An overview of insulin pump therapy: appropriate use of an expensive resource

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Abstract

Insulin pump therapy is an option for intensive insulin therapy in patients with type 1 diabetes who meet the criteria described in this article. Pump therapy may assist in the reduction of haemoglobin A_{1c} (HbA_{1c}) and the frequency of severe hypoglycaemia. It can also lead to improvements in awareness of hypoglycaemia and quality of life. Careful assessment of patients is vital, as pump therapy is an expensive treatment option and can be dangerous if used incorrectly. Intensive education of patients who meet the criteria is essential. This will reduce possible risks associated with pump therapy. A team approach is needed, consisting of a minimum of a doctor and a diabetes educator who are experienced in pump therapy, as well as a registered dietitian who has expertise in carbohydrate counting. A psychologist is also a useful member of the team and can help with patient assessment and selection.

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Insulin pump therapy, alternatively known as continuous subcutaneous insulin infusion (CSII), was first used in the late 1970s.[1] The insulin pump is a portable electromechanical device that is worn externally on the body. It is filled with short-acting insulin that is delivered subcutaneously via an infusion catheter.[2] The infusion site is rotated every two to three days. The aim of pump therapy is to replicate the physiological delivery of insulin as closely as possible. This necessitates a pre-programmed continuous background or basal rate, as well as patient-controlled boluses for meals and snacks, and for the correction of hyperglycaemia.[1]

The original pumps were very basic. They were able to deliver a fixed basal rate for 24 hours. Boluses were delivered manually by the patient in 1 U increments. Infusion sets were inserted with an indwelling steel cannula, similar to a butterfly needle. These pumps were not very popular because of their large size, high rates of infusion-site infections, and more frequent diabetic ketoacidosis (DKA) than that associated with insulin injections.[1] These pumps were used in South Africa in the 1980s by some diabetologists, but were soon abandoned because of poor results.

After the results of the Diabetes Control and Complications Trial (DCCT) were published in 1993, insulin pumps gained popularity in the USA.[1] Insulin pump therapy was revived in South Africa in 2002, with the introduction of the MiniMed 508® pump. These pumps were smaller than the first pumps and were able to deliver variable basal rates. Smaller adjustments were possible, at 0.1 U increments. The additional ability to deliver a temporary basal rate was useful for managing illness and exercise. Teflon cannula-tipped infusion sets and sensitive high-pressure alarms became available. Consequently, rates of infusion-site infections and DKA were very low; similar to the DKA rates associated with multiple daily injections (MDI) of insulin.[2]

Insulin pumps have now evolved even further, with the addition of even smaller insulin unit increments of 0.025 U, features such as bolus calculators that help patients to determine their bolus dose based on their carbohydrate intake and current blood glucose readings, additional meal bolus options to better match high-fat content and very low glycaemic index meals, and continuous real-time glucose monitoring. Two pump brands are available in South Africa: the Medtronic Paradigm range of pumps and the Accu-Chek Spirit Combo pump.

Insulin pumps are very sophisticated devices that can assist patients to achieve better blood glucose control without the increased risk of hypoglycaemia.[1,3-5-7] A meta-analysis of 12 randomised controlled trials demonstrated an average HbA_{1c} reduction of 0.51%.[5] Some studies have also shown an increase in hypoglycaemia awareness with the use of the pumps,[8,9] which has also resulted in an improvement in quality of life.[1,10,11] Despite these advantages, they do not work well for all patients. The cost of the pumps and pump consumables remains very high. This limits pump

use to wealthy patients or those with medical aids that reimburse the cost of the pump therapy. An ethical dilemma exists, the resolution of which seeks to balance individual patient benefits with the need for society and healthcare providers to act as good stewards of scarce healthcare resources. The considerable initial and ongoing costs, and the defined and measurable clinical benefits for a particular patient, must be considered on a case-by-case basis. A comparison of costs between MDI using insulin analogue pen devices and CSII is given in Table I.

Assessing patients for suitability for pump therapy, as well as training and education to initiate pump therapy, is very time-consuming for the healthcare provider. A typical pump training session lasts a minimum of three hours and frequent follow-up is necessary in the first few months. In general, patients using pumps require more frequent visits to the healthcare provider, on an ongoing basis.

Therefore, careful selection of candidates for insulin pump therapy is essential. The current South African insulin pump therapy guidelines state that pumps should be reserved for patients with type 1 diabetes who are performing multiple daily injections of insulin, and have carried out self-monitoring of blood glucose (SMBG) at least four times a day for at least the last six months. Patients need to adhere to their diabetes treatment plan and be motivated to attain good glycaemic control. If, despite these efforts, target HbA_{1c} levels have not been achieved, pump therapy should be considered,[12] for which there should also be a specific indication.

Table I: Comparison of costs of MDI and CSII

Insulin administration method	Monthly cost (including VAT)
Multiple daily injections	
Insulin aspart disposable pens, based on 25 U daily	R260
Insulin glargine disposable pens, based on 25 U daily	R380
Pen needles (10 per month)	R32
Total	R672
Continuous subcutaneous insulin infusion	
Insulin aspart 10 ml vials, based on total daily dose of 50 U	R544
Infusion sets (10 per month)	R1 187-R1 460*
Reservoirs/cartridges (10 per month)	R330-R383*
Initial cost of pump R20 000-R38 000 (amortised over four years)**	R416-R791
Total	R2 477-R3 178

* Prices are given for the cheapest and most expensive choices of these items
** Most patients upgrade their pumps after four years, when the manufacturer's warranty has expired
This cost comparison does not include test strips for the self-monitoring of blood glucose. This cost would be similar for both modes of treatment.

The National Institute for Clinical Excellence (NICE) guidelines, used in the UK for National Health Service funding, describe the following indications:[10,13]

- Patients with type 1 diabetes, where attempts to achieve target HbA_{1c} with MDI results in hypoglycaemia that is disabling (i.e. unpredictable, causing anxiety and with adverse effects on quality of life).
- Patients with type 1 diabetes, where HbA1c remains above 8.5% on MDI, despite a high level of care.
- Children under 12 years of age with type 1 diabetes, where MDI is impractical or inappropriate.

Quality of life issues that may be improved with insulin pump therapy include shift work, frequent travel across time zones, a pathological fear of hypoglycaemia, needle phobia, impaired exercise capacity and the adverse impact of diabetes on family dynamics.[10]

Insulin pump therapy is a good option for women planning pregnancy. Studies suggest that CSII helps to lower HbA_{1c} in the preconceptual period, although no difference was seen during pregnancy. These studies also suggest that CSII may reduce hypoglycaemia during pregnancy. Pumps are a safe and effective treatment method for patients with type 1 diabetes who are pregnant.[14-17]

The use of insulin pump therapy in children and adolescents is also safe and effective. Compared to the use of MDI, studies show reductions in HbA_{1c} and hypoglycaemia similar to those seen in adults, and improvement in quality of life.[18-20]

When evaluating patients for insulin pump therapy, it is vital to discuss the associated advantages and disadvantages with them (see Table II), as well as their expectations. A patient who believes that the pump will monitor their blood glucose and deliver insulin accordingly will be very disappointed if the logistics of pump therapy have not been explained properly when he or she commences using it.

It is important that the patient is not forced into insulin pump therapy. Some patients find it disagreeable to be attached to a device all the time, especially young girls who wear tight clothing and whose body image is important to them. Scarring at infusion sites may also be unacceptable. A patient who is not enthusiastic about pump therapy constitutes a contraindication for its use.

Table II: Advantages and disadvantages of insulin pump therapy

Advantages
• More flexible delivery of basal insulin, allowing easier control of the "dawn phenomenon"[21]
• A reduction in severe nocturnal hypoglycaemia
• Improved flexibility in terms of meal size and timing, and sleeping late[22]
• Use of the temporary basal rate allows for easier management of exercise and illness[22]
• Smaller increments of insulin can be delivered accurately
• Less frequent pricks for insulin delivery (once every three days, compared to four times a day in the case of MDI)
Disadvantages
• Expensive
• Continuous attachment to a device
• A higher risk of DKA if there are problems with insulin delivery[23,24]
• The risk of infusion site infection and/or contact dermatitis[23]
• Scarring at infusion sites in some individuals

One of the more serious disadvantages of pump therapy is the risk of developing DKA if insulin delivery is interrupted. This can happen if the patient forgets to attach the pump, if the infusion set pulls out or becomes blocked, if there is a large quantity of air in the system, or if there is pump failure due to a flat battery, an empty reservoir or any other technical problems. Therefore, regular SMBG, at least four times per day, is recommended. This helps with the early detection of possible problems. Patients who have not demonstrated SMBG four times daily for at least the last six months should not be considered for pump therapy, as they have not demonstrated the necessary commitment to self-care.

Infection at the infusion sites is another potential risk. This can be minimised by regularly changing infusion sites (at least every two to three days), as well as by maintaining good hygiene practices. The patient who does not perform the minimum requirements when using MDI is likely to extend the use of infusion sets and skip important steps such as hand washing and disinfecting the skin with alcohol. Insulin pump therapy is not an easier way of treating diabetes. Therefore, it will not work well in a patient who is looking for something that will control his or her diabetes automatically. Pump therapy success is dependent on a patient who is motivated, conscientious, and able to learn and practise carbohydrate counting,[2] and who is willing to keep comprehensive diaries of his or her blood glucose values, intake of food and insulin administration.

In the South African environment, where funding for pump therapy is limited, it is essential that candidates are selected who abide by the guidelines. In addition, patients who are on pump therapy should be continually reviewed to see if they meet the indications for pump therapy. Funders are more likely to continue to fund pump therapy if the treatment is successful in offering clinical benefit.

Once a potentially successful candidate has been selected, he or she will need to learn or review carbohydrate counting. Accurate carbohydrate counting is essential in order to achieve good results with pump therapy. The patient must be referred to a registered dietitian who is experienced in teaching this skill. Ideally, this should occur at least one month before starting pump therapy. The patient will need to keep a food, blood glucose and insulin dose diary, which should be sent to the dietitian every few days. This will help the health professional to gain a more accurate idea of the patient's insulin-to-carbohydrate ratio and his or her diurnal variation, and to eliminate common mistakes. Gram counting of carbohydrates is recommended for better accuracy.

The ideal insulin to use in insulin pump therapy is a rapid-acting insulin analogue. Several studies have shown improved HbA_{1c} and postprandial blood glucose control when using rapid-acting analogues, rather than regular short-acting insulin in pumps.[25-29] A 2011 study, that compared insulin glulisine, insulin aspart and insulin lispro in insulin pump therapy, demonstrated a similar performance and no difference in metabolic outcome or infusion set occlusion.[30]

The patient must be advised on which long-acting insulin to take the night before or on the morning of the start of pump therapy. If the patient is on once-daily insulin glargine at night, the normal dose should be given. It should be taken into account whether or not there will be any overlap between the long-acting insulin and the pump basal rate on the first day and night. The temporary basal rate function must be used to reduce the basal rate until the insulin glargine has worn off. If the patient is on insulin detemir or neutral protamine Hagedorn insulin twice daily, he or she should take the normal dose the night before and skip the morning dose.

The basic guidelines to calculate the starting pump settings are as follows:

- Add up the patient's current total daily dose (TDD) of insulin on injections.

- Calculate the total daily pump dose (TDPD) by reducing the TDD by 20-30% (depending on current glycaemic control). A meta-analysis has shown an average reduction in insulin requirement of 14% with pump therapy, compared to the use of MDI.[3] The reduction will also reduce the risk of hypoglycaemia, which apart from other associated disadvantages, will complicate the interpretation of blood glucose readings in the first few days.
- Divide the TDPD by 2 to obtain the total basal insulin requirement for 24 hours. This can then be divided by 24 to obtain a flat hourly rate, or be set according to pre-set circadian rhythm patterns.
- The initial insulin-to-carbohydrate ratio can be calculated as 500 divided by TDPD, or more accurately from the food, blood glucose and insulin diaries.
- Insulin sensitivity is calculated as 100 divided by TDPD.

For example, in a patient on insulin lispro 6 U three times daily and insulin glargine 22 U at night:

- TDD = 40 U
- TDPD = 40 U - 25% = 30 U
- Daily basal dose = 30 U ÷ 2 = 15 U
- Hourly basal rate = daily basal dose (15 U) ÷ 24 = 0.6 U/hour
- Insulin:carbohydrate ratio = 500 ÷ 30 = 16.6 (round up to 17), i.e. 1 U insulin covers 17 g carbohydrate
- Sensitivity = 100 ÷ 30 = 3.3, i.e. 1 U insulin lowers blood glucose by 3.3 mmol/l.

Insulin pump training must be carried out by a diabetes educator or a doctor who is experienced in pump therapy. Typically, an initial start-up training session lasts three hours. The patient should be encouraged to bring a close relative or friend to the training session. The training must be individualised, but initially it is best to convey basic pump functions to most patients and to teach them the more advanced functions later on.

Essential knowledge after the first session includes:

- An understanding of pump terminology.
- How to deliver and cancel a bolus dose.
- How to disconnect and reconnect the pump.
- How to change the infusion set.
- The prevention, detection and management of hypoglycaemia.
- The management of hyperglycaemia.
- Ketone monitoring and treatment.

In the induction period, SMBG should be carried out before and two hours after all meals, as well as at 00h00 and 03h00. The patient needs to keep a comprehensive diary of food intake, carbohydrate count, bolus dosages and blood glucose readings. This is essential to optimise settings. The patient must have access to a 24-hour emergency line in the event of any problems. Follow-up is required three days after starting on the pump so that the patient can change the infusion set under supervision. This visit also allows for a review of the diabetes diary and the adjustment of settings. Further follow-up should be conducted within the next month to review data and to teach advanced pump functions. Weekly contact with the patient by e-mail or fax is essential in the first month until pump settings are optimised. Visits to the diabetes educator and doctor are recommended at three-monthly intervals. The HbA_{1c} level should be checked at each of these visits. Regular reviews, in terms of meeting the desired outcome for the indication for pump therapy, should be carried out. This can be achieved using HbA_{1c}, hypoglycaemia awareness questionnaires and quality of life questionnaires. If the indications are not being met, it is worth considering changing the patient back to MDI.[10]

Some patients do not have improved outcomes with insulin pump therapy, even though they may have met the criteria for patient selection. In a study that examined the influence of psychological factors on metabolic control in patients with type 1 diabetes using CSII, it was shown that high HbA_{1c} levels correlated with a high external locus of control and more depressive symptoms.[31] Therefore, it is valuable to include a psychological assessment when considering a patient for pump therapy.

Insulin pump therapy is costly for the patient and time consuming for the healthcare provider. It requires specialised skills and a team (doctor, educator and dietitian) that is experienced in pump therapy.[1,10,12] Twenty-four-hour emergency access is essential for patients using pump therapy. Ideally, the latter should only be initiated and managed by specialised "insulin pump centres". Careful selection of patients is vital to ensure success and to make certain that this limited, costly and time-consuming potential resource is not wasted.

References

1. Lenhard MJ, Reeves GD. Continuous subcutaneous insulin infusion. A comprehensive review of insulin pump therapy. Arch Intern Med. 2001;161(19):2293-2300.
2. Pickup J, Keen H. Continuous subcutaneous insulin infusion at 25 years. Evidence base for the expanding use of insulin pump therapy in type 1 diabetes. Diabetes Care. 2002;25(3):593-598.
3. HirschIB, Bode BW, Garg S, et al. Continuous subcutaneous insulin infusion (CSII) of insulin aspart versus multiple daily injection of insulin aspart/insulin glargine in type 1 diabetic patients previously treated with CSII. Diabetes Care. 2005;28(3):533-538.
4. Doyle EA, Weinzimer SA, Steffen AT, et al. A randomized, prospective trial comparing the efficacy of continuous subcutaneous insulin infusion with multiple daily injections using insulin glargine. Diabetes Care. 2004;27(7):1554-1558.

5. Pickup J, Mattock M, Kerry S. Glycaemic control with continuous subcutaneous insulin infusion compared with intensive insulin injections in patients with type 1 diabetes: meta-analysis of randomised controlled trials. BMJ. 2002;324(7339):1-6.
6. Bode BW, Steed DR, Davidson PC. Reduction in severe hypoglycaemia with long-term continuous subcutaneous insulin infusion in type 1 diabetes. Diabetes Care. 1996;19(4):324-327.
7. Haardt MJ, Berne C, Dorange C, et al. Efficacy and indications of CSII revisited: the Hotel Dieu cohort. Diabetic Med. 1997;14(5):407-408.
8. Del Rio G, Baldini A, Carani C, et al. Adrenomedullary hyperactivity in type 1 diabetic patients before and during continuous subcutaneous insulin treatment. J Clin Endocrinol Metab. 1989;68(3):555-559.
9. Kanc K, Janssen MJ, Keulen ETP, et al. Substitution of night-time continuous subcutaneous insulin therapy for bedtime NPH insulin in a multiple injection regimen improves counterregulation of hypoglycaemia in IDDM. Diabetalogia. 1998;41(3):322-329.
10. Hammond P, Boardman S, Greenwood R. Association of British Clinical Diabetologists position paper on insulin pumps. Pract Diab Int. 2006;23(9):395-400.
11. Pickup J. Advanced technologies and treatment for diabetes: Pumps. Int J Clin Pract. 2012;66(Suppl 175):15-9.
12. Insulin infusion pump therapy in type 1 diabetes: clinical guidelines and recommendations by the South African Insulin Pump Advisory Board, April 2008. South African Journal of Diabetes and Vascular Disease. 2008;5:184-186.
13. Continuous subcutaneous insulin infusion for the treatment of diabetes mellitus. London: National Institute for Clinical Excellence (NICE); 2008
14. Pickup J. Advanced technologies and treatment for diabetes: Pumps. Int J Clin Pract. 2011;65(Suppl 170):16-9.
15. Gabbe SG, Holing E, Temple P, et al. Benefits, risks, costs, and patient satisfaction associated with insulin pump therapy for the pregnancy complicated by type 1 diabetes. M J Obstet Gynecol. 2000;182(6):1283-1291.
16. Mancuso S, Caruso, Lanzone A, et al. Continuous subcutaneous insulin infusion (CSII) in pregnant diabetic women. Acta Endocrinol. 1986;277:112-116.
17. Hayat H, Carling J, Dudley S, et al. Benefits of pump therapy in diabetic pregnancy. Diabetic Med. 2005;22(Suppl 2):279.
18. Fox LA, Buckloh LM, Smith SD, et al. A randomized controlled trial of insulin pump therapy in young children with type 1 diabetes. Diabetes Care. 2005;28(6):1277-1281.
19. Boland EA, Grey M, Oesterle A, et al. Continuous subcutaneous insulin infusion. A new way to lower risk of severe hypoglycaemia, improve metabolic control, and enhance coping in adolescents with type 1 diabetes. Diabetes Care. 1999;22(11):1779-1784.
20. McMahon SK, Airey FL, Marangou DA, et al. Insulin pump therapy in children and adolescents: improvements in key parameters of diabetes management including quality of life. Diabetic Med. 2005;22(1):92-96.
21. Koivisto VA, Yki-Jarvinen H, Helve E, Pelkonen R. Pathogenesis and prevention of the dawn phenomenon in diabetic patients treated with CSII. Diabetes. 1986;35(1):78-82.
22. Marcus AO. Patient selection for insulin pump therapy. Pract Diabetol. 1992:12-18.
23. Mecklenburg RS, Benson EA, Benson JW Jr, et al. Acute complications associated with insulin pump therapy: report of experience with 161 patients. JAMA. 1984;252(23):3265-3269.
24. Home PD, Marshall SM. Problems and safety of continuous subcutaneous insulin infusion. Diabet Med. 1984;1(1):41-44.
25. Bode B, Strange P. Efficacy, safety and pump compatibility of insulin aspart used in continuous subcutaneous insulin infusion therapy with type 1 diabetes. Diabetes Care. 2001;24(1):69-72.
26. Melki V, Renard E, Lassmann-Vague V, et al. Improvement of HbA1c and blood glucose stability in IDDM patients with lispro insulin analogue in external pumps. Diabetes Care. 1998;21(6):977-981.
27. Renner R, Pfutner A, Trautman M, et al. Use of insulin lispro in continuous subcutaneous insulin infusion treatment. Diabetes Care. 1999;22(5):784-788.
28. Schmauss S, Konig A, Landraf R. Human insulin analogue [LYS(B28), PRO(B29)]: the ideal pump insulin? Diabet Med. 1998;15(3):247-249.
29. Zinman B, Tildesley H, Chiasson J-L, et al. Insulin lispro in CSII: results of a double-blind crossover study. Diabetes. 1997;46(3):440-443.
30. Van Bon AC, Bode BW, Seri-Langeron C, et al. Insulin glulisine compared to insulin aspart and to insulin lispro administered by continuous subcutaneous insulin infusion in patients with type 1 diabetes: a randomised controlled trial. Diabetes Technol Ther. 2011;13(6):607-614.
31. Aberle I, Scholz U, Back-Kliegel B, et al. Psychological aspects in continuous subcutaneous insulin infusion: a retrospective study. J Psychol. 2009;143(2):147-160.