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Insulin pumps:

What you and your patients should know

Continuous infusion is the gold-standard for type 1 diabetes, offering greater flexibility for some; but cost can be a factor

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While treatment of type 1 diabetes mellitus (T1DM) has improved dramatically over the 80 years since insulin treatment was first developed, the search continues for better ways to duplicate the action of a healthy pancreas. Continuous subcutaneous insulin infusion (CSII) using an insulin pump is an attractive option available to many T1DM patients.

Some 18 years ago, the landmark Diabetes Control and Complication Trial clearly demonstrated the benefits of effective glycemic control in T1DM, namely near-normal glycemia and delayed onset of diabetic complications. Effective control can be achieved by CSII or multiple daily injections. Either way, the goal is to maintain blood glucose levels in the range of 3mmol/l to 7 mmol/l in the fasting state and between meals. This target range ensures that all tissues have sufficient glucose available for fuel, but not so much that the patient faces acute or long-term complications of hyperglycemia.

Insulin delivered by pump therapy matches physiological insulin secretion more closely than is possible with multiple daily injections. Maintaining normoglycemia throughout the day is challenging with multiple injections, because the rate of basal insulin secretion is not constant, being higher in the morning and lower during sleep. Both exercise and stress can also perturb insulin secretion rates. CSII allows patients to deliver bolus doses of insulin at mealtimes to counterbalance post-meal blood glucose spikes. The patient can also select variable levels of basal insulin secretion during the day and night.

Numerous studies have demonstrated that compared with multiple daily injections, CSII is associated with improved levels of glycosylated hemoglobin (A1c) without increasing the risk of hypoglycemia. By establishing more nearly physiologic glycemic control, CSII could also reduce the risk of both macrovascular and microvascular complications associated with T1DM, which is the ultimate goal in managing this disease.

The safety and efficacy of CSII therapy has also been demonstrated in various patient populations with T1DM, including pregnant women and children with uncontrolled diabetes. Patients who are properly trained and educated about the use

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Dr. Hugh Tildesley (right) shows Heath Stone, a type 1 diabetes patient, the data from his insulin pump at the first followup appointment after he received the device. Patients using sensor-augmented pump therapy have been able to achieve greater reductions in A1c than those taking multiple insulin injections daily.

of CSII therapy also appear to be at decreased risk of hypoglycemia, glycemic variability and weight gain, compared with those who use multiple daily injections.

Equally important, CSII also frees patients from having to administer multiple injections on a daily basis and may allow them more flexibility in terms of mealtime scheduling and their ability to engage in physical activity. Delivering insulin via a pump that can be worn under clothing is also clearly more discreet than having to use a traditional vial and syringe, potentially an important factor for treatment acceptance, especially in the workplace setting.

Basics of pump therapy

Insulin infusion pumps were first introduced in the late 1970s. Essentially, an infusion pump is an external mechanical pump that provides insulin from a reservoir or a syringe, the delivery of which is controlled by a computer chip. All components of the system are contained in a small case about the size of a deck of cards. Long plastic tubing (an infusion set) connects the pump to a cannula, usually in the abdomen, creating an open-loop insulin delivery system.

Patients program the pump so it delivers requisite amounts of insulin to match both basal and prandial needs and to correct for high and low blood glucose levels. They have to be prepared to monitor blood glucose four times a day and make the necessary adjustments in response to test results. However, current models provide multiple options in terms of basal rates, and their software can calculate bolus doses needed based on current blood glucose levels, the amount of insulin currently available and other factors including the carbohydrate "dose" a patient is going to be consuming. All pumps deliver insulin instantly, so only rapid-acting formulations of insulin are used.

In most pumps, the reservoir holds enough insulin to last for several days. When the reservoir runs low or if an obstruction occurs in the catheter, an alarm alerts users to potential problems.

Sensor-augmented pump therapy

It is likely that relatively few patients who self-monitor their blood glucose (SMBG) with traditional meters are consistent about taking measurements after meals or overnight. Failure to monitor can result in both hyper- and hypoglycemia, including, most seriously, nocturnal hypoglycemia.

Continuous glucose monitoring devices improve on traditional SMBG by recording blood glucose levels automatically and continuously throughout the day and night. Several approved devices, including Medtronic's MiniMed, DexCom's Seven Plus device, and Abbott's FreeStyle Navigator, can provide close to 300 blood glucose measurements every 24 hours.

These continuous glucose monitoring devices can therefore be used to identify fluctuations in an individual's blood glucose levels that would not be detected with intermittent finger-stick measurements. Used with a logbook, continuous glucose monitoring records can also help patients and health-care providers

Table 1: Annual type 1 diabetes out-of-pocket expenses in Canada as of June 2011

	Annual individual income <$15,000		Annual individual income $43,000		Annual individual income $75,000	
	No pump	With pump	No pump	With pump	No pump	With pump
Newfoundland/Labrador	$0	$0	$3,021.10	$2,910.31	$3,021.10	$2,910.31
Prince Edward Island	$1,564.58	$5,673.01	$1,564.58	$5,673.01	$1,564.58	$5,673.01
Nova Scotia	$559.76	$4,428.35	$1,282.16	$5,150.75	$2,722.75	$6,411.72
New Brunswick	$29.20	$3,937.60	$2,954.68	$6,819.64	$2,954.68	$6,819.64
Quebec	$847.55	$3,945.70	$1,715.70	$5,681.42	$1,715.70	$5,681.42
Ontario	$942.61	$783.09	$2,010.61	$1,889.09	$2,102.19	$2,290.00
Manitoba	$395.85	$1,655.85	$2,051.10	$3,311.10	$2,848.10	$4,957.50
Saskatchewan	$499.20	$4,414.35	$1,462.00	$5,385.08	$2,550.00	$6,473.00
Alberta	$0	$0	$2,963.65	$6,823.76	$2,963.65	$6,823.76
British Columbia	$475.20	$1,805.28	$1,925.20	$3,255.28	$2,481.33	$4,505.28
Nunavut	$0	$0	$0	$0	$0	$0
Northwest Territories	$0	$0	$0	$0	$0	$0
Yukon	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00
First Nations (federal)	$0	$0	$0	$0	$0	$0

Source: Canadian Diabetes Association

identify the cause of glucose fluctuations, allowing them to adjust insulin dosing.

Used individually, CSII and continuous glucose monitoring have each made it increasingly possible to deliver insulin in a way that more closely matches normal insulin secretion. The advantages are still greater when the two technologies are coupled, in a process called sensor-augmented pump therapy (SAPT).

Like other continuous glucose monitoring systems, SAPT allows patients to collect and store glucose and insulin delivery information. This information can then be uploaded to a computer where it can be formulated into reports. Armed with a visual record of their blood glucose patterns, patients and their caregivers can identify causes when these patterns to go awry and take steps to correct them.

The MiniMed Paradigm REALTime System is a sensor-augmented insulin pump that wirelessly transmits information every five minutes from a subcutaneous sensor to a CSII device. It is equipped with an alarm indicating when glucose levels are high or low. Several similar devices are also available, including the Animas device (www.animas.ca/animas-insulin-pumps/onetouch) and a newer model by Omnipod (www.myomnipod.com), which features a disposable pump, to be replaced every three days, rather than a separate infusion set. This device is controlled by a remote control operator which includes a glucose meter.

Differences in cost and operation among these are minimal, so patients should be encouraged to research which device they prefer.

How well does SAPT work?

The STAR3 study, published in the *New England Journal of Medicine* in July 2010, provides clear confirmation of the benefit of SAPT for patients with type 1 diabetes. In STAR3, 485 type 1 subjects were randomized to either continue on multiple daily injections with standard blood glucose monitoring or to be introduced to SAPT in a stepwise protocol. After one year, adult patients using SAPT had a 1.0% reduction in A1c, compared with 0.4% in patients using multiple daily injections. The difference was also seen in pediatric patients, where A1c declined 0.4% in the SAPT group but rose 0.2% in the multiple daily injections group. Throughout the study, A1c levels remained significantly lower in SAPT subjects versus multiple daily injection subjects. However, rates of severe hypoglycemia, diabetic ketoacidosis and weight gain were not significantly different between the two groups. **>>> page 22**

Risks and disadvantages of pump therapy

As welcome as CSII and related technologies are in the management of T1DM, patients need to be aware of the risks and the disadvantages of insulin pump therapy. These include:

Price: Insulin pumps cost approximately $6,000, while infusion sets and dressings cost between $150 to $400 a month. Insurance coverage for pump costs and related services vary considerably. For information on coverage available in different provinces and territories, see table 1.

Training and use of the pump: Intensive insulin therapies all require extensive training, and pump therapy requires even more so than others. Patients need to spend time learning how to manage the daily operation of the pump itself, as well as related software required to make the pump maximally effective.

Mechanical problems: Current models can be expected to be mechanically reliable, but if a problem occurs, the flow of insulin may be either excessive or interrupted. Any disruption in insulin flow has important implications, because blood glucose can quickly become elevated. Patients should always keep an insulin syringe or pen as a backup in case of mechanical failure.

Skin infections: Skin infections may result when the use of a single injection site is prolonged or skin hygiene is not optimal. The risk of skin infections may be reduced by changing the infusion sets every two to three days. Patients should be instructed to keep the infusion site clean and dry.

Who can benefit from insulin pump therapy?

CSII is appropriate for type 1 diabetes patients who experience inadequate glycemic control while on multiple daily injections. Thus, patients who are experiencing unpredictable, severe hypoglycemia, elevated A1c levels, glycemic fluctuations or marked morning-time hyperglycemia (the "dawn phenomenon") would all be good candidates for CSII. In each of these cases, there is substantial evidence suggesting the benefits of pumps over standard therapy.

Contraindications to other forms of intensive insulin therapy also apply to CSII. Beyond this, there are no absolute contraindications that apply specifically to the insulin pump. However, patient selection remains important, since patients must be motivated to train, and capable of doing so, if they are to use the pump safely and effectively. Patients also need to feel comfortable wearing a pump.

Ongoing care by skilled professionals continues to be needed after patients begin CSII. For this reason, if for no other, the patient must be discouraged from seeing pump therapy as a "cure" for what is clearly a lifelong and incurable condition.

Nevertheless, the insulin pump represents the gold standard for T1DM management, and patients may appreciate the relative freedom that it offers them from some of the burdens of insulin injection. Patients who express a desire for greater flexibility in the daily demands of treating T1DM may be particularly satisfied with CSII, as it should allow them to miss the occasional meal, exercise more vigorously and have less rigid sleep patterns. ■

Getting going: Determining basal rate and bolus doses

- In patients transitioning from MDI to pump therapy, the total daily dose of insulin should be 10% to 25% less than their prior total dose.
- Basal insulin usually accounts for approximately half of the pump dose in adult patients, with the other half consisting of bolus doses. For children, the basal dose is usually somewhat higher, and the bolus doses lower.
- A single basal rate is used at the beginning of pump therapy, but patients may add one or two additional rates as their daily and nightly insulin requirements become clearer.
- Bolus doses, given within 15 minutes of beginning a meal, may be based on premeal blood glucose readings. They may also be set based on estimated food intake, using either a sliding scale or carbohydrate counting method.

Recommended reading

Much of the advice above is based on information found in the following sources:

An Overview of Continuous Subcutaneous Insulin Infusion Therapy. A continuing education monograph for physicians, pharmacists and nurses. www.MedEdToday.com

Rubins RR et al. Crossing the Technology Divide: Practical Strategies for Transitioning Patients From Multiple Daily Insulin Injections to Sensor-Augmented Pump Therapy. Diabetes Educator 2011;37: 5S.

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