pump therapy do not necessarily need to discontinue this type of therapy while hospitalized. They are often more knowledgeable than their healthcare providers about diabetes management and should be encouraged to self-manage their diabetes during hospitalization (3). However, to promote a collaborative relationship between the hospital staff and patient, and to ensure patient safety, hospitals should have clear policies and procedures in place to guide the continued use of insulin pumps in the inpatient setting (4).

COMPETENCY

Any patient admitted to hospital using an insulin pump should be assessed for their physical and mental competency to continue using their device. In addition, the patient should also have adequate insulin pump supplies, including infusion sets, reservoirs and batteries. If the patient is not deemed competent or does not have adequate supplies, the insulin pump should be discontinued and the patient placed on a subcutaneous insulin regimen or intravenous insulin infusion.

Occasionally, some patients may be dependent on family members to manage their insulin pump due to vision or coordination issues. These patients may be considered for continuation of insulin pump therapy in hospital as long as knowledgeable family

Table 1. Insulin pump settings made easy

Target glucose range e.g. 5.0–6.5 mmol/L (some pumps display as 5.5 ± 1 mmol/L)	Most people on pumps program 1 target blood glucose range for an entire 24-h period. However, they can program different target ranges for different times of the day (e.g. they may set a higher target range for overnight periods).
Basal rate e.g. 24–04 h = 0.6 units/h 04–07 h = 0.9 units/h 07–18 h = 0.8 units/h 18–24 h = 0.7 units/h	Can be set for up to hourly changes in the infusion rate. Most people on pumps use 1 to 4 different basal rates per day. The total 24-h basal rate can be calculated and displayed on the pump. Ask the patient to show you this information.
Meal bolus settings e.g. 24–06 h = 1 unit/12 g CHO 06–10 h = 1 unit/7 g CHO 10–15 h = 1 unit/8 g CHO 15–21 h = 1 unit/7 g CHO 21–24 h = 1 unit/12 g CHO	May be the same all day or vary with different meals. Using the example settings, If 28 g CHO breakfast, dose = 4 units If 32 g CHO lunch, dose = 4 units If 63 g CHO supper, dose = 9 units
Insulin sensitivity factor or correction dose e.g. 24–06 h = 1 unit/3 mmol/L 06–10 h = 1 unit/1.5 mmol/L 10–24 h = 1 unit/2 mmol/L	Can be set by sections of the day. Using the example settings, If glucose 12 mmol/L before breakfast, 3.7 units added to correct to 6.5 mmol/L.

CHO = carbohydrate

members remain constantly in the hospital.

Pump manufacturers provide 24-hour help lines that the patient can contact for device-related problems. The telephone number can usually be found on the back of the pump.

CONTRAINDICATIONS

Contraindications to remaining on insulin pump therapy while in hospital include (5):

- Impaired level of consciousness. (One exception is that insulin pump therapy can be continued during anesthesia, as long as the anaesthetist is aware of and willing to manage the pump during anesthesia.)
- Critical illness requiring intensive care.
- Psychiatric illness that interferes with the patient's ability to self-manage their diabetes or places the patient at risk for suicide.
- Diabetic ketoacidosis.
- Refusal or unwillingness to participate in self-care.

Cessation of insulin pump therapy will result in the patient becoming relatively insulin deficient within 1 hour and absolutely insulin deficient within 4 hours. There is a major risk of severe hyperglycemia and diabetic ketoacidosis occurring within hours following discontinuation of therapy. **If the insulin pump must be discontinued, the patient should be placed on a subcutaneous basal/bolus insulin program prior to pump withdrawal or an intravenous insulin infusion immediately upon pump withdrawal.**

It is helpful for the patient if information about carbohydrate content is provided with each meal to allow accurate calculation of meal boluses. For patients able to eat, the usual basal rates should be continued, and the patient should bolus for meals and correct for higher or lower blood glucose readings, as usual. For patients who are NPO, the usual basal rates should be continued; however, they should bolus only for high blood glucose levels typically at 4 to 6 hourly intervals. If they experience hypoglycemia, the basal rate can be reduced by 50% for several hours, or suspended with severe hypoglycemia.

PATIENTS UNABLE TO REMAIN ON INSULIN PUMP THERAPY

If patients cannot manage their pump, they should be switched to subcutaneous insulin. The 24-hour basal dose of insulin delivered by the pump should be replaced with an injection of glargine or detemir divided into once- or twice-daily injections. In hospital, it is often easier to eventually adjust back to insulin pump therapy if the dosing of long-acting basal insulin is twice daily. The insulin pump should be discontinued 2 hours after the first injection of basal insulin. Mealtime insulin should be provided with subcutaneous rapid-acting insulin. The dose can be calculated as half the patient's usual TDD divided by 3 and given before each meal. For example, for a patient taking a usual TDD of insulin of 28 units, give, [(28 units ÷ 2) ÷ 3] = 5 units of rapid-acting insulin before each meal. Additional points to take into consideration include the following:

- A correction (supplemental) scale of rapid-acting insulin should be ordered for high and low blood glucose levels.
- The pump should be resumed when the patient is able to resume responsibility.
- Critically ill patients should be started on intravenous insulin.

Guidelines for switching a patient from insulin pump therapy to multiple daily injections are shown in Table 2.

INSULIN PUMPS IN THE EMERGENCY DEPARTMENT

Diabetic ketoacidosis

Insulin pump failure can lead to diabetic ketoacidosis. Pump failure may be related to blockage or leakage in the reservoir (syringe) or the infusion set or connectors, causing an interruption of infusion flow or mechanical failure. Because the subcutaneous depot of insulin is very small with pump therapy, any interruption in the continuous flow of insulin quickly leads to hypoinsulinemia, hyperglycemia and possibly diabetic ketoacidosis. Often, the patient will be unaware that their pump has stopped administering insulin.

When diabetic ketoacidosis occurs, the pump must be discontinued and the patient should be treated according to guidelines, such as the 2008 Canadian Diabetes Association clinical practice guidelines (6). The patient may be transitioned back to the pump after resolution of the diabetic ketoacidosis. Typically, intravenous insulin is continued for the first 2 hours of the pump restart to allow the formation of a subcutaneous depot of insulin.

Patient presenting with hyperglycemia (not in diabetic ketoacidosis)

As patients using insulin pump therapy can develop diabetic ketoacidosis faster than patients taking subcutaneous injections, education about the management of high blood glucose levels is a critical component of initial pump training. If a patient presents to the emergency department with hyperglycemia and is not found to

Table 2. How to switch a patient from insulin pump therapy to multiple daily injections

Step	Example
Determine typical TDD of insulin on pump. Ask patient to display TDD for past few days on the pump.	TDD = 44 units
Calculate dose of SC basal insulin. Divide TDD by 1/2 and administer as long-acting basal insulin (glargine or levemir) given once daily or as a divided dose twice daily (it is easier to eventually adjust back to insulin pump therapy if the dosing is twice daily).	44 units ÷ 2 = 22 units. Administer as long-acting insulin 22 units once daily or 11 units twice daily.
Calculate mealtime bolus insulin. Divide TDD by 1/2 and administer as 1/3 before each meal. Or Ask patient to select dose of mealtime insulin using their usual insulin-to-carbohydrate ratio.	42 units ÷ 2 = 22 units. Administer 1/3 of 22 units (7 units) as rapid-acting insulin before each meal. If usual insulin-to-carbohydrate ratio is 1:10 g CHO, and patient consumes a 60 g CHO meal, they should take 6 units of rapid-acting insulin before the meal.
Create a correction dose scale of rapid-acting insulin. Ask patient for their usual ISF and write an appropriate scale.	If usual ISF is 1 unit/2 mmol/L, then for each 2 mmol/L above the target range, the patient should receive 1 extra unit of rapid-acting insulin. For inhospital blood glucose target range of 6–10 mmol/L: **Blood glucose AC meals:** — **Action:** <4.0 mmol/L — Notify MD, treat hypoglycemia by medical directive (if available) and reduce mealtime rapid-acting insulin by 2 units SC 4.0–6.0 mmol/L — Reduce mealtime rapid-acting insulin by 1 unit SC 6.1–10.0 mmol/L — Give ordered bolus dose without correction 10.1–12.0 mmolL — 1 unit rapid-acting insulin SC 12.1–14.0 mmol/L — 2 units rapid-acting insulin SC 14.1–16.0 mmol/L — 3 units rapid-acting insulin SC 16.1–18.0 mmol/L — 4 units rapid-acting insulin SC 18.1–20.0 mmol/L — 5 units rapid-acting insulin SC >20.0 mmol/L — 6 units rapid-acting insulin SC and notify MD
Adjust insulin doses based on daily review of capillary blood glucose monitoring results.	
Transition back to insulin pump when patient competent.	

CHO = carbohydrate
ISF = insulin sensitivity factor
SC = subcutaneous
TDD = total daily dose

be in diabetic ketoacidosis, emergency room (ER) personnel can review with the patient management of hyperglycemia and refer the patient back to their diabetes education team for reinforcement of the teaching (Table 3). As with anyone who has diabetes and presents with poor glucose control, an underlying illness or error in insulin dosing may be present and should be ruled out before the patient is discharged.

If a patient presents with hyperglycemia that has not responded to 2 or more correction boluses for high glucose given with the pump, then it should be assumed that there is a problem with insulin delivery. Use the patient's ISF to treat hyperglycemia, but give the insulin dose by insulin pen or syringe until normal glu-

Table 3. Management of hyperglycemia on insulin pump therapy

If blood glucose is >14 mmol/L, patients on pump therapy should check for urine or capillary ketones.

If ketones are negative, the patient should:

- Take a correction bolus of insulin with their pump.
- Recheck their blood glucose in 1 hour. If blood glucose has started to decrease, the patient should continue to monitor their blood glucose until is in the target range.
- If the patient's blood glucose has not started to decrease 1 hour after the first correction dose, they should take a correction dose of rapid-acting insulin using a syringe or insulin pen. They should change their infusion set, tubing, reservoir and insulin. They should continue to check their blood glucose until it is in the target range.

If ketones are positive, the patient should:

- take a correction dose of rapid-acting insulin using a syringe or insulin pen
- change their infusion site, infusion set, reservoir and insulin
- check their blood glucose every 1 to 2 hours and continue to take correction insulin as needed using a syringe or insulin pen until their blood glucose is in the target range
- drink plenty of water or noncarbohydrate fluids.

If their blood glucose continues to rise or if they have moderate-to-high ketones, nausea, vomiting or difficulty breathing, they should go to the ER.

cose levels are achieved, at which point the patient may be able to help resolve the pump delivery problem. The most common cause of delivery failure is a plugged, obstructed or disconnected infusion site. If the pump does not seem to be delivering insulin, the reservoir, tubing and infusion set should be replaced.

Patient presenting with severe hypoglycemia

For patients on pump therapy who present with severe hypoglycemia (i.e. confusion, loss of consciousness or seizure), the insulin pump should be suspended or disconnected and the hypoglycemia corrected with intravenous dextrose 50% in water (D50W). Pump programming is quite intuitive, so that when the screen is on, the option of "basal suspend" is usually easy to find. Additionally, the pump can often be disconnected from the catheter connection or the battery removed if the "pump suspend" command cannot be found by ER staff. The patient should be restarted on their insulin pump once hypoglycemia has been treated, as cessation of insulin pump therapy will result in the patient quickly becoming insulin deficient and rebound hyperglycemia will occur. The cause of hypoglycemia should be identified (i.e. too high a basal rate for background insulin needs, taking more insulin than needed for food or to correct high blood glucose, exercising without setting a temporary basal rate or drinking alcoholic beverages without eating carbohydrate-containing food). The patient should be instructed to contact their diabetes care team to discuss strategies to avoid severe hypoglycemia in the future. In the interim, they should be encouraged to run a temporary basal with a reduced rate of 30% to 50% until they are certain that they will not continue to have hypoglycemia, and to permanently decrease the basal rate at the time that the severe hypoglycemia occurred by 10% to 20%. Family members should be instructed on the management of hypoglycemia, including administration of glucagon.

Patient presenting with infusion site abscess or infection

Infusion site infections can occur because of poor insertion technique or leaving the infusion set in place for too long. Infusion sets should be changed every 2 to 3 days or sooner if redness, swelling or tenderness develops. Most skin infections associated with pump therapy are cellulitis secondary to *Staphylococcus aureus* bacteria (7). The infusion set and reservoir must be removed and discarded and another infusion site used until the infection has cleared. Treatment with oral antibiotics is needed, potentially with activity against methicillin-resistant *Staphylococcus aureus* (MRSA) in high prevalence areas; although if the patient is not allergic to penicillin, cloxacillin will often work. Skin abscesses should undergo incision and drainage, and debrided material sent for culture and susceptibility testing.

INSULIN PUMP THERAPY AND SURGERY

General principles

Elective surgery should be planned in advance in consultation with the patient's usual endocrinologist or diabetes specialist. The infusion site should be placed in a location away from the area where surgery will occur. Consideration should be given to where a diathermy pad may be placed. The patient must replace a metal insertion cannula with a plastic one before any surgical procedure that may involve diathermy. Insulin pumps should not be worn for procedures that involve exposure to radiation due to the strong electromagnetic field. The anesthetist must have access to the insulin pump during surgery to enable it to be turned off or disconnected, if necessary.

For minor elective surgery

If surgery is in the morning

The patient should administer their usual basal, bolus and correction insulin until midnight the night before surgery. They should then continue their usual basal infusion rates for the rest of the night. At the initiation of surgery, a temporary basal rate of 80% of the usual rate should be commenced. Capillary blood glucose level should be checked hourly.

Once the patient is able to eat or drink, intravenous fluids can be discontinued, the patient can resume their usual basal rates as well as bolus insulin using their usual pump settings. Patients should check their capillary blood glucose more frequently in the 1 to 2 days after surgery.

If surgery is in the afternoon

The procedure is similar to that followed above for morning surgery except that if the patient can eat a light breakfast, the preprandial capillary blood glucose should be entered into the pump and preprandial insulin administered per the patient's usual pump settings.

For major elective surgery

Discontinuation of the insulin pump and commencement of intravenous insulin therapy is recommended for major elective surgery. The pump should be discontinued half an hour after intravenous insulin and fluids are commenced.

Transition back to subcutaneous insulin in the postoperative period should be determined on an individual basis and will vary depending on the patient's usual insulin regimen and ability to tolerate an oral diet. It is possible to recommence insulin pump therapy in the postoperative period, even if the patient is being kept NPO, with administration of the usual basal rates and correction boluses. Mealtime boluses are not given, as the patient is not eating.

Other circumstances

The insulin pump may need to be temporarily discontinued during hospitalization in a number of other circumstances. These include:

- any radiographic procedure (pump must be removed)
- CT scan (pump must be removed)
- MRI scan (pump must be removed, including metal cannula).

The physician should order a one-time dose of rapid-acting insulin if the pump is expected to be off for longer than 60 minutes. This should be calculated as the usual basal rate the patient would have received during this time interval. For example, if a patient usually receives 1.0 unit/hour and will be off the pump for 3 hours, they should receive a subcutaneous injection of 3 units of rapid-acting insulin.

REFERENCES

1. Grunberger G, Bailey T, Cohen AJ, et al. Statement by the American Association of Clinical Endocrinologists Consensus Panel on insulin pump management. *Endocr Pract.* 2010;16:746-762.
2. Bailon RM, Partlow BJ, Miller-Cage V, et al. Continuous subcutaneous insulin infusion (insulin pump) therapy can be safely used in the hospital in select patients. *Endocr Pract.* 2009;15:24-29.
3. Noschese M, Donihi A, Ruppert K, et al. A guideline for diabetes self management in the hospital: experience with 50 patients using continuous insulin infusions. Paper presented at: 67th Scientific Sessions of the American Diabetes Association. June 22–27, 2007; Chicago, IL. Abstract 0845-P.
4. Bailon RM, Partlow BJ, Miller-Cage, V, et al. Continuous subcutaneous insulin (insulin pump) therapy can be safely used in the hospital in select patients. *Endocr Pract.* 2009;15:25-29.
5. Cook C, Boyle ME, Cisar NS, et al. Use of continuous subcutaneous insulin infusion (insulin pump) therapy in the hospital setting: proposed guidelines and outcomes measure. *Diabetes Educ.* 2005;31:849-857.
6. Canadian Diabetes Association Clinical Practice Guidelines Expert Committee. Canadian Diabetes Association 2008 clinical practice guidelines for the prevention and management of diabetes in Canada. *Can J Diabetes.* 2008;32(suppl 1):S65-S69.
7. Mecklenburg RS, Benson EA, Benson JW, et al. Acute complications associated with insulin infusion pump therapy. Report of experience with 161 patients. *JAMA*. 1984;252:3265-3269.

NOTE DE LA RÉDACTION… SUITE DE LA PAGE 19

clinique 2008 de l'Association canadienne du diabète pour la prévention et le traitement du diabète au Canada. *Can J Diabetes*. 2008;32 (suppl. 2) : S1 à S225.

3. Harris SB, Ekoe J, Zdanowicz Y, Webster-Bogaert S. Glycemic control and morbidity in the Canadian primary care setting. Results of the Diabetes In Canada Evaluation Study. *Diabetes Res Clin Pract.* 2005; 70:90-97.
4. Ross SA, Yale JF, Conway JR. SOLVE—a multinational, observational study to evaluate insulin detemir added to OADs in insulin-naïve patients with type 2 diabetes: baseline characteristics from the Canadian cohort. *Can J Diabetes.* 2010;34:272. Abstract 98.
5. Cheng AYY. The rules of 3's: insulin use in type 2 diabetes. *Can Diabetes*. 2011;24(1):3-9.