The insulin pumps of the 1970s were bulky and heavy, offering little flexibility in the rate of basal insulin delivery and with few safety features. Improvements in pump technology have fuelled a dramatic increase in pump use with about 300,000 individuals worldwide now using pump therapy.

Today’s pumps deliver insulin via a subcutaneously inserted infusion set and provide a wide range of basal and bolus delivery options. Continuous glucose monitoring systems (CGMs) and downloadable data have added more value to pump therapy and further expanded its role in diabetes management.

For insulin-dependent patients, today’s pumps come closer than ever to approximating physiological insulin secretion, thus enabling a more “normal” lifestyle and improving users’ quality of life and sense of well-being.

That said, pump therapy may not be the best solution for all insulin-dependent patients, as it requires a level of motivation that not all patients are willing or able to achieve. It is important for clinicians to understand which patients are best suited for pump therapy.
Pump therapy and type 2 diabetes

Insulin pump therapy can be considered in type 2 diabetes patients who require large doses of insulin or who have inadequate control on MDI therapy. When such patients inject large doses of insulin, a subcutaneous pool or “depot” can linger and, when mobilized, lead to unexpected hypoglycemia. Pumps deliver insulin in slow controlled pulses, leading to more uniform and predictable insulin absorption. Insulin requirements may decrease by an average of 15% to 20% in type 2 patients and use of oral agents may also decrease.

To succeed at pump therapy, patients with type 2 diabetes must be able to monitor blood glucose three to six times a day, determine their premeal insulin needs and tolerate a device that reminds them they have diabetes. They must also have the motivation to achieve glucose control, and they must have a reasonable level of psychological stability.

FEATURES OF PUMP THERAPY

Insulin delivery

Unlike the MDI approach, which combines rapid-, intermediate- and long-acting insulin injections, insulin pump therapy requires only rapid-acting insulin because the insulin is delivered continuously. Pumps can deliver basal insulin at variable and programmable rates—a mode of delivery that cannot be matched by intermittent injection of longer-acting insulin.

This feature enables the pump to mitigate the "dawn phenomenon," the abrupt increase in glucose levels that occurs in the early-morning hours in many patients with diabetes. The dawn phenomenon is not caused by antecedent hypoglycemia and can present a significant challenge to diabetes management. To counteract it, pump users can increase their basal insulin delivery rate prior to the dawn hours. Other patients find they have higher or lower insulin needs on weekends than on weekdays.

The DCCT showed that achieving and maintaining glucose levels as close to normal as possible can prevent or delay microvascular complications in people with type 1 diabetes. The trial also found that the cohort using CSII systems maintained better glucose control than those on MDI.

The years following the DCCT saw a rapid increase in the use of insulin pumps, and numerous studies (notably, those comparing pumps to MDI) have shown that pumps help maintain glucose levels as close to normal as possible. Short-acting insulin analogues with greater responsiveness to the immediate physiologic environment further enhance the pump’s effectiveness.

Today’s pumps can be programmed to vary the basal insulin delivery to accommodate changing insulin needs in response to patients’ individual patterns. Variable bolus patterns mean bolus insulin can be delivered more quickly or stretched out over a longer period of time, in an attempt to approximate the normal pancreatic secretion of insulin.

Perspective

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Benefits & Drawbacks

Insulin pumps have proved successful both in clinical trials and in daily clinical practice. The benefits of insulin pump therapy include:

• More precise insulin dosing and elimination of daily multiple injections
• Improved insulin absorption with continuous delivery (more closely approximating pancreatic delivery in people without diabetes)
• Better ability to manage illness, varying activity levels, and the dawn phenomenon
• Reduced “peaks and valleys” in glucose levels
• Ability to reverse hypoglycemia unawareness
• Better management of delayed food absorption (by adjusting the bolus delivery to match food absorption)
• Stabilization of A1C levels
• Ability to follow a flexible eating regimen, including the guiltless enjoyment of special-occasion foods
• Ability to exercise safely, as basal insulin rates can be reduced or temporarily stopped as needed
• Ability to travel with ease, as basal insulin rates can be adjusted to the destination time zone
• Insulin pumps require some motivation and vigilance, and are not suited for every insulin-dependent patient. Patients must monitor their glucose levels frequently (four to eight times a day), learn to count carbohydrates, and exercise consistent attention to their insulin needs. Costs are considerable: several thousand dollars for the pump and about $200 to $300 per month for supplies. Many private insurers, realizing the benefits of pump therapy, will pay for at least a portion of these costs if patients provide a certificate of medical necessity from their physician. Provincial health plans in Ontario, Saskatchewan, Newfoundland and Quebec cover pumps or pump supplies for certain people, usually in pediatrics. Since coverage policies may change, it’s worth verifying the current status with the appropriate authorities.

Another potential drawback is the possibility of infection at the infusion site, but this complication can be prevented in most cases with proper attention to hygiene. Infusion system failures, generally due to blockages or leaks that interrupt the flow, may also occur, though they are less common with today’s systems.

Because pump users do not take long-acting insulin, ketonemia and diabetic ketoacidosis can develop more rapidly and frequently if the flow of short-acting insulin is interrupted for any reason.
Most patients with type 1 diabetes are candidates for insulin pump therapy. The use of pumps in insulin-dependent patients with type 2 diabetes is somewhat more controversial, as these patients may still be producing some endogenous insulin, which complicates the task of establishing a pump regimen.

In my practice, about half of my patients with type 1 diabetes – particularly younger people – are using insulin pumps. To be considered for pump therapy, my patients must meet one or more of the following criteria:

- Diagnosed type 1 diabetes as documented by a family doctor, pediatrician or endocrinologist
- Wide fluctuations in blood glucose levels
- History of severe hypoglycemia or hypoglycemia unawareness
- Inability to achieve optimal diabetes control as per the Canadian Diabetes Association guidelines (A1C < 7% and, if safely achievable, < 6%)
- Difficulty coping with multiple daily injections

It is also preferable if candidates for pump therapy meet at least some of the following behavioural and psychosocial criteria:

- Self-monitoring blood glucose levels at least 4 times a day
- Consistent recording of results in a logbook
- Motivation to strive for optimal diabetes control

A: Just as with driving a car, using the pump requires some advance knowledge and mental preparation. Candidates meet with a dietitian for instruction on carbohydrate counting and insulin dose adjustment. Reassurance is important, as many patients are anxious and overwhelmed with new information. They need to know their feelings are normal.

Q: What are some of the things that can go wrong with the pump, and how to prevent them from happening?

A: Because the pump uses only shorter-acting insulin, it carries a greater risk of diabetic ketoacidosis (DKA). Pump users can minimize the risk of DKA by monitoring blood glucose routinely throughout the day to ensure insulin is flowing without disruption. If blood glucose rises above 14 mmol/L, patients can monitor their blood ketones with a specially designed precision meter.

Another potential problem with insulin pumps is poor glucose control. Of course, this problem can also occur with other treatment strategies. To pursue the car analogy, glucose monitoring is essential to keep the “car” from veering into hyper- or hypoglycemic terrain. At our centre, pumpers can monitor their blood ketones with a specially designed precision meter. Another potential problem with insulin pumps is poor glucose control. Of course, this problem can also occur with other treatment strategies. To pursue the car analogy, glucose monitoring is essential to keep the “car” from veering into hyper- or hypoglycemic terrain. At our centre, pumpers can monitor their blood ketones with a specially designed precision meter.

Q: How can a diabetes management team assist insulin pump users?

A: Because pump users need to count carbohydrates, the dietitian plays a vital educational role. Social workers can advocate for financial assistance for patients for whom cost may pose a barrier. A certified pump trainer can provide the bulk of teaching and follow-up care. Pump trainers liaise with the rest of the medical team to ensure a smooth flow of communication. I believe that effective communication between the trainer and the patient’s family doctor can make pump therapy an exciting and positive experience for both parties.

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At our clinic, we have a 24/7 advice line, which all pump users can call if they need medical advice. Patients can also attend group educational sessions to share their problems and concerns.
adjustments in basal and/or bolus doses as needed. The device is now available for day-to-day or intermittent use. Both clinical studies and reports from my patients have been extremely encouraging. One patient has compared current glucose monitoring recommendations to buying a watch that tells the correct time four times per day. My patients who have incorporated continuous glucose-sensing technology report an increased sense of safety and control.

**TREATMENT CONSIDERATIONS**

**Patient selection**

Some clinicians recommend pumps only after MDI fails to equalize glycemia, while others consider it for motivated patients whose lifestyle may not lend itself very easily to MDI. In my practice, I occasionally (though infrequently) start patients on the pump before a trial of MDI. Patients who exercise should not be discouraged from using the pump, as it is fully compatible with exercise. Some of my pump-using patients are even marathon runners.

Diabetes care requires sustained effort and attention, and pump therapy may further increase these requirements. Stress, mental health and emotional issues may impact patients’ ability to use the pump effectively, so these psychological aspects must be taken into consideration when selecting patients.

Depression is about three times more common in people with diabetes than in the general population, but often goes unrecognized and untreated. A number of brief screening instruments can be used to identify depression, stress and quality of life in patients considering the use of a pump. Failure to take into account an undiagnosed depression may adversely affect a patient’s chance of success with pump therapy.

**Model of care**

The traditional, authoritarian model of medical care may not be appropriate for pump users. An empowerment model, which shifts the primary management responsibility to the patient while providing ample support, facilitates learning and tames normal fears in new pump users. In this model, patients freely choose their behavioural changes, and research has shown that freely chosen changes are more likely to be maintained than those mandated by others.

**Pumps for children**

Many young patients find it easier and more convenient to take their multiple daily doses of insulin via the pump than with a syringe or insulin pen. The pump also allows for quick and accurate compensations for the often-erratic eating patterns of children. On the other hand, the level of knowledge and vigilance required by pump users precludes the unsupervised use of pumps in children. The pump should only be considered in children who are closely monitored by a parent or other adult willing and able to learn how to manage all aspects of pump therapy. This requirement may be easier to meet in preschool children, as most schools do not have on-site personnel who can assume this responsibility.

**Patient satisfaction**

While the literature sometimes reports high rates of discontinuation of pump therapy, my own experience has been that properly selected and educated patients rarely seek to go off the pump. In my practice, pump users report a consistently high level of satisfaction.

**Future directions**

Pump technology is constantly evolving. Current research and development efforts are leading toward fully automated pumps. The pumps of the future will likely feature moment-by-moment sensors that instantaneously translate glucose readings to insulin output.

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**Case Study: BRIAN IS A 49-YEAR-OLD CAUCASIAN MAN WHO DEVELOPED TYPE 1 DIABETES IN CHILDHOOD. CONTROL OF HIS DIABETES OVER THE YEARS HAS BEEN SUBOPTIMAL AND HE HAS BEEN DIAGNOSED WITH MILD RETINOPTHAPY AND HAS EXPERIENCED SOME ERECTILE DYSFUNCTION. HE ALSO HAS A HISTORY OF ASYMPTOMATIC HYPOGLYCEMIA, INCLUDING A RECENT SERIOUS EPISODE THAT REQUIRED A BRIEF HOSPITALIZATION. HIS BMI IS 26 KG/M2, MAKING HIM OVERWEIGHT BUT NOT OBESE. HIS CURRENT MEDICATIONS INCLUDE NPH AND RAPID-ACTING INSULIN, ALONG WITH A STATIN.**

His most recent laboratory testing results are as follows:

- **A1C**: 8.5%  
- **Total cholesterol**: 6.3 mmol/L  
- **LDL cholesterol**: 4.7 mmol/L  
- **HDL cholesterol**: 1.17 mmol/L  
- **Triglycerides**: 2.2 mmol/L  
- **Creatinine**: 79.2 µmol/L  
- **Microalbumin**: 4 µg

Brian’s records reveal a pattern of mid-afternoon hypoglycemia. You refer him to a dietitian specializing in diabetes care who adjusts his insulin regimen and teaches him how to calculate his mealtime dose of rapid-acting insulin, based on the amount of carbohydrates in the meal and his preprandial blood glucose level. Despite following this new regimen, over the ensuing month he experiences two more episodes of severe hypoglycemia, following which he comes to see you again. (You had started him on ACE inhibitor therapy as well as modifying his LDL-lowering therapy.)

His subjective experience of hypoglycemia is not reliable. Carbohydrate counting and insulin adjustments have helped, but have not adequately controlled his hypoglycemic episodes. As well, he has begun to experience diabetes complications. You suggest he consider insulin pump therapy. His initial reaction is positive, as he admits to finding it a nuisance to “carry all these different types of insulin” with him.

The equipment is ordered. Brian visits his endocrinologist to discuss his therapy and undergoes a training session with his dietitian, who is also a certified pump trainer. His baseline insulin rate is set at 0.7 units per hour starting at midnight and 1.1 units per hour from 5 a.m. to 8 a.m. At 8 a.m., he switches to 0.8 units per hour and continues this rate until the following midnight. He experiences some early problems with elevated blood glucose levels, but a bent-needle infusion set (to improve absorption) resolves these problems.

Six months after starting the pump (and attending regular educational workshops), Brian’s laboratory values have reached target ranges. His A1C has stabilized at just under 7%. He has recovered a physical sense of impending hypoglycemia and has been free of serious hypoglycemic episodes since starting the pump.

He feels more hopeful than ever about his ability to control his diabetes, and expresses a desire to begin an exercise program in order to shed 10 pounds.