Using CSII therapy in the management of type 1 diabetes: The Leeds experience

Fiona Campbell, Carole Gelder, Claire Reynolds, Philip Holland, Richard Feltbower

Article points

1. All children with type 1 diabetes should be considered for continuous subcutaneous insulin infusion therapy if clinically indicated.
2. Funding is applied for in writing to the patient's PCT and, once authorised, arrangements made for delivery of consumables to the patient's home.
3. A comprehensive pump education pathway facilitates optimal self-management prior to commencing CSII.
4. CSII can provide the solutions and flexibility to meet the special considerations of children throughout their development.

Key words
- Type 1 diabetes
- Continuous subcutaneous insulin infusion (CSII)
- Paediatrics

Full author details can be found at the end of the article.

To ensure the success of CSII (continuous subcutaneous insulin infusion) therapy, a trained multidisciplinary team, including a consultant, a DSN and a dietitian, is essential. In this article, the authors describe their interpretation of the NICE guidance for CSII therapy, methods for accessing funding and providing the infrastructure and resources to successfully support the care of people treated with CSII therapy. They discuss starting bolus and correction doses, together with basal rates, and illustrate the benefits that continuous glucose monitoring has in the paediatric diabetes service, and explain how existing technology can further improve the diabetes management of children with the condition.

The challenge for children with type 1 diabetes and their families is to balance the need for optimal blood glucose control to prevent long-term microvascular and macrovascular disease with avoiding hypoglycaemia. CSII (continuous subcutaneous insulin infusion) therapy is an important technology that can help with this.

When used effectively, CSII therapy can aid in the pursuit of optimised glucose control without increasing the risk of hypoglycaemia. The authors believe that all children with type 1 diabetes should be considered for CSII therapy, and this treatment supported if clinically indicated.

It is likely, in the light of the revised NICE guidance for CSII therapy (NICE, 2008), that there will be an increase in demand for this therapy. In this article, the authors describe their experience of setting up and embedding CSII therapy in the routine management of children with type 1 diabetes in Leeds.

CSII therapy in the paediatric diabetes service at Leeds

In July 2008, NICE recommended the use of CSII therapy in two distinct age groups, both with specific criteria (*Box 1*).

It remains essential that CSII therapy only be initiated by a trained specialist team, which

Box 1. NICE recommendations for continuous subcutaneous insulin infusion (CSII) therapy (NICE, 2008).

CSII therapy is recommended as a treatment option for children younger than 12 years of age with type 1 diabetes if:

- MDI (multiple daily injection) therapy is considered to be inappropriate.
- Those receiving the treatment and their carers have the commitment and competency to use the therapy effectively.

CSII therapy is recommended as a treatment option for adults (including pregnant women and women planning pregnancy) and children older than 12 years of age with type 1 diabetes provided that:

- MDI therapy (including, if appropriate, the use of long-acting insulin analogues) has failed to provide adequate control of their diabetes (for example, HbA_{1c} >8.5% [>69mmol/mol] or the repeated and unpredictable occurrence of hypoglycaemia that creates anxiety).
- Those receiving the treatment and their carers have the committment and competence to use the therapy effectively.

should include a consultant with a special interest in CSII therapy, a DSN and a dietitian.

All of our current patients have fulfilled the NICE criteria for CSII therapy, and to assist us with patient selection we have developed a list of requirements,(*Box 2*).

Accessing funding and resources for insulin pump therapy

It is the responsibility of the clinician caring for the child with diabetes to assess the child's suitability for CSII therapy, as well as accessing funding to initiate this therapy and supporting its continued use.

The implementation by healthcare organisations of NICE technology appraisals, such as that for CSII therapy, forms part of Standard 5 of the NSF for diabetes (Department of Health [DH], 2001), which stresses that the implementation of technology appraisals by the NHS is not optional. Importantly, the NHS is legally obliged to provide the resources and funding for the universal implementation of the NICE technology appraisals across England and Wales within 3 months of the publication of the guidance (DH, 2004).

Box 2. Commitment and competency requirements before starting continuous subcutaneous insulin infusion therapy.

- Be motivated to succeed on insulin pump therapy.
- Have realistic expectations of insulin pump therapy.
- Be able to communicate and work with the diabetes team.
- Be willing to monitor blood glucose at least four times a day.
- Be able to show an ability to technically use the insulin pump and to adjust insulin doses.
- Be able to carbohydrate count effectively and calculate appropriate insulin doses.
- Be able to take immediate action in response to hyperglycaemia and hypoglycaemia.

At the authors' diabetes service, the majority of individuals using CSII therapy reside within Leeds PCT. A letter is written to the director of public health stating the case for justifying CSII therapy for each person. Once funding approval has been obtained, a contract between the relevant CSII device company and the PCT is drawn up, and arrangements are made for delivery of the pump and its consumables to the individual's home.

When people with diabetes attend the authors' service from PCTs outside of Leeds, a letter requesting funding approval may be sent from either the referring consultant paediatrician, GP, or the authors once an assessment of the individual's suitability for CSII therapy has been completed. The authors encourage shared care to facilitate referring centres in increasing their knowledge and skills with CSII therapy to better support children with type 1 diabetes and their families in the longer term.

Infrastructure

At present, the Leeds Paediatric Insulin Pump Therapy Service is delivered from two sites: St James's University Hospital and Leeds General Infirmary. The service includes two consultants (0.5 WTE), seven part-time paediatric diabetes specialist nurses (4.8 WTE) and one full-time dietitian (1.0 WTE) who are all trained in, and have a minimum of 5 years experience with, CSII therapy. The service dedicates 55.5 hours of healthcare professional time within the first 12 months to train each child and their caregivers in the effective use of insulin pump therapy. More specifically, this includes 10 hours of consultant time, 36 hours of DSN time, 7 hours of dietitian time and 2 hours of psychologist time.

Page points

1. The level of education of the child and the caregiver will govern the benefit that they receive from CSII therapy.
2. Parents and children should be competently matching insulin requirements to carbohydrate intake using a basal–bolus regimen prior to being considered for CSII therapy.
3. At the start of the CSII therapy programme, all children and their families received education in the use of CSII therapy on an individual basis.
4. The opportunity to try out an insulin pump, with or without saline, is very important as it provides an opportunity to identify and overcome any perceived difficulties prior to the CSII therapy initiation.

Patient education for CSII therapy

The education of children and their parents, and the timing of this educational delivery prior to CSII therapy initiation, is directly related to the success of the therapy (Wood et al, 2006). In addition, psychosocial instability (Phillip et al, 2007) and exaggerated expectations of the likely benefit of CSII therapy are reasons to consider delaying the initiation of CSII therapy.

The level of education of the child and the caregiver will govern the benefit that the child receives from CSII therapy. It has been extremely beneficial to provide the parent with the opportunity to insert and wear an infusion set and insulin pump, as it serves to reassure them and, in turn, the child about the change in therapy and acceptability of wearing the device.

Parents and children should be competently matching insulin requirements to carbohydrate intake using a basal–bolus regimen before being considered for CSII therapy, but the opportunity to revise carbohydrate counting and estimation is offered and strongly encouraged, and time to refine these skills in practice is provided. At the authors' clinic, the team provide the full range of insulin pumps, and after describing the benefits of the different insulin pumps to the child and family, the patient decides which insulin pump they want to use.

Group versus individual starts

At the start of the CSII therapy programme, all children and their families received education in the use of CSII therapy on an individual basis. As the numbers of children starting CSII therapy has grown, the opportunity to initiate therapy in groups, without delaying the initiation of treatment with a pump, has arisen.

Group starts have facilitated the training of two families in almost the same amount of time as one, with families reporting additional benefits related to the group dynamic. The authors recommend a maximum of three families being taught simultaneously, otherwise the group may be too large to facilitate effectively and ensure that both caregivers and children have the opportunity to be actively involved in the training.

Insulin versus saline starts

The opportunity to try out an insulin pump, with or without saline, is very important as it provides an opportunity to identify and overcome any perceived difficulties prior to the CSII therapy initiation. In the authors' experience this allows the smoother transition from MDI (multiple daily injections) to CSII therapy.

Calculating total daily insulin requirements when converting from MDI therapy to CSII therapy

Total daily insulin dose

When converting from MDI therapy to CSII therapy, a reduction of 25–30% is often seen in the total daily insulin dose (Danne et al, 2005).

An age-dependent increase in the total insulin dose has been shown with CSII therapy, and should be routinely adjusted in 3-monthly follow-ups (Danne et al, 2005). The age-related increase in the total daily insulin dose through puberty is related, at least in part, to the increased action of growth hormone (Klinkert et al, 2007).

Calculating the basal rate

The basal rate is usually between 30% and 50% (35–40% in those under 5 years of age) of the total daily insulin dose. However, findings from a European multicentre survey conducted by Danne et al (2005) has shown that this can vary from between 35% in pre-pubescent individuals and 60% in adolescents, due to peripheral insulin resistance.

Calculating bolus dose

Starting bolus doses are determined by previous doses via injection or calculated using the "500 rule" (500/total daily dose of insulin on CSII therapy = grams of carbohydrate covered by one unit of insulin [Walsh and Roberts, 2006]). Examples of "test meals" to check this bolus dose (i.e. those with a known amount of carbohydrate and a high or medium GI) are available at www.leedsth.nhs.uk/sites/diabetes.

Bolus calculator technology is available on new generation insulin pumps. These use target glucose values, insulin:carbohydrate ratios, insulin sensitivity, the current blood glucose value

and the amount of carbohydrate to be ingested to recommend bolus doses of insulin. In addition, the technology is able to account for active insulin, and has been shown to be successful in achieving postprandial glucose targets with fewer correction boluses and supplemental carbohydrate intake needed (Chase et al, 2006). The authors have found that these decision support tools can provide great reassurance to the patient or carer administering the insulin dose.

Calculating correction doses

Correction doses can be calculated in different ways. At the authors' service, they generally use the "100 rule" (100/average total daily dose of insulin on CSII therapy = the number of mmol/L that one unit of insulin will lower blood glucose [Walsh and Roberts, 2006]). A simple rule (for older children) is that if the person is >11 years of age then 1 unit will reduce blood glucose levels by 2.5 mmol/L. If <11 years, then 1 unit will reduce it by 5 mmol/L. This is merely a guide and should be reviewed once established.

Patient information leaflets have been developed and are available on the Leeds PCT website to facilitate this (www.leedsteachinghospitals.com/sites/diabetes).

Ongoing assessment

Children are reviewed in the clinic at least once every 3 months as part of their routine care in the paediatric diabetes service. The following are assessed:

- Height and weight are routinely measured and may identify issues specifically related to insulin pump therapy.
- HbA_{1c} and number of hypoglycaemic episodes.
- Daily insulin dose compared with height and weight.
- Basal rate totals.
- Blood glucose targets.
- Average number of bolus injections per day.
- Correction doses and insulin sensitivity factors.
- Infusion site rotation and possible infection.
- Insulin:carbohydrate ratio for different meals.
- Overnight and postprandial blood glucose or continuous glucose monitoring (CGM) values.
- Effective use of decision-making tools, such as carbohydrate counting.

The role of CGM at the Leeds CSII therapy service

The differential benefit of CGM over fingertip blood glucose sampling in enabling more precise adjustments in diabetes management has often been cited (Ludvigsson and Hanas, 2003; Gandrud et al, 2007). In one such study, Luvigsson and Hanas (2003) found a significant benefit to glycaemic control with a reduction in HbA_{1c} levels when using the CGM profiles as opposed to seven-a-day fingertip blood glucose sampling. CGM has also been successfully used to identify nocturnal hypoglycaemia and significant postprandial hyperglycaemia in children less than 7 years of age that had not been diagnosed by fingertip blood sampling (Gandrud et al, 2007).

The ability of CGM to accurately monitor glucose fluctuations in responses to diet, exercise and insulin has made the technology an invaluable adjunct to the Leeds Paediatric Diabetes Service. *Box 3* describes the situations in which the team have successfully used CGM.

Importantly, the use of CGM systems are endorsed by NICE (2004) for individuals with diabetes who experience repeated glucose excursions, hypoglycaemia unawareness or both.

Page points

1. Children are reviewed in the clinic at least once every 3 months as part of their routine care in the paediatric diabetes service.
2. Continuous glucose monitoring (CGM) has been successfully used to identify nocturnal hypoglycaemia and significant postprandial hyperglycaemia in children less than 7 years of age that had not been diagnosed by fingertip blood sampling.
3. The ability of CGM to accurately monitor glucose fluctuations in responses to diet, exercise and insulin has made the technology an invaluable adjunct to the Leeds Paediatric Diabetes Service.

Box 3. Situations in which continuous glucose monitoring has been successfully used in paediatric patients in the Leeds diabetes service.

- Analysis of nocturnal glucose levels.
- Diagnosis of unawareness of hypoglycaemia.
- Analysis of postprandial glucose values.
- To optimise adjustment of basal–bolus doses.
- As an educational tool in patient training.
- When for various reasons it is difficult to get the patient or family to perform an adequate number of blood glucose tests.
- Recurrent severe hypoglycaemia.
- Unexpectedly high HbA_{1c} values.
- Use as a motivation instrument.
- To facilitate insight and behaviour modification.
- To detect the overcorrection of hypoglycaemia.
- Evaluate the impact of exercise.
- To detect dawn phenomenon.
- Rebound hypoglycaemia.

Page points

1. Children, particularly those under 11 years of age, need support in managing their insulin pump.
2. Babies and toddlers often require very small total daily doses and adjustments of insulin, which makes CSII therapy the treatment of choice in this age group.
3. Exercise should be encouraged for children with type 1 diabetes, but the individual and carer should be made aware of the increased risk of hypoglycaemia, both during and on the night immediately following exercise.
4. The authors recognise that the length and intensity of exercise in children often cannot be predicted, and, as such, do not recommend suspending the insulin pump during exercise, unless it involves a high level of contact.

Special considerations

Schools

Children, particularly those under 11 years of age, need support in managing their insulin pump; however, for one-third of each day someone at school will be *in loco parentis*. The authors would advocate that responsibility during this period is shared between the parents and the education and healthcare teams, and that a tripartite agreement is constructed. This may include assistance with numeracy skills, immediate action plans for hypoglycaemia and hyperglycaemia, and the recognition of equipment alarms. This process is time consuming, and requires significant collaboration between the DSN, school nurse, school personnel, child and family to maximise its success.

Babies and toddlers

Babies and toddlers often require very small total daily doses and adjustments of insulin, which makes CSII therapy the treatment of choice in this age group.

Babies require food every 3–4 hours (British Nutrition Foundation, 2004), which would equate to eight to nine injections as part of a basal–bolus regimen. In contrast, frequent bolusing via an insulin pump is an accurate and acceptable mode of insulin delivery. In this age group, the authors have found a basal rate of just 35% of the total daily insulin dose to be effective, which concurs with Danne et al (2005). Insulin dilution may be necessary, especially if the total daily dose is less than 4 U/day. In babies, infusion sites that avoid the nappy area, such as the upper thigh, are useful for obvious reasons. Once the infant becomes mobile and starts toilet training, the upper outer quadrant may be a better option, as this may interfere less with learning to walk and be less vulnerable to curious hands.

Very young children are inconsistent in their eating habits and activity patterns. Families report the immediacy of temporary basal-rate reductions along with the predictability of rapid-acting analogues, and this has increased their confidence in maintaining blood glucose levels within the recommended range without the fear of hypoglycaemia.

Advice for physical activity

Exercise should be encouraged for children with type 1 diabetes, but the individual and carer should be made aware of the increased risk of hypoglycaemia, both during and on the night immediately following exercise (Tansey et al, 2006a). The same study group later found that this risk of hypoglycaemia was significantly reduced when the insulin pump was suspended during the exercise period (Tansey et al, 2006b), and this advice recently became a recommendation in the European Society for Paediatric Endocrinology consensus statement (Phillip et al, 2007). This endorsement stems from evidence collected from hypoglycaemic risk in response to a 75 minute moderate exercise period.

The authors recognise that the length and intensity of exercise in children often cannot be predicted, and, as such, do not recommend suspending the insulin pump during exercise, unless it involves a high level of contact.

A significant advantage of CSII therapy during exercise is that the technology allows the individual to temporarily lower their basal rate 1–2 hours prior to the exercise, rather than using supplemental carbohydrate to avert exercise-induced hypoglycaemia. A temporary basal rate may also be required 1–2 hours following the activity, and in some cases overnight, but this requires individual assessment.

The future of the Leeds insulin pump therapy service

Today, an ever increasing body of evidence exists advocating the clinical advantage of "real-time" continuous glucose sensing (Deiss et al, 2006; Garg et al, 2006). Interestingly, observational trials have shown the potential of an additive benefit to HbA_{1c} when combining insulin pump therapy with real-time CGM in a semi-automatic insulin pump (Mastrototaro et al, 2006; Halvorsson et al, 2007). Therefore, as we move ever closer to the closed-loop system, it is important that we continue to maximise the use of technology to benefit people with diabetes.

In Leeds, the authors plan to increase the use of both insulin pump therapy and CGM. They believe that this will assist people with

"CSII therapy should be seriously considered for every child with type 1 diabetes in the UK, and initiated where clinically indicated."

diabetes to further optimise their diabetes control without the possibility of experiencing an increase in the risk of hypoglycaemia.

Conclusion

When CSII therapy is supported by a well trained and committed diabetes team, significant benefits to the child with type 1 diabetes can be seen. The authors believe that CSII therapy should be seriously considered for every child with type 1 diabetes in the UK, and initiated where clinically indicated. ■

Author details

Dr Fiona Campbell is Medical Director and Paediatric Diabetologist, St James's University Hospital, Leeds; Philip Holland is a Consultant Paediatrician, Leeds General Infirmary, Leeds; Carole Gelder is a Lecturer/Practitioner, St James's University Hospital, Leeds, and University of York, York; Claire Reynolds is a member of the Paediatric Epidemiology Group, University of Leeds; Richard Feltbower is Senior Research Fellow, Paediatric Epidemiology Group, University of Leeds, Leeds.

Acknowledgements

The authors would like to gratefully acknowledge the support of the Leeds Paediatric Diabetes Service and both inpatient and outpatient nursing staff. We would also like to thank Carolyn Stephenson and Angela Herbert from the Paediatric Epidemiology Group, University of Leeds, for help with data collection.

Declaration of interests

Dr Fiona Campbell has received speaker's fees from Medtronic and Roche and gratefully acknowledges financial support from both companies for a financial contribution towards a DSN salary for a nurse within the children's diabetes team.

British Nutrition Foundation (2004) *Nutrition Through Life: School Children*. BNF, London

Chase HP, Horner B, McFann K et al (2006) The use of insulin pumps with meal bolus in children with type 1 diabetes to improve glycemic control. *Diabetes Care* **29**: 1012–15

Danne T, Battelino T, Kordonouri O et al (2005) A cross-sectional international survey of continuous subcutaneous insulin infusion in 377 children and adolescents with type 1 diabetes mellitus in 10 countries. *Pediatr Diabetes* **6**: 193–8

Deiss D, Bolinder J, Riveline JP et al (2006) Improved glycaemic control in poorly controlled patients with type 1 diabetes using real-time continuous glucose monitoring. *Diabetes Care* **29**: 2730–2

Department of Health (2001) *National Service Framework for Diabetes: Standards*. DH, London

Department of Health (2004) *Standards for Better Health*. DH , London

Gandrud LM, Xing D, Kollman C et al (2007) The Medtronic Minimed Gold continuous glucose monitoring system: an effective means to discover hypo- and hyperglycemia in children under 7 years of age. *Diabetes Technol Ther* **9**: 307–16

Garg S, Zisser H, Schwartz S (2006) Improvement in glycemic excursions with a transcutaneous, real-time continuous glucose sensor: a randomized controlled trial. *Diabetes Care* **29**: 44–50

Halvorsson M, Carpenter S, Kaiserman K, Kaufman FR (2007) A pilot trial in pediatrics with the sensor-augmented pump: combining real-time continuous glucose monitoring with the insulin pump. *J Pediatr* **150**: 103–5

Klinkert C, Nachran R, Heidtmann B et al (2007) Age-specific characteristics of the basal insulin-rate for pediatric patients on CSII. *Exp Clin Endocrinol Diabetes* **116**: 118–22

Ludvigsson J, Hanas R (2003) Continuous subcutaneous glucose monitoring improved metabolic control in pediatric patients with type 1 diabetes: a controlled crossover study. *Pediatrics* **111**: 933–8

Mastrototaro JJ, Cooper KW, Soundararajan G et al (2006) Clinical experience with an integrated continuous glucose sensor/insulin pump platform: a feasibility study. *Adv Ther* **23**: 725–32

NICE (2004) *Diagnosis and Management of Type 1 Diabetes in Children, Young People and Adults*. NICE, London

NICE (2008) *Guidance on the Use of Continuous Subcutaneous Insulin Infusion for Diabetes. Technology Appraisal Guidance No. 151*. NICE, London

Phillip M, Battelino T, Rodriguez H et al (2007) Use of insulin pump therapy in the pediatric age-group: consensus statement from the European Society for Paediatric Endocrinology, the Lawson Wilkins Pediatric Endocrine Society, and the International Society for Pediatric and Adolescent Diabetes, endorsed by the American Diabetes Association and the European Association for the Study of Diabetes. *Diabetes Care* **30**: 1653–62

Tansey MJ, Tsalikian E, Beck RW et al (2006a) The effects of aerobic exercise on glucose and counterregulatory hormone levels in children with type 1 diabetes. *Diabetes Care* **29**: 20–5

Tansey M, Tsalikian E, Beck RW et al (2006b) Stopping basal insulin during exercise markedly reduces the risk of hypoglycemia in children with type 1 diabetes on insulin pump therapy. *Diabetes* **55**: A240

Walsh J, Roberts R (2006) *Pumping Insulin*. 4th edn. Torrey Pines Press, California

Wood JR, Moreland EC, Volkening LK et al (2006) Durability of insulin pump use in pediatric patients with type 1 diabetes. *Diabetes Care* **29**: 2355–60