

Figure 1: Average Hourly Basal Rate Values by Age Group (Scheiner and Boyer(7)).

Open squares = age 11-20; Solid squares = age 21-60; Open triangle = age 3-10; Solid triangle = age >60.

the day when the CSII insulin activity is higher than it was while on a single injection of a basal insulin analogue. Safety for the patient is always the primary concern. Using this 70% formula (35% as the basal insulin), we have found a rare patient who still experienced mild hypoglycemia during his/her first night on the insulin pump, but never a severe hypoglycemic event. All of our patients initiate insulin pump therapy in an outpatient setting.

Using the total MDI dose the person is currently receiving as a part of the pump basal insulin calculation obviously allows continuation of a low insulin dose in the person still making some endogenous insulin. When the person begins insulin pump therapy in the first year after diagnosis, the person's pancreas often adjusts endogenous insulin output to supplement the pump basal insulin. Frequent adjustments of the basal rates over the next few weeks are often then not needed. This is more likely for adults, who usually continue endogenous insulin production longer than children. (6)

An additional factor related to total basal insulin dosage is age. It has been shown that teenagers generally have the highest insulin

dose per kg body weight (Figure 1). (7) This is presumed due to insulin resistance, although use of basal insulin to supplement missed bolus dosages may also be a factor. (8) In contrast, older adults have the lowest basal rates and infants, preteens and young adults fall in between. (7) While one might consider calculating basal rates based on the average insulin dose per kg body weight for the age of the patient and by time of day (as in Figure 1), there is so much individual variability that this would not be wise.

Subdividing Initial Basal Insulin Dosages

One of the advantages of using an insulin pump is the ability to vary basal rates throughout different periods of the day. Although it is almost never needed, some pumps allow variation of the basal rate every thirty minutes with the possibility of 48 different basal rates. This is in contrast to one basal rate from a single injection of a basal insulin analogue.

After determining the total 24 hour basal insulin dosage, some HCPs divide the dose by 24 and initially give the same hourly rate throughout the day. This works most effectively when the person is still producing endogenous insulin and their pancreas can adjust insulin output as necessary. It is our practice to divide the day into eight three-hour periods beginning at midnight. (5) These periods can be varied depending on meal times, periods of frequent lows, a dawn phenomenon or other factors. It is often helpful to have a slightly higher basal rate after meals,

as most people under-bolus for food. Additionally, for safety, we usually begin with slightly lower basal rates during the night. In 93 children receiving insulin pump therapy, only younger age and use of more basal rates were predictive of good diabetes control. (9)

Holterhus et al (10) looked at the basal insulin infusion rates in 1,248 German/Austrian children and adolescents with type 1 diabetes (T1D) using CSII. Seven different basal patterns were noted (examples in Figure 2). In general, prepubertal children tended to have peak basal rates at 9-10 PM whereas pubertal patients had peak basal rates in the early morning hours (5 AM). Age was the most important determinant of basal infusion rate clustering. Puberty and increased levels of insulin-antagonizing hormones (including growth hormone and IGF-1) have been linked to insulin resistance in pubertal patients.

Adjustment of Basal Dosages

Good communication with the HCP is one of the determinants for initiating pump therapy within our clinic. (5) At no time is it more essential than during the week following the initiation of insulin pump therapy. Daily e-mails, faxes or phone calls to report the results of the seven or more BG measurements in the past 24 hours are essential for safety and fine-tuning of the basal rates. It is highly recommended that at least one of those BG readings be during the sleep hours.

Most insulin pumps allow a basal rate insulin adjustment in increments of 0.05 U/hr. The Animas® 2020 allows changes of 0.025 U/hr, which can be helpful with very young children.

Our experience with adjusting basal insulin dosages in the period after pump initiation is that most patients gradually adjust to a lower dose than their previous MDI dose (Table). This previously unpublished data from our clinic is from 15 consecutive youth (mean age = 14.1 yrs) who received Lantus plus RAI

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versus 15 age-matched youth (mean age = 14.9 yrs) who received Lantus, NPH, and RAI prior to CSII initiation. All were managed similarly by the same physician (HPC). The basal insulin dose in the latter group represents the sum of the Lantus and NPH dosages. In both groups, the basal insulin dose (in U/kg body weight/day) remained lower after 3 or 12 months of pump use compared to the pre-pump basal insulin. The subjects receiving NPH in the morning generally refused or were unable to receive a noon injection of RAI. Their mean HbA1c values were higher than patients receiving only Lantus + RAI. In both groups the HbA1c values tended to decrease with CSII usage.

Basal Rate Testing

Basal rate testing refers to checking glucose levels when other factors that influence the BG levels are absent. These factors include food, exercise, infections, menses and stress. Basal rate checking determines if the glucose levels stay in range (generally between 70 and 150 mg/dl [3.9-8.3mmol/L]) when other influences are removed.

Many physicians request basal rate checking at regular intervals, whereas others request it only when there is a question about glycemic control. It is usually not done until a person has been on a pump for at least a week, so that

other body hormones will have adjusted to the new insulin patterns. During the period of basal rate checking, the glucose levels should remain in the desired range for the person's age. If glucose levels do vary outside of range, appropriate insulin dose changes should be made.

It would be ideal to routinely test basal insulin rates using continuous glucose monitoring (CGM). When 101 patients (60 with T1D, 41 with T2D) wore blinded CGM sensors for an average of 12 days each, approximately 30% of the day was found spent with glucose levels >180mg/dl (>10mmol/L) and 55% of the day with glucose levels >130mg/dl (>7.3mmol/L). (11) Patients with T1D spent an average of 2.3 hrs/day and those with T2D spent 1.0 hr/day with glucose levels <70mg/dl (<3.9mmol/L) ($p<0.0001$). Hypoglycemia was most frequent between 11 PM and 6 AM. It would be ideal to do the CGM basal testing both on nights following "typical" days and on nights following days with intense exercise. This could help in identifying periods of hypoglycemia and in choosing temporary basal rates (see below) for future nights post-intense exercise.

Zisser et al (4) studied 16 adults with T1D using CGM and asked them to skip a meal to test the subsequent basal infusion rate. Although the adults were already in good glycemic control (mean HbA1c $7.1 \pm 1.2\%$),

the CGM showed a need for adjustment of early morning basal insulin levels.

Alternate Basal Patterns

Most pumps have additional 24 hour basal rate settings (e.g.: an "A" or "B" setting) that the person can use as needed. Some people will preprogram a second basal rate for weekend days or heavy exercise days (often 0.1 to 0.2 U/hr lower) or for times of stress, illness, menses, no exercise, etc. (often 0.1 to 0.2 U/hr higher). People know their own bodies better than anyone and can get into the habit of using their alternate basal settings as needed.

Temporary Basal Rates

Some patients in our clinic use temporary basal rates on a daily basis. Temporary basal rate decreases are used most frequently for managing periods of exercise. As RAI does not peak for 90 to 100 minutes, it may be necessary to begin the temporary basal rate decrease 30 to 60 minutes prior to the beginning of exercise. A major decrease in physiologic RAI activity occurs 60 minutes after the decrease or cessation of basal insulin. Thus, one of the reasons for high BG levels after an hour of reduced basal insulin for exercise is the decrease in RAI activity. The DirecNet Study group found that BG levels greater than 200mg/dl (>11.1mmol/L) following the same 1 hour of exercise occurred in 27% of patients when CSII was discontinued vs. in 4% of patients when the CSII was continued ($p=0.002$). (12) Most pumps allow the user to decrease basal rates to 0%. The number of minutes or hours that the decreased basal rate is to be in effect also needs to be entered. The advantage of using a temporary basal rate of 0% rather than turning the pump off is that the pump will automatically resume the current basal rate after the allotted time elapses. This avoids forgetting to turn the pump back on. One of the great advantages of CSII therapy is the ability to decrease basal insulin levels for the period of exercise. It is well known that non-diabetic people reduce insulin secretion to very low levels during exercise. There is no way to simulate this if a person with diabetes has received a basal insulin analogue injection. The DirecNet study group found an incidence of 43% of patients having hypoglycemic events (BG <70mg/dl or <3.9mmol/L) during exercise when the usual pump basal rate was continued. (12) In contrast, if the basal rate was discontinued during a similar one-hour exercise period, only 16% of patients became hypoglycemic during the exercise ($p=0.003$). The discontinuation of

Understanding Insulin Pumps and Continuous Glucose Monitors

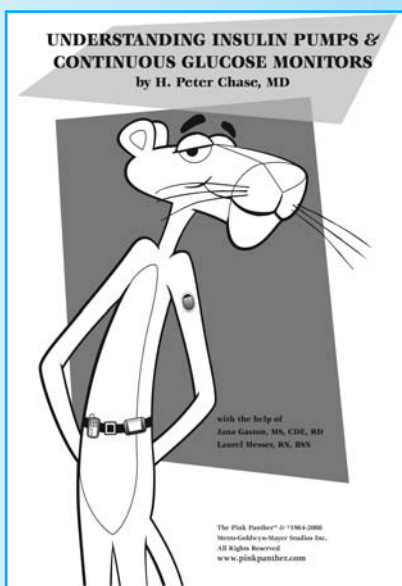
Peter Chase has recently written another excellent practical manual introducing pumps and continuous glucose monitoring to potential young pump patients and their families.

Indeed, the book is easy to read and abundantly illustrated. However, it can also address adult patients as well as physicians because of uncompromised technical and financial details e.g. comparative costs of pumps vs. injections and comprehensive coverage of all aspects e.g. psychological issues, diet adjustments, comparative descriptions of current CGM systems etc...

The book is non-profit and the property of the Children's Diabetes Foundation at Denver, Colorado. It can be ordered by calling 1-800-695 2873.

To my knowledge, this is the first practical book integrating pumps and continuous glucose monitoring, a must for the new generation of pumps users.

J.L. Selam



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the insulin 30 or 60 minutes prior to the intense exercise (our usual practice) was not studied.

Temporary basal rate increases (e.g., 120% which is a 20% increase) are most commonly used with illnesses that increase the BG levels. Basal rate increases may also help with long car trips (i.e., reduced activity), menstrual periods, stress or anything else that increases BG levels. Most pumps allow up to a 200% basal rate (i.e., double the usual rate).

Disadvantages of Basal CSII Therapy

About the only disadvantage of basal CSII therapy is the slight but significant increase in episodes of ketosis and ketoacidosis described by ourselves (3) and others. Several studies have shown that the RAI effectively suppresses ketone formation for two to three hours after interruption of the CSII. When the interruption occurs during the sleep hours, most commonly due to the infusion catheter dislodging or becoming blocked, it may be more than three hours before the problem is discovered. A BG level above 300 mg/dl (>16.7mmol/L) must signal the need for immediate ketone checking. We encourage all of our insulin pump users to have the Precision Xtra™ meter for checking blood β-OH-butyrate levels. (5) Then, if a urine sample cannot be obtained, or if the urine ketones are elevated, the blood ketone level can be determined quickly. The greater use of CGM, with alarms for high glucose levels, will eventually help to prevent this problem.

We are sometimes asked the question "Might my pump accidentally administer too much insulin?" All pumps now have settings for maximal basal rates (and for maximum boluses) to prevent administration of excessive

insulin. Thus, one could not mistakenly enter "10 U/hr", rather than the intended 1.0 U/hr, if the maximum basal rate was set at 2.0 U/hr. The pump trainer usually sets the upper limits at the time of initiating insulin therapy with the pump.

Summary

Different HCPs manage basal insulin pump therapy in many different ways. All probably work equally well as long as there is good communication between the patient and the HCP. With the gradual increase in use of CGM, routine checking of basal rates (usually involving not eating a meal) will help to optimize glycemic control for patients using CSII. Patient safety will always be the number one priority.

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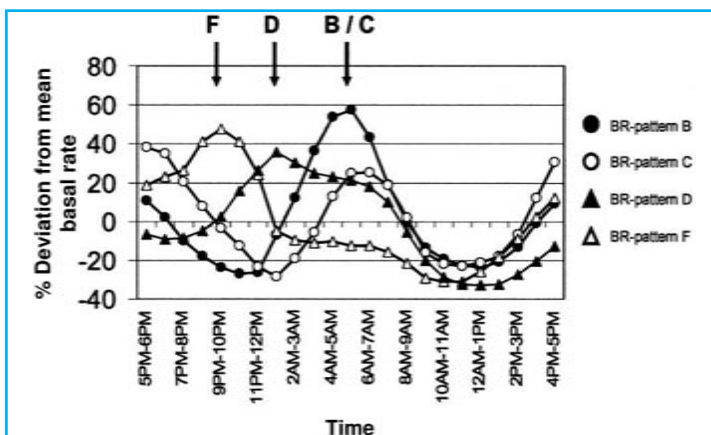


Figure 2: Patterns of Basal Insulin Infusion Rates (Holterhus et al (10)) Group F represented 117 primarily prepubertal subjects (peak insulin: 9-10 PM). Groups B and C represented primarily pubertal subjects (708 and 83 subjects, respectively) with a pre-dawn (5 AM) insulin peak. Group D (152 subjects) had a broad insulin peak with a maximum between 12 AM and 1 AM.

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	Lantus		Lantus + NPH	
	Basal Insulin Dose (U/kg/day)	HbA1c (%)	Basal Insulin Dose (U/kg/day)	HbA1c (%)
Pre-Pump*	0.391 (0.191)	8.05 (1.09)	0.714 (0.254)	8.66 (0.683)
Pump Initiation**	0.320 (0.114)	n/a	0.332 (0.108)	n/a
(+) 3 months	0.345 (0.117)	7.77 (1.16)	0.401 (0.076)	7.79 (0.808)
(+) 1 year	0.344 (0.140)	7.81 (1.12)	0.413 (0.108)	8.21 (1.28)

Table: Basal Insulin Dosages (U/kg/day) and HbA1c Levels as Related to Time on Pump Data described as mean (standard deviation).

*Data from the last visit prior to initiating insulin pump therapy.

**Basal insulin dose as ordered by the physician.

2007 Consensus Statement on the Use of Insulin Pump Therapy in the Pediatric Age-Group Endorsed by the American Diabetes Association and European Association for the Study of Diabetes¹

CSII should be considered in the conditions listed below:

- Recurrent severe hypoglycemia
- Wide fluctuations in blood glucose levels regardless of A1C
- Suboptimal diabetes control (A1C exceeds target range for age)
- Microvascular complications and/or risk factors for macrovascular complications
- Good metabolic control but insulin regimen that compromises lifestyle

Other circumstances in which CSII may be beneficial include:

- Infants and neonates
- Adolescents with eating disorders
- Children and adolescents with pronounced dawn phenomenon
- Children with needle phobia
- Pregnant adolescents
- Ketosis-prone individuals
- Competitive athletes

Adapted from the 2006 American Academy of Pediatrics Position Statement: Continuous Subcutaneous Insulin Infusion in Very Young Children with Type 1 Diabetes²

- All children with diabetes, regardless of age, should be considered potentially eligible for insulin pump therapy
- Decision to use insulin pump therapy should rest solely with physician and parents or legal guardians
- Ensure parents have realistic expectations and requirements with insulin pump therapy
- Eligibility criteria for insulin pump therapy include motivated, compliant parents with mastery of carbohydrate counting and excellent to good compliance with diabetes care
- Selecting against insulin pump therapy is as reasonable as selecting for insulin pump therapy
- Evidence that insulin pump therapy a priori improves diabetes control in children aged six years and younger is currently lacking

CSII Contraindications³

- Insulin pump therapy is not recommended for people who are unwilling or unable to perform a minimum of four blood glucose tests per day and to maintain contact with their healthcare professional
- Successful insulin pump therapy requires sufficient vision or hearing to allow recognition of the pump signals and alarms

CSII = continuous subcutaneous insulin infusion

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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

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Young patients with diabetes, their families, and their diabetes care providers continue to be faced with the challenge of striving to maintain blood glucose levels in the near-normal range. High blood glucose levels with elevated A1C levels are associated with long-term microvascular and macrovascular complications. Recurrent episodes of hypoglycemia, especially at young ages, may cause short- and long-term adverse effects on cognitive function and lead to hypoglycemia unawareness and may be associated with significant emotional morbidity for the child and parents. Fear of hypoglycemia, especially during the night, may compromise quality of life (QOL) for the family and jeopardize efforts to achieve optimal metabolic control.

Over the past decade, continuous subcutaneous insulin infusion (CSII) has gained increasing popularity among patients with diabetes. CSII is the most physiologic method of insulin delivery currently available. It is able to closely simulate the normal pattern of insulin secretion, namely continuous 24-h adjustable "basal" delivery of insulin upon which are superimposed prandial "boluses." In addition, CSII offers the possibility of more flexibility and more precise insulin delivery than multiple daily injection (MDI). However, there is still debate among diabetes care practitioners around the world as to whether CSII has advantages over MDI in terms of reduction in A1C levels, occurrence of severe hypoglycemic events,

episodes of diabetic ketoacidosis (DKA), and frequency of hospitalizations in young patients. Furthermore, no clear criteria have been established to help the physician choose the "appropriate" patient for CSII therapy.

To address these issues, the European Society for Pediatric Endocrinology (ESPE), the Lawson Wilkins Pediatric Endocrine Society (LWPES), and the International Society for Pediatric and Adolescent Diabetes (ISPAD) convened a panel of expert physicians for a consensus conference endorsed by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD).

For each major topic area, clinical experts were chosen to review the literature and provide evidence-based recommendations according to criteria used by the ADA. Key citations identified for each topic were assigned a level of evidence (indicated in bold throughout the text) and verified by the expert panel. This article summarizes the consensus recommendations of the expert panel and represents the current state of knowledge about CSII in pediatric and adolescent patients with type 1 diabetes.

CSII use in the pediatric patient

The following summarizes the consensus recommendations convened by the expert panel.

Initiating CSII

The decision to begin pump therapy should be made jointly by the child, parent(s)/guardians, and diabetes team. All pediatric patients with type 1 diabetes are potential candidates for CSII, and there is no lower age limit for initiating CSII (E). The timing of pump initiation remains an important consideration for the family and health care team in optimizing the likelihood of successful implementation and outcomes (B: 28). CSII should be considered in the conditions listed below:

1. Recurrent severe hypoglycemia (C: 1,4)
2. Wide fluctuations in blood glucose levels regardless of A1C (C: 50)
3. Suboptimal diabetes control (i.e., A1C exceeds target range for age) (C: 1)
4. Microvascular complications and/or risk factors for macrovascular complications (A: 68,69)
5. Good metabolic control but insulin regimen that compromises lifestyle (E)

Other circumstances in which CSII may be beneficial include:

Young children and especially infants and neonates (B: 34–36; C: 10,12,13)

1. Adolescents with eating disorders (E)
2. Children and adolescents with a pronounced dawn phenomenon (E)
3. Children with needle phobia (E)
4. Pregnant adolescents, ideally preconcep-

tion (A: 70)

5. Ketosis-prone individuals (C: 71)

6. Competitive athletes (E)

Recommendations

1. A pediatric multidisciplinary diabetes team experienced in insulin pump therapy is required to initiate CSII and supervise the ongoing management of a child on CSII (E).
2. Frequent contact between the family/child and diabetes team is required after initiating pump therapy, and 24-h access to a diabetes team member is desirable (E).

3. CSII can be safely initiated at diagnosis (A: 72; C: 73; B: 74) or anytime thereafter (A: 70; B: 34–36).

4. The child's parent/s, guardian, and daytime care provider must be willing and able to provide the supportive care necessary for successful CSII implementation.

- Psychosocial instability within the family or emotional problems in the child are reasons to consider postponing initiation of pump therapy (E).

- Lack of an available parent during the day is not a contraindication to initiating CSII in the young child, as other caregivers can be taught to supervise and manage pump therapy (C: 10).

CSII supportive care

The child and caregivers should be educated on the following concepts:

1. Nutrition therapy including carbohydrate counting/estimation
2. Principles of basal-bolus therapy
3. Insulin kinetics and pump failure
4. Recognition and management of hypoglycemia and hyperglycemia
5. The effects of activity and exercise on blood glucose
6. Sick day management

Recommendations

1. Caregivers must be assessed to ensure proper supervision and responsibility for pump management and frequent blood glucose monitoring (E).

2. Children and their caregivers must receive initial and ongoing education regarding warning symptoms and strategies for prevention of DKA and problem-solving strategies for pump problems.

3. Children, adolescents, and caregivers must receive initial and ongoing education regarding pump functions, proper infusion set insertion, and pump catheter maintenance by a professional very knowledgeable about pumps (E).

- Patients and families should be instructed to notify their diabetes care provider if pain, inflammation, purulent discharge, or recurrent irritation occurs at the infusion site.

- Adequate training for adolescents and young adults using CSII should include a discussion about handling the pump in intimate situations.

4. Children and their caregivers should be counseled as to the possibility of weight gain with improved glycemic control.

Personalizing CSII

Selecting an insulin pump

The choice of a specific pump will be influenced by the experience and comfort of the diabetes team with a particular model, as well as by the personal preference of the patient and family. Pumps that automatically calculate meal or correction boluses based on insulin-to-carbohydrate ratios and insulin sensitivity factors are useful features that aid other caregivers, such as grandparents, nannies, and day care workers. The ability to review insulin boluses, carbohydrate intake used in bolus calculations, and blood glucose levels from pump memory may be useful for counseling patients on their diabetes management, particularly for adolescents, who often omit boluses and have difficulty with manual record keeping (C: 19).

Pump features requiring consideration include:

1. Small basal rate increments for infants and toddlers

Some pumps allow for 0.025 or 0.05 unit/h incremental changes, which is important when there is a low total daily insulin dose.

2. Sufficient reservoir volume

Sufficient reservoir volume may be important, particularly in teenagers, who may have high total daily insulin requirements.

3. Direct communication with a home blood glucose meter

Direct communication with a home blood glucose meter may be beneficial for pumps that assist with bolus dose calculation; however, the accuracy of the blood glucose meter must be considered.

4. Alarm features

- Alarm features remind a child that a meal bolus has been missed.

5. Waterproof casing

- Waterproof casing should be considered for youth active in water sports where inadvertent submersion is likely.

Determining which concentration and type of insulin to use

Rapid-acting insulin analogs result in a modest but significant reduction in A1C compared with soluble (regular) insulin when used in CSII and are preferred by adult patients (B: 75). Both insulin lispro and insulin aspart are approved for CSII in most countries. Rapid-acting analogs are only available in a concentration of 100 IU/ml (U100).

Recommendations

1. Although there are no data from controlled studies in children, the use of rapid-acting insulin analogs for CSII is recommended (E).

Selected "ketosis-prone" patients may benefit from the longer lasting effect of regular insulin. Alternatively, one could add an injection of basal insulin, such as insulin glargine or levemir, to decrease the risk of DKA.

2. Particularly in neonates or toddlers, or during low insulin requirements such as the "honeymoon period," insulin dilution with a compatible diluent may be required (E).

- In a simulated continuous insulin infusion, U10 and U50 dilutions of U100 insulin aspart were found to be stable for 7 days at 37°C (C: 76).

- Although similar studies with diluted insulin lispro (using Sterile Diluent ND-800) are not yet published, diluted insulin lispro has been successfully used in single cases (B: 35; C: 77).

3. To avoid dosing errors or bacterial contamination, U50 or U10 dilutions should only be used in those cases requiring very low hourly insulin infusions (<0.2 IU/h) (E).

Selecting a catheter

Selection of catheters, adhesives, and tubing is dependent on age and individual circumstances. Children and adolescents involved in frequent physical exercise and outdoor activities prefer catheters that can be disconnected.

Several approaches have been used to minimize the discomfort of inserting infusion catheters, including topical anesthetics, application of ice, autoinsertion devices, distraction, and insertion while the child is asleep.

Catheter features requiring consideration include:

1. Needle length

- Children usually have significantly less subcutaneous fat than adults. Therefore, the preferred needle length is 6–8 mm.

- If frequent catheter dislodgement occurs or if the overall success of CSII is less than expected, one should consider the use of longer needles/catheters or catheter insertion angles $<90^\circ$, especially in adolescents.

2. Needle type

- Children fearful of an indwelling steel needle may prefer Teflon catheters; however, catheter obstruction may occur less frequently with steel needles (controlled studies are lacking).

3. Tubing length

The infusion set tubing length should be tailored for the individual child and his/her activities.

Recommendations

1. Trials with different catheter tubing lengths may be necessary, and when in doubt, the shorter catheter length should be tried first (E).

2. For infants and toddlers, the tubing should not be so long that it could pose a risk of strangulation (E).

3. To prevent accidental dislodgement of the pump catheter secondary to pulling, a catheter loop (pig tail) or a second piece of tape should be used to secure the tubing close to the insertion site (E).

Calculating the total daily insulin requirements when switching from MDI to CSII

The starting insulin dose is based on the pre-pump total daily dose and is guided by continued frequent blood glucose measurements before and after meals and during the night. The higher the insulin dose required with MDI (in insulin units per kilogram), the more pronounced the insulin reduction should be when switching to CSII.

Recommendations

1. In children with good glycemic control and a low frequency of hypoglycemia, the total dose may need to be reduced by 10–20% (C: 12,42,78).

2. In a patient who has been experiencing frequent hypoglycemia, the dose should be reduced by 20% (E).

Calculating the basal insulin rate

The basal rate of insulin delivery addresses the child's food-independent insulin requirement and regulates hepatic glucose production. As with MDI, this comprises 30–50% of the total daily dose. With the correct dose of basal insulin, all food intake (even small snacks) will necessitate a food bolus, and, conversely, skipping a meal will not lead to hypoglycemia.

Recommendations

1. The basal rate is typically 30–50% of the total daily dose (E).

2. The total daily basal rate should be programmed in hourly intervals, according to the patient's circadian variation in insulin sensitivity (E).

- The circadian variations in basal insulin are age dependent (C: 78; B: 79).

- Adolescents and young adults typically have a two-waved basal rate profile (decreased insulin sensitivity from 5:00–9:00 A.M. and, to a lesser extent, in the late afternoon [dawn-dusk phenomenon]).

- Young children often need more basal insulin between 9:00 P.M. and midnight (C: 78,80,81).

3. Extreme care is required if prandial boluses are programmed into the basal rate for meals that occur at the same time every day, as hypoglycemia will occur if this meal is missed or delayed (E).

Calculating and timing the prandial (bolus) insulin requirement

A method of accurately estimating the carbohydrate content of meals and snacks (carbohydrate counting) is a prerequisite for successfully determining the bolus insulin requirement (C: 82). Prandial boluses are dependent on carbohydrate intake as well as circadian variation of insulin sensitivity, current blood glucose levels, and planned physical activity. The amount of insulin per gram of carbohydrate is usually highest in the morning (breakfast).

Recommendations

1. Patients with CSII must have a method to calculate the appropriate insulin dose.

- Various algorithms exist that assist in calculating insulin to carbohydrate ratios (C: 83).

- Receiving more than seven daily boluses has been associated with a significantly lower A1C levels (C: 80).

- A dual-wave bolus may be beneficial when eating foods that are gradually absorbed, such as pizza, beans, and meals with a high fat content (C: 84).

2. The prandial bolus should be designed to preserve the physiological variation in postprandial blood glucose, i.e., blood glucose 30–40 mg/dl (1.67–2.2 mmol/l) higher 2 h after a meal and returning to the preprandial level by 4 h after a meal (E).

3. In very young children or fussy eaters, parents may prefer to administer the bolus after the meal (C: 85) in order to choose an insulin dose that is appropriate for the amount of food actually eaten. However, if

postprandial insulin doses are frequently forgotten, administration of the bolus after the meal should not be encouraged (C: 86).

Calculating the correction dose

The correction insulin dose depends on insulin sensitivity and the blood glucose target. It is calculated based on the difference between the current blood glucose and the desired target blood glucose level. As with meal boluses, formulae are available to calculate insulin sensitivity factors (C: 83). Some pump models offer calculation tools for this purpose, whereas other models require manual calculation or the use of other devices (C: 25,87).

Insulin analogs have a total duration of activity of 4–6 h, with the main activity occurring during the first 3 h after injection, followed by a prolonged tail of decreasing insulin effect. Many new pumps allow the user to set the "insulin on board" duration to a variable length, and most patients use between 3 and 6 h. Subjects seeking very tight control prefer a shorter duration of action, whereas subjects concerned about hypoglycemia tend to choose a longer duration of insulin action.

Frequent administration of boluses is associated with better glycemic control (80). The putative benefits of different bolus modes and timing obtained with bolus calculators has yet to be established in the pediatric age-group.

Recommendations

1. Infants and toddlers typically are more sensitive to insulin than older children and adolescents and therefore require less insulin to correct hyperglycemia (E).

2. "Active insulin" or "insulin on board" from a previous insulin bolus should be taken into consideration when determining the subsequent bolus dose to prevent "stacking" of correction insulin boluses (E).

- The duration of action of large boluses is generally longer than small doses of insulin.

- If the pump does not have an "insulin on board" function, a second correction dose should not be given within 2 h of the first.

3. If a correction bolus fails to reduce the blood glucose within 2 h, and particularly in the presence of ketosis, a correction dose with a pen or syringe should be given immediately and the infusion set should be changed (E). This is most important, since most episodes of DKA in pump users could have been avoided by this simple measure. Ketones should be tested whenever there are continued high blood glucose readings or the patient feels unwell or has nausea/vomiting (E). Blood ketone testing (measures β -

hydroxybutyrate) is more appropriate for preventing metabolic deterioration, but urine ketones (measures acetoacetate) will be sufficient if this is not available (C: 88).

Monitoring patients on CSII Recommendations.

After initiation of CSII, frequent contact with the diabetes team is required to review and optimize CSII (E). Scheduled outpatient visits should address the following:

1. Glycemic control (A1C, blood glucose values, and hypoglycemic episodes)
2. Weight gain
3. Average (7 days) total daily insulin dose—compared with body weight
4. Average total daily basal dose (should be 0.2–0.4 IU/h for toddlers, 0.4–0.6 IU/h for prepubertal children, and 0.8–1.2 IU/h for adolescents)
5. Insulin-to-carbohydrate ratio
6. Correction dose and target blood glucose
7. Average number of boluses per day (to assess for missed boluses)
8. Basal-to-bolus ratio
9. Postprandial and overnight blood glucose values
10. Are the total carbohydrates entered into the bolus calculator appropriate for the child's age?

Terminating CSII Recommendations.

Discontinuation of CSII should be consid-

ered temporarily or permanently under the following circumstances (E).

1. Child wishes to return to injection therapy
2. Conditions that put the child at undue risk
 - Recurrent DKA due to pump mismanagement
 - Ineffective pump management (e.g., recurrent missed boluses, inadequate frequency of blood glucose monitoring, or set changes)
 - Intentional insulin overdosing to cause hypoglycemia
 - Recurrent site infections

Conclusions

There are very few published long-term studies on pump use in children and adolescents, and almost all of those are observational studies.

The vast majority of the studies cited use a multidisciplinary trained team that usually is not available to the general pediatrician or nonacademic pediatric endocrinologist. This may be a caveat to prescribing CSII. However, based on the available evidence and the experience of the expert panel, CSII therapy may be appropriate for children and youth of all ages provided that appropriate support personnel are available. CSII use in children and adolescents may be associated with improved glycemic control and improved QOL and poses no greater, and possibly less, risk than MDI. Minimizing risks of CSII entails the same interventions that promote safety in all patients with type 1

diabetes, including proper education, frequent blood glucose monitoring, attention to diet and exercise, and the maintenance of communication with a diabetes team. Additional risk reduction may be possible with current continuous glucose sensors and will almost certainly decline further with advances in this technology and the eventual development of "closed-loop" insulin delivery systems.

Participants in the consensus forum

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(References provided upon request)

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