

A fresh look at continuous subcutaneous insulin infusion

First introduced in the 1960s, insulin pumps were big, bulky, and cumbersome to use. Today's models are smaller, lighter, and considerably more patient-friendly.

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Advances in technology have allowed persons with diabetes to choose an insulin-delivery method.¹ Insulin pump therapy, also known as *continuous subcutaneous insulin infusion* (CSII), has become a preferred insulin-delivery method among patients with diabetes in recent years. CSII mimics the function of a healthy pancreas by continuously delivering insulin into the subcutaneous tissue. Insulin pump therapy gives patients more flexibility in food intake and physical activity, as well as improves their quality of life. Currently, 8% of persons with type 1 diabetes in the United States and more than 200,000 persons with diabetes worldwide are using CSII to manage their disease.^{2,5} Patients using insulin pumps are likely to present to you for care, regardless of your practice setting, and a number of others might benefit from pump therapy. This article reviews the basics.

The first insulin pump was designed in the 1960s, but it was large and cumbersome, making it impractical for routine use.⁶ Insulin pumps were reintroduced in the mid to late 1970s, but interest again waned because of their size, poor efficiency, and associated safety issues.^{2,7} In 1985, CSII was approved by the American Diabetes Association as an alternative treatment for patients with type 1 diabetes.⁸ After the Diabetes Control and Complications Trial (DCCT) results were published in 1993, the development of smaller, safer, and more efficient pumps helped to renew the popularity of this delivery method.⁴ Current models have an electronic memory, multiple basal rates, several bolus options, a safety lockout feature, and a remote control.^{6,7} Some insulin pumps also have an alarm that signals when to change the battery or refill the syringes.⁶ Newer tapes attach the cannula to the skin more securely and with less irritation; quick releases permit the user to disconnect the pump for activities such as showering, swimming, and sexual intimacy.⁶

MECHANICS OF PUMP THERAPY

Many patients with diabetes and even many health care providers do not fully understand the concept of CSII therapy.² An insulin pump does not eliminate the need to monitor glucose levels. Patients using CSII still must check their glucose levels at least four times a day, before each meal and at

bedtime.⁹ The device is worn 24 hours a day; however, it can be taken off for up to 1 hour without producing any major effect on glucose levels.⁶ The device consists of the pump, an infusion set, and a syringe (see Figure 1). The patient can clip the pump, which is approximately the same size and shape as a pager, onto a belt or carry it in a pocket.^{2,9} Although initially intimidated, most patients quickly adapt to using the pump.⁶

The syringe is filled with a maximum of 300 U of rapid-acting insulin (a 2- to 3-day supply) and is attached to the



FIGURE 1. Continuous insulin infusion and a subcutaneous depot of insulin (inset) are the mainstays of CSII therapy.

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infusion set.^{4,10} Rapid-acting insulin is employed because of its immediate onset of action.⁹ The injection site should be cleaned with antiseptic solution and allowed to dry before the cannula is inserted.⁹ Skin barriers help to reduce irritation at the injection site.⁹ The infusion set, insulin reservoir, and injection site should be changed every 2 to 3 days at the same time of day, to prevent the insulin reservoir from emptying. This procedure takes an experienced patient about 5 minutes to complete.^{2,4,6,9,11,12}

The insulin pump is a portable electromechanical device that is programmed to infuse insulin continuously at a basal rate that matches the patient's metabolic need for insulin. Basal rates are usually 0.5 to 1.5 U/h.⁹ The patient can adjust the basal rate if circumstances warrant a temporary increase or decrease in insulin.^{7,10,12,13} The patient also activates the pump to administer a bolus dose of insulin when he or she is ready to eat. This allows patients to be flexible with their meal times and the amount of food eaten.

The amount of insulin in a meal bolus is determined in part by using a carbohydrate-to-insulin ratio. The ratio is different for each patient and may even be different for the same person at different times of the day.^{4,12,13} Only rapid-acting insulin analogs can be used with this treatment modality.¹² Some insulin pumps have additional features for bolus insulin delivery called *square wave bolus* and *dual wave bolus*; these features address the postprandial glycemic excursion associated with high-fat and high-protein meals.^{4,12} Factors for determining an accurate bolus dose are the current glucose level, the target glucose level, the carbohydrate-to-insulin ratio, total grams of carbohydrates in the meal, and insulin sensitivity.¹³ Some pumps include a calculator for calculating the bolus dose.¹³ Glucose control is attained through a combination of adjusting the basal rate as needed and appropriate timing of bolus doses of insulin.⁹

IMPLEMENTING INSULIN PUMP THERAPY

A primary indication for insulin pump therapy is when a regimen of multiple daily injections (MDI) has failed to adequately manage a patient's glucose levels. Table 1 (page 41) lists the indications for considering CSII. In addition, CSII will be effective only if the patient is motivated, willing, and capable of managing the disease with this method.

However, no standard tool can verify a patient's motivation, will, and capacity to use CSII. Therefore, the health care provider must carefully assess whether or not the patient is a potential candidate for pump therapy before initiating CSII.⁹

In the switch from MDI to CSII, the patient's prepump glucose levels are a major factor for calculating the basal rate and the amount of insulin in the bolus doses;¹⁴ both need to be determined before insulin pump therapy is initiated.¹⁰ The basal rate may need to be adjusted at certain periods of the day.¹⁴ Insulin needs are affected by individual lifestyle factors and the presence of the *dawn phenomenon*, which results when increased hormone production antagonizes insulin action; it generally occurs between 2 AM and 8 AM.¹⁴

The ideal candidate for pump therapy must be motivated to improve glucose control, willing to check glucose levels frequently, and willing to learn how to manage the disease with an insulin pump (see Table 2, page 41).⁷ After the decision is made to switch to CSII, the patient should be thoroughly educated.^{2,6} The patient must learn how to count carbohydrates and calculate insulin needs.⁶ A certified diabetes educator should instruct the patient in insulin pump management.¹³ Patients may need 24-hour online support from a multidisciplinary team with experience in CSII.^{6,12} Typically, young children are admitted to the hospital for 1 to 2 nights, whereas older children, teenagers, and adults are trained on an outpatient basis.¹⁴ Table 3 (page 42) lists some steps that can help patients make a smooth transition to CSII.

Success with CSII therapy is defined as improved glucose control and an improved quality of life.¹ CSII is recognized as a viable therapeutic option for children.³ Elderly patients who are computer literate, health focused, and have the ability to properly manage their diabetes also can be considered for CSII.¹³ Persons with psychological or social problems are not well suited for insulin pump therapy.⁵ Patients who have difficulty adhering to their MDI regimens typically are poor candidates for insulin pump therapy.⁵

BENEFITS AND RISKS

Benefits The primary advantage to CSII is better insulin pharmacokinetics using only rapid-acting insulin.^{3,6,14} CSII more closely simulates the function of the islet cells prior to

KEY POINTS

- Currently, 8% of persons with type 1 diabetes in the United States and more than 200,000 persons with diabetes worldwide are using continuous subcutaneous insulin infusion (CSII) to manage their disease.
- An insulin pump does not eliminate the need to monitor glucose levels. Patients using CSII still need to check their glucose levels at least four times a day, before each meal and at bedtime. The device is worn 24 hours a day; however, it can be taken off for up to 1 hour without producing any major effect on glucose levels.
- Factors for determining an accurate bolus dose are the current glucose level, the target glucose level, the carbohydrate-to-insulin ratio, total grams of carbohydrates in the meal, and insulin sensitivity. Glucose control is attained through a combination of adjusting the basal rate as needed and appropriate timing of bolus doses of insulin.

COMPETENCIES

- Medical knowledge
- Interpersonal & communication skills
- Patient care
- Professionalism
- Practice-based learning and improvement
- Systems-based practice

their destruction.^{2,15} A small subcutaneous depot of insulin and the stability of rapid-acting insulin contribute to consistent insulin absorption.¹⁴ CSII also decreases glucose variability and lowers fasting glucose.^{2,16} Patients using CSII experience fewer severe hypoglycemic events.^{2,16} Patients are able to engage in activities that otherwise might be risky, such as skipping or delaying meals, sleeping late, and exercising vigorously.² CSII has been shown to slow the progression of microvascular complications.⁴

Absorption of long-acting insulin varies by as much as 55%, resulting in wide fluctuations in glucose control.^{7,17} Absorption of rapid-acting insulin varies by less than 3%⁷ and, when insulin is administered continuously via a pump, is more consistent on a day-to-day basis; insulin availability is more reliable, and unexpected fluctuations in glucose occur less frequently.¹³ Therefore, the rapid-acting insulin analogs have become the preferred insulin for pump therapy.³ CSII provides better glucose control with fewer dangerous glycemia excursions; however, episodes of severe hypoglycemia or hyperglycemia are not completely eliminated.²

Risks The pump becoming disconnected from the injection site is a concern.¹⁸ Excessive weight gain also is a common side effect of pump therapy.^{2,16} However, the most serious risk is diabetic ketoacidosis.⁶ Ketones begin to form 4 to 6 hours after the last dose of rapid-acting insulin is infused.⁹ The incidence of diabetic ketoacidosis in patients using CSII is directly related to the education and skill levels of the patient using the device. Some patients may experience irritation or scarring at the insertion site.⁸ Some patients see the connection to the pump as a constant reminder of their disease; they may feel uncomfortable explaining it to persons who see and ask about the device.⁹ Most of the risks associated with CSII can be avoided by ensuring that patients are educated and properly trained. The patient also must use and maintain the device carefully.

CSII is expensive. The average cost of an insulin pump is more than \$5,000, and the supplies can cost approximately \$250 a month.² However, CSII is covered by Medicare, Medicaid, and most insurance companies.¹⁷ Insulin pumps are usually classified as durable medical equipment.²

FUTURE DEVELOPMENTS

A new development in insulin pumps is a sensor-augmented pump that continuously transmits glucose readings to the insulin pump.^{19,20} A continuous glucose sensing device is another new development. In this device, the pump gives continuous glucose readings for up to 72 hours.²¹ Researchers' goal is for continuous glucose monitoring technology to lead to a closed-loop system that would ultimately serve as an artificial pancreas.²² Future developments that are based on this sensor technology include wireless transmission of glucose levels to a hand-held monitor, thus providing real-time data of glucose levels.²²

The future of CSII therapy is promising, with rapid growth expected to continue.¹⁷ It is expected that up to 40% of all persons with type 1 diabetes will use CSII, and with

TABLE 1. Indications for CSII

Dawn phenomenon
Elevated A1C
Frequent admissions for diabetic ketoacidosis
Frequent episodes of severe hypoglycemia
Low insulin requirement
Need for a flexible insulin administration schedule
Onset of diabetes-related complications
Patient desire
Pregnancy
Renal transplantation
Unstable glucose control with MDI
<small>Key: CSII, continuous subcutaneous insulin injection; MDI, multiple daily injections.</small>
<small>Data from Weissberg-Benchell J et al,¹ Lenhard MJ and Reeves GD,² Renard E,³ Pickup J and Keen H,⁵ Weintrob N et al,⁶ and Wittlin SD.¹³</small>

TABLE 2. Attributes of an ideal candidate for CSII

Ability to communicate with the health care team
Ability to manage the infusion set
Ability to understand the concept of CSII therapy
Adequate health insurance
Adherence to current treatment regimen
Desire to proactively manage own treatment
Motivation to improve glucose control
Psychological stability
Realistic expectations
<small>Key: CSII, continuous subcutaneous insulin infusion.</small>
<small>Data from Lenhard MJ and Reeves GD,² Renard E,³ Pickup J and Keen H,⁵ Weintrob N et al,⁶ and Wittlin SD.¹³</small>

the expanded Medicare coverage, use will also increase in persons with type 2 diabetes who require insulin.^{7,17} CSII therapy will also increase in frequency in the pediatric population.¹² Newer pump designs with remote control features and programmable capabilities will be available to facilitate management of diabetes.⁷

A surgically implanted programmable insulin pump is available in Europe and is under investigation in the United States.¹⁴ This implantable insulin pump has a major advantage over external pumps or MDI: significantly fewer incidences of hypoglycemia because the insulin is administered

TABLE 3. Patient preparation for transition to CSII

Arrange for patient to talk with a person who is currently using an insulin pump
Attempt to manage diabetes with MDI
Discuss the importance of adhering to treatment regimen
Ease patient anxiety
Educate the patient on proper diet
Educate the patient on signs, symptoms, and treatment for hypoglycemia and hyperglycemia
Show patient a video about the use of insulin pumps
Review patient's dietary journal
<p>Key: CSII, continuous subcutaneous insulin injection; MDI, multiple daily injections.</p> <p>Data from Lenhard MJ and Reeves GD,² Renard E,³ Pickup J and Keen H,⁵ Bode BW et al,⁷ Barrio Castellanos R.¹²</p>

directly into the peritoneal cavity or bloodstream.¹⁴ However, the implantable device is more prone to catheter blockages, and some patients have developed anti-insulin antibodies while using the device.¹⁴

CONCLUSION

Successful implementation of CSII starts with careful patient selection by clinicians skilled in the use and maintenance of insulin pumps.² Potential candidates for CSII must be thoroughly evaluated and properly trained before implementation.² Some patients who may find CSII especially attractive include women receiving preconception care, pregnant women, and children.² Ongoing contact between the patient and health care provider and close follow-up are also essential to success.^{2,7}

The number of patients who use CSII to manage their diabetes has dramatically increased since the release of the DCCT results.^{12,18} Insulin pumps are a feasible alternative for diabetes management that can be used safely by patients with diabetes in any age group.^{6,7,12,13,16,18} For a significant number of patients with diabetes, CSII is an easier way to cope with the tremendous daily burden of managing their disease, and less than 3% of patients who use CSII to manage their diabetes discontinue using the modality.^{4,6} **JAAPA**

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