



ISPAD Clinical Practice Consensus Guidelines 2022: Diabetes technologies: Insulin delivery

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1 | WHAT IS NEW OR DIFFERENT?

In 2018, the inaugural guideline on diabetes technology was published. Like the technology used in daily life, the field of diabetes technology has seen rapid innovation and growth in the devices used for management. To review technologies more clearly, these guidelines have been divided into two parts: Diabetes Technologies: Glucose Monitoring and the present chapter, which focuses on insulin delivery methods.

Updates in insulin delivery include the advent of connected pens, which have created a means to utilize technology without requiring on body devices, though studies in the pediatric population remain sparse. Across a wide age spectrum, both clinical trials and real-world data have clearly demonstrated improvements in glycemia with use of automated insulin delivery (AID), especially overnight. Thus, the most advanced insulin delivery technology that is available, affordable, and appropriate for the individual should be offered, with the goal of personalized care. Use of insulin delivery devices requires special attention to psychosocial aspects of care as well as delivery of structured, yet tailored, education to create the foundation for

success. These issues are covered in greater detail in this updated chapter.

2 | EXECUTIVE SUMMARY AND RECOMMENDATIONS

2.1 | General principles for insulin delivery technology

- It is recommended that youth be offered the most advanced insulin delivery technology that is available, affordable, and appropriate for them. **B**

2.2 | Pens

- Connected insulin pens have the potential to improve diabetes management on intensive insulin therapy with multiple daily injections (MDI). **C**

- Connected pens if available may be offered to interested youth who prefer not to have an on-body device. **E**

2.3 | Pump therapy general principles

- Continuous subcutaneous insulin infusion (pump) therapy is recommended and appropriate for youth with diabetes, regardless of age. **A**
- Infusion set failures are common with any insulin pump therapy and must be recognized promptly to avoid diabetic ketoacidosis (DKA). **B**

2.3.1 | Not-integrated pumps

- Insulin pump therapy is safe and effective in youth with type 1 diabetes (T1D) to assist with achieving glycemic targets. **A**
- Insulin pump therapy reduces episodes of hypoglycemia. **B**
- Insulin pumps reduce chronic complications of T1D in youth, even when compared to those with similar hemoglobin A1C (HbA1c) levels on MDI therapy. **B**

2.3.2 | Sensor augmented pump (SAP)

- Sensor augmented pump (SAP) therapy is superior to MDI with self-monitoring of blood glucose (SMBG) in reducing HbA1c without an increase in hypoglycemia or severe hypoglycemia (SH). **A**
- Sensor use must be at least 60% to realize these benefits. **A**

2.3.3 | Low glucose suspend (LGS) system

- LGS systems reduce the severity and duration of hypoglycemia as compared to not integrated pump and SAP, without a deterioration in glycemia, as measured by HbA1c. **A**

2.3.4 | Predictive low glucose suspend (PLGS) system

- PLGS systems reduce frequency of and exposure to hypoglycemia. **A**
- Both LGS and PLGS systems do not lead to a rise in mean glucose levels, and lead to increased confidence and trust in the technology, more flexibility around mealtimes, and reduced diabetes distress for both people with diabetes and caregivers. **A**
- If AID systems are not available, PLGS is strongly recommended for all people with T1D to mitigate hypoglycemia; in cases of limited availability of more advanced technology, LGS is strongly recommended for all people with T1D to reduce the severity and duration of hypoglycemia. **A**

2.3.5 | AID system

- AID systems, also known as closed loop (CL), are strongly recommended for youth with diabetes. **A**
- AID systems improve time in range (TIR) by minimizing hypoglycemia and hyperglycemia. **A**
- AID systems are especially beneficial in attaining targeted glycemia in the overnight period. **A**
- If people with diabetes choose to use open-source automated insulin delivery systems, support from care providers is encouraged. **E**

2.4 | Behavioral, psychosocial, and educational considerations of insulin delivery devices

- It is strongly recommended that diabetes providers/educators implement a standardized training approach when new insulin delivery devices are integrated into care. **C**
 - For optimal outcomes, people with diabetes and their families should be advised to use the AID system as intended. **C**
- Counsel youth and their caregivers about realistic expectations for glycemic outcomes and the effort required for successful use of all insulin pump technologies. **B**. This is especially important in those with suboptimal glycemia, challenges with engagement with the current treatment plan, or higher burnout/mood concerns. **C**. Expectations include:
 - Glycemia will likely improve but will not always be at the desired target, and glucose fluctuations will still occur, especially after meals.
 - There will be an ongoing need for engagement in diabetes management behaviors (including engagement with the AID system), especially around mealtimes. People with diabetes should count carbohydrates and deliver meal boluses for most AID systems.
 - An adjustment period of approximately one month should be anticipated when transitioning to new devices.

3 | INTRODUCTION

Despite over 100 years of insulin therapy, glycemia remains suboptimal for many individuals living with diabetes. Data from international diabetes registries highlight that most youth with T1D do not meet the ISPAD targets for HbA1c.¹⁻⁶ Additionally, hypoglycemia and SH continue to plague youth with T1D.⁷⁻¹⁰ While moderate fear of hypoglycemia may be beneficial, significant fear of hypoglycemia may prevent people with diabetes, and their caregivers, from attaining glycemic targets.¹¹ Yet, population-based studies show that reductions in HbA1c are not associated with increased risk of SH.^{8,12} Importantly, use of diabetes technologies have been shown to improve glycemia.^{5,13-18} Despite this, integration of diabetes technologies into the care of youth with diabetes remains variable and there are disparities in the care of youth from racial and ethnic minority

backgrounds and those of lower socioeconomic status.^{19–24} A recent meta-analysis highlighted that most of the existing literature on pump therapy in youth with T1D reflects studies conducted in high-income countries; only 38% reported race/ethnicity of the population included and <25% of studies provided details regarding family socioeconomic status, parental occupation, and parental education/literacy.²⁵ Yet, a subanalysis of individuals from historically disadvantaged groups suggested that the use of diabetes technologies improved overall glycemia.²⁵

While care has hitherto focused predominantly on achievement of consensus guideline targets for HbA1c, in recent years, there has been more widespread adoption of time in range (TIR) to guide clinical decision-making and define treatment goals.^{26,27} See ISPAD 2022 Consensus Guidelines Chapter 8 on Glycemic targets and glucose monitoring in children, and adolescents with diabetes and Chapter 16 on Diabetes technologies: glucose monitoring. Studies demonstrate a correlation between TIR, defined as 3.9–10.0 mmol/L (70–180 mg/dl), and HbA1c concentration.^{28–30} Also of central importance are metrics to assess disease management that extend beyond glycemia, particularly patient-reported outcomes.²⁷ These assessments are especially important as early advances in diabetes treatment may have inadvertently increased the burden of diabetes care, detracting from quality of life and psychosocial health.^{31–34} Thus, a body of research has explored how the burdens of these technologies can be offset by the benefits they may provide, determining how to set realistic expectations for what assistance new therapies may provide, and methods to ensure transition to more advanced technology is associated with appropriate training on device use.

In 2018, ISPAD created the first consensus guidelines on Diabetes Technology.³⁵ However, with the rapidly evolving technology landscape, future iterations of these guidelines will be divided into two parts. Information on Insulin Delivery will be covered herein, and Glucose Monitoring with discussion of both capillary fingerstick glucose measurements and continuous glucose monitoring (CGM) will be presented in ISPAD 2022 Consensus Guidelines Chapter 16 on Diabetes technologies: glucose monitoring. These two chapters are intertwined, but the purpose of this chapter is to review insulin delivery technologies in children, adolescents, and young adults and to provide practical advice and approaches on their use. Topics include connected insulin pens, insulin pumps, SAP, LGS, PLGS, and AID, and culminates with behavioral, psychosocial, and educational considerations of insulin delivery devices.

4 | CONNECTED INSULIN PENS

Insulin pens continue to be a popular insulin delivery modality in young people with diabetes due to their ease of use and increased dosing accuracy compared to insulin delivery using vials and syringes. While the number of children utilizing insulin pump therapy continues to rise,³ many children and adolescents do not wish to be tethered to a device and desire the less visible nature of MDI. Pen device technology has advanced significantly over the past 40 years, including the addition of a memory function in some pens. More recently, “smart” or connected insulin pens or pen cap devices that pair with smart

phone applications and CGMs have been developed, allowing pen users access to benefits such as data collection, alerts and reminders, and dosing calculators that take insulin on board into account.

Data on the use of connected insulin pens in children are limited. A number of studies have reported high satisfaction and ease of use of pens with a memory function^{36–39}; however, no significant improvement in glycemia has been noted when compared to use of insulin pens without a memory function.^{40,41} One study noted that youth aged 2–18 years using the NovoPen ECHO device demonstrated increased rates of self-injection as compared to the mode of insulin delivery used prior to the study, which included conventional insulin pens or syringes.⁴¹ Literature suggests Bluetooth-enabled pen cap device accurately detect insulin dosing and provide the person with diabetes and healthcare team with useful data, including assessing engagement with the prescribed regimen and the opportunity to optimize insulin doses through retrospective report review.^{42–44}

A cost-effectiveness analysis based on adult data reported that connected pens could improve life expectancy compared to standard of care with a cost savings due to lowered frequency and delayed onset of complications.⁴⁵ Pediatric studies are needed to determine the impact connected pens will have on glycemic measures, including both TIR and HbA1c, as well as usability and satisfaction with these devices.

4.1 | Practical considerations for connected pens

“Smart” or connected pens eliminate the burden of dose calculation. Further, the insulin on board feature may reduce the risk of hypoglycemia from stacked correction doses that are given too frequently in response to hyperglycemia. Like pump therapy, success hinges on ensuring people with diabetes have the information necessary to program the dose calculator. Set up of the dose calculator requires the correction factor, target glucose, duration of insulin action, and insulin to carbohydrate ratios to be used. The calculator can also be programmed with different settings by time of day. Meal coverage with some connected pens allows for a simplified approach where the size of the meal (small, medium, large) is used to select a discrete insulin dose to be delivered. Long-acting insulin dose reminders, temperature tracking, and information about the units of insulin remaining in the pen can also aid with daily diabetes management. Currently, one system provides tracking of both rapid- and long-acting insulin doses with delivery of the dose recorded, but not the actual amount administered. Many connected pens allow for half-unit dosing increments, which can be especially helpful for young children. For youth with diabetes, who go back and forth between home and school settings, the ability to have more than one rapid-acting insulin pen paired can allow for one pen to be kept at school. Downloading device data obtained with these pens is essential to have the best success with dose optimizations.

5 | INSULIN PUMPS

Insulin pump therapy is recommended for all youth with T1D. This mode of insulin delivery has been found to be safe and effective for

children, adolescents, and adults. Additionally, insulin pump therapy is the foundational component of more advanced insulin delivery methods, which are discussed later in this chapter.

5.1 | The dawn of technology use in diabetes care

Insulin pump therapy was introduced in the late 1970s.^{46–48} However, insulin pump therapy integration into the care of youth with T1D was minimal until the turn of the century. Since then, observational and cohort studies have shown pump use is associated with mean reductions in HbA1c of 0.2%–1.1%^{49–62} and decreases in clinically-important hypoglycemia^{49–54,57–63} without associated increases in BMI.^{49,51–62} These data hold true regardless of whether the MDI comparator group used NPH^{49–58,61,64} or glargine insulin.^{65–68} Yet, randomized controlled trials (RCTs) assessing insulin pump use have yielded conflicting results, with some showing improvement of glycemia with use of the technology.^{65,66} Even in RCTs where no lowering of HbA1c was observed, continued use of the devices after the end of the study,^{69–71} higher reports of treatment satisfaction,⁷² and decreased diabetes-related worry highlight that benefits extend beyond glycemic metrics.⁷³ Interestingly, a prospective examination of nearly 1000 youth on either pump or MDI therapy found lower rates of retinopathy and peripheral nerve abnormality in the insulin pump-treated group despite similar HbA1c.⁷⁴ Meta-analyses have shown reductions in mean HbA1c^{75–77} and decreased rates of SH⁷⁷ with pump therapy as well as a reduction of total daily insulin dose with pump use.^{75,76}

Given that people recruited into RCTs generally do not reflect the general population of children with T1D, real-world registries provide important data regarding the benefits of pump use. In a cross-sectional comparison of three large, transatlantic registries, which included the U.S. based Type 1 Diabetes Exchange clinic registry (T1DX), the German/Austrian Prospective Diabetes Follow-up Registry (DPV), and the English/Welsh National Paediatric Diabetes Audit (NPDA), a pooled analysis of nearly 55,000 pediatric participants showed that pump use was associated with lower mean HbA1c (pump $8.0 \pm 1.2\%$ vs injection: $8.5 \pm 1.7\%$, $p < 0.001$).¹⁵ The T1DX and DPV registry have both demonstrated increased pediatric use of pump therapy over time.^{3,78} The SWEET (Better control in Pediatric and Adolescent Diabetes: Working to create Centers of Reference) centers found that almost half of the 16,000 registry participants used pumps, and this technology was associated with lower HbA1c and lower daily insulin dose as compared to MDI.⁷⁹ More recent data have corroborated this finding.^{17,18} The long-term benefits of pump therapy have been demonstrated with sustained improvement in glycemia.^{63,80,81} Further, registry data have also shown pump therapy is associated with lower rates of SH and DKA.^{9,81–83}

5.2 | Incorporation of pump therapy regardless of age, HbA1c or disease duration and clinical follow up

In 2007, a consensus guideline on use of pump therapy in youth with T1D (adapted in Table 1) provides solid evidence that every child with

TABLE 1 Indications for use of insulin pumps in pediatrics—adapted from Reference 84

Insulin pumps are recommended for all youth with diabetes. Specific factors that support the recommendation for insulin pump therapy include:

- Recurrent severe hypoglycemia
- Wide fluctuations in glucose levels regardless of HbA1c
- Suboptimal diabetes control (i.e., HbA1c exceeds target of 7.0% or TIR is <70%)
- Microvascular complications and/or risk factors for macrovascular complications
- Targeted metabolic control but insulin regimen that compromises lifestyle
- Young children and especially infants and neonates
- Children and adolescents with pronounced dawn phenomenon
- Children with needle phobia
- Pregnant adolescents, ideally preconception
- Ketosis prone individuals
- Competitive athletes

Contraindications to pump therapy:

- Preference of the person with diabetes not to use technology^a
- Significant skin irritation/allergy making pump/sensor wear difficult^b

^aProviders should still provide information on technologies at each follow up visit to assess if there is a desire to change mode of insulin delivery.

^bConsider referral to dermatology to aid with overcome issues with skin irritation.

T1D is recommended to be on pump therapy.⁸⁴ Indeed, as evidenced by the accumulated data presented above, standard insulin pump therapy is recommended for all youth with diabetes if access to more advanced diabetes technologies, including sensor augmented pump therapy (SAP), LGS, PLGS, and AID (described fully later in this chapter), is limited. Further, the ISPAD 2022 Consensus Guidelines Chapter 23 on Managing Diabetes in Preschoolers states pump therapy is the recommended mode of insulin delivery for those under the age of 7 years.⁸⁵ While concern is sometimes expressed over how daycare providers/school personnel will adopt this technology, one study suggests that children whose parents work outside of the home tended to see the largest improvement in glycemia with transition to pump therapy.⁶²

Data demonstrate that pump therapy can be successfully used in children who have suboptimal glycemia prior to the transition to this mode of insulin delivery. In a study of 125 youth, those with the highest HbA1c levels (>9.0%) showed the largest decrement in HbA1c once pump therapy was initiated.⁸⁶ Immediate incorporation of pump therapy from the time of diagnosis has been shown to be successful in terms of achievement of glycemic targets.^{87–90} While it has been postulated that achieving more targeted glycemia shortly after diagnosis may preserve beta cell function, this has not yet been substantiated.^{89,91}

5.3 | Barriers to adoption of pump therapy and predictors of success

Universal adoption of insulin delivery technologies has not occurred, with wide variation in implementation among centers, even those with similar

populations.⁹² A Pediatric Diabetes Consortium study of 8 US clinical centers demonstrated frequency of pump use within the first year after diagnosis ranged from 18% to 59% of participants.⁹³ Initiation of pump therapy within a year was more common in those with private health insurance, annual family income over \$100,000, a parent with a college education, and in non-Hispanic White individuals.⁹³ A T1DX study also reported widely variable pump use among centers and concluded health-care provider preferences influence the proportion of people using pumps in a given center.⁹⁴ Consistent findings of inequities in pump and CGM use in those of lower socioeconomic status and racial disparities with integration of these technologies have also been described in the literature.^{19–24} Further potential barriers to uptake of the technology voiced by those with diabetes have included concerns regarding the physical footprint and interference of the device, therapeutic effectiveness of the technology and, to a lesser extent, financial burdens this mode of insulin delivery may cause.⁹⁵ In some countries, non-coverage, or incomplete coverage of pump therapy by the health care/insurance system likely influences the low adoption rates of this technology.^{15,92}

5.4 | Frequency and causes of discontinuation of pump therapy

Pump therapy discontinuation is uncommon. Over the period of 1995–2009, the DPV registry found low attrition at 4%.⁹⁶ Adolescents aged 10–15 years had the highest rate of pump discontinuation, and those who discontinued were more likely to be female.⁹⁶ Similar results were noted in a T1DX registry analysis.⁹⁷ Reasons for discontinuing pump therapy included problems with wearability (57%), disliking the pump or feeling anxious (44%), and problems with glycemic control (30%).⁹⁷ Higher depressive symptoms, as captured by the Children's Depression Inventory, have also been reported to precede cessation of pump use.⁹⁸ Those who started on pump therapy and discontinued this mode of insulin delivery ($n = 9$) were predominately female and mean depressive symptom scores were reduced with the transition to MDI therapy.⁹⁸ To identify what might facilitate resumption of this technology, data collected via self-report for those >13 years old and via parental response for children aged 6–<13 showed improvements in infusion catheters, integration of blood glucose levels directly into the pump, and advances in some technical aspects of the pump, including reduced size of devices, water-resistant devices, and a reduction in emitted noise, would be motivating factors.⁹⁷

5.5 | Complications of pump therapy: infusion sets and hypertrophy

Insulin pump-related adverse events are common and include infusion set failures, pump malfunctions, alarms, and other problems, with 40% to 68% of pump users experiencing such events.^{99–103} Questions remain regarding whether steel cannulas or flexible Teflon catheters are ideal and whether certain infusions sets are better based on the age of the person using the pump or individual body habitus. As steel cannulas are less likely to kink or dislodge, they may be the ideal

infusion set for the youngest children. The major concern is full or partial occlusion or dislodgement of the site thereby interrupting the insulin delivery and putting the user at risk for developing ketoacidosis. Strategies for failed infusion set detection continue to be explored and include fault detection algorithms, whereby the sensor glucose levels and amount of insulin delivered by the system are used to help detect or predict an infusion set failure,^{104,105} and more recently the feasibility of using subcutaneous continuous ketone monitors.¹⁰⁶

Some studies have documented between a 2 to 5-fold higher risk of DKA in those on pump therapy.^{107,108} Education on the risk of DKA and how to manage persistent hyperglycemia is the cornerstone to avoiding these issues. Mild DKA can often be quickly ameliorated by administering additional insulin with either a syringe or pen as soon as hyperglycemia and hyperketonemia/ketonuria occur.¹⁰⁹ See ISPAD 2022 Consensus Guidelines Chapter 13 on Diabetic ketoacidosis and hyperglycemic hyperosmolar state. For more details. Some have explored the concomitant use of a small dose of basal insulin, like glargine, to help minimize the likelihood of this complication.¹¹⁰

Lipohypertrophy, or local fat accumulation, at the site of insulin administration, is another frequently encountered issue with pump therapy.¹¹¹ Lipoatrophy, fat loss at the site of prior insulin infusion sites, is less common and has been seen more frequently in those with concomitant multiple autoimmune diseases.¹¹² Both conditions are categorized as lipodystrophy. A cross-sectional study of children and adolescents with T1D demonstrated a greater risk of these issues in those with higher insulin autoantibodies.¹¹³ Lipodystrophy can impact how insulin is absorbed and thus lead to deterioration in glycemia. To avoid lipohypertrophy, it is recommended that infusion set placement be rotated. Once detected, placement of infusion sets should avoid the affected area to allow the tissue to heal, which often takes several months. See ISPAD 2022 Consensus Guidelines Chapter 19 on Other complications and associated conditions in children and adolescents with type 1 diabetes. Interestingly, placement of a CGM sensor in an area of lipohypertrophy was found not to impact sensor accuracy.¹¹⁴ Thus, while the abnormal tissue is not being used for insulin infusion, the area of lipohypertrophy may continue to be used for sensor placement.

Finally, with repeated exposure to adhesives from medical devices, skin irritation is often noted. In one study where comprehensive dermatological examinations were done, localized eczematous reactions at the site of infusion cannula insertion were noted in 14% of youth,¹¹⁵ and a survey of 143 youth documented that nearly half of the cohort reported non-specific eczema.¹¹⁶ For more information on skin related issues, please refer to ISPAD 2022 Consensus Guidelines Chapter 19 on Other complications and associated conditions in children and adolescents with type 1 diabetes.

5.6 | Practical considerations with pump therapy

As pump therapy is the basis for other advanced insulin delivery technologies, the benefits and issues mentioned above may also apply to the technologies discussed in the next sections.

5.6.1 | Provider training

Clinicians need to be trained on devices to be competent and feel comfortable with offering diabetes technology. Yet, a survey of pediatric endocrinology fellows in the United States and Canada found that only 14.7% had formal training on pump and CGM.¹¹⁷ A subsequent study of pediatric endocrine fellows ($n = 64$) in North America employed case-based vignettes with 20 multiple choice questions on either CGM or pump therapy delivered either via email or a mobile app.¹¹⁸ Both curricula were effective in increasing the pre- to post-test assessment of knowledge base and participants found this method of education engaging.¹¹⁸ This suggests potential for providers to be trained on these technologies through user-driven online learning modules. Without keeping abreast of technological advances, clinicians may inadvertently hinder device adoption and their optimal use.

5.6.2 | Educational materials

To help inform families of various insulin delivery modalities, simplified guides regarding options can be helpful to supplement in clinic conversations. One such resource is The Simple Guides (<https://www.uscdiabetes.com/simple-guides>), which is free to use and available in both English and Spanish. Another is available in French (<https://www.ajd-diabete.fr/le-diabete/tout-savoir-sur-le-diabete/la-pompe-a-insuline/>).

When preparing to transition from MDI to insulin pump therapy, one of the first steps is to have the person with diabetes, and their family, select the pump model they would like to use if insurance coverage or regional availability does not dictate a decision. To accomplish this, charts and literature describing the differences among models are helpful; online resources include the American Diabetes Association's consumer guide (<https://consumerguide.diabetes.org>), Diabetes Wise (<https://diabeteswise.org>), or the Panther Program (<https://pantherprogram.org>). Pump selection should be based on features desired by the person with diabetes, and their family, with guidance provided by the clinical team members. In some health systems, people with diabetes may not have a choice of systems.

5.6.3 | Initiating pump therapy

Generally, initial pump settings should be derived from the individual's total daily insulin dose. Table 2 provides some suggestions to determine initial pump settings. At the time of pump start it is also critical to advise families on associated risks, particularly that of potential infusion set failure and consequent metabolic decompensation. A useful framework for optimizing the transition is presented by Deiss et al.¹²⁴ For very young children or those with minimal insulin requirements, diluted insulin can be used to accurately deliver very small amounts of insulin.^{125–128} See ISPAD 2022 Consensus Guidelines Chapter 23 on Managing Diabetes in Preschoolers and Chapter 9 on Insulin treatment in children and adolescents with diabetes for further details.

TABLE 2 Basic guidelines for starting insulin pump therapy

<p><i>Total daily dose (TDD) prior to pump initiation</i></p> <ul style="list-style-type: none"> • Generally used to determine initial pump settings • Consider reducing total daily dose at initiation in those at glycemic target or in youth with diabetes who have frequent or severe hypoglycemia. <p><i>Proportion basal versus bolus insulin delivery</i></p> <ul style="list-style-type: none"> • In older children and adolescents expect a 50/50 split • In children <7 years, basal insulin delivery may be ~30%–35% of the TDD¹¹⁹ <p><i>Determination of basal rates</i></p> <ul style="list-style-type: none"> • Take the amount to be delivered as basal (i.e., 50% of the TDD) and divide by 24 for the number of hours in a day (e.g., if daily basal insulin will be 20 units then hourly rate would be set at 0.8 units/h) • Pre-school aged children may have higher basal insulin requirements between 9 p.m. and 12 a.m. and lower basal rates during early morning hours before breakfast¹²⁰ • Adolescents may need increases in basal rates in the early morning to counter the dawn phenomenon^{120,121} <p><i>Determination of correction factors/Insulin sensitivity factors</i></p> <ul style="list-style-type: none"> • If using correction factors prior to transition to the pump, start with the usual factors. • Otherwise, a correction factor can be determined by dividing 1800 by the TDD if glucose values are in mg/dl (or by dividing 100 by the TDD if glucose values are in mmol/L). Depending on insulin sensitivity, the 1800 rule can be adjusted upward (2000/TDD) for those who are insulin sensitive or downward (1500/TDD) for those who are more insulin resistant. <p><i>Determination of insulin to carbohydrate ratios</i></p> <ul style="list-style-type: none"> • If using carbohydrate ratios prior to transition to the pump, start with the usual factors. • Otherwise, carbohydrate ratio can be determined by dividing 500 by the TDD • Young children may need more aggressive meal coverage and a 350 rule may be employed^{122,123} <p><i>Close monitoring following initiation</i></p> <ul style="list-style-type: none"> • Use sensor glucose data with attention to pre-meal and 2-h post meal values to inform insulin dose titrations. For those using fingerstick blood glucose values, test blood glucose both pre- and 2-h post meal to guide dose titrations. • Use overnight sensor glucose values to assess overnight basal rates. For those using SMBG, consider overnight checks at midnight and 3 a.m. to assess overnight basal rates <p><i>Optimal engagement with pump therapy includes</i></p> <ul style="list-style-type: none"> • Bolusing for carbohydrate intake, ideally prior to eating • Understanding of how to treat hypoglycemia^a → 10–15 g of rapid-acting carbohydrates should be given orally. This may need to be lowered to 5–10 g for those on LGS, PLGS, or AID systems • Changing the infusion set at least every 3 days • Continuous CGM use will allow for optimal performance for systems that integrate sensor glucose data to alter insulin delivery (i.e., LGS, PLGS, and AID)
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^aSee ISPAD 2022 Consensus Guidelines Chapter 11 on Management of Hypoglycemia in Children and Adolescents with Diabetes.

Various factors have been associated with successful pump therapy. These include having more pre-programmed basal rates (correlated with lower HbA1c levels)¹²⁹; the total number of boluses delivered daily correlates with HbA1c achieved; and basal insulin delivery accounting for <50% of the total daily dose. It is critical to encourage people with diabetes and their families to be engaged with

care.^{130,131} Reviewing the importance of meal announcements should be emphasized at each follow up visit.

5.6.4 | Advanced pump features

More advanced features of pump therapy include the ability to set temporary basal rates that adjust the usually programmed basal rate for unique day-to-day variations in insulin sensitivity. This includes decreasing delivery for physical activity or increasing doses for situations like inter-current illness.¹¹⁹ Temporary basal rates, including complete suspension of basal insulin delivery can help mitigate hypoglycemia associated with exercise.¹³² Similarly, different pre-programmed basal patterns can be utilized for predictable times of differing insulin sensitivity, for example during menstruation in women.

Boluses of insulin can also be delivered in different manners to accommodate differences in food composition: (1) immediately, as a standard or normal bolus, (2) slowly over a certain duration of time, an extended or square bolus, or (3) a combination of the two, that is, a combo or dual wave bolus.¹¹⁹ Boluses for high fat foods might be best handled as extended or combo boluses as the rise in blood glucose levels following the meal will be delayed by fat. For the extended bolus, the user sets the duration of the extension; whereas, for combo boluses the user not only chooses the duration to extend but also the amount to be delivered upfront (e.g., 40% of the bolus immediately and the remaining 60% over 4 h). Pumps can also reduce bolus insulin delivery based on the proportion of insulin that is still “active” from the last bolus, which may decrease the likelihood of post-bolus severe hypoglycemia.

5.6.5 | Reviewing data to optimize management

As insulin pump data can be uploaded or, more recently, are available through cloud-enabled sharing, clinic visits can be more productive with the wealth of data afforded. In addition to determining if insulin pump settings need to be optimized, these reports serve as the basis for clinicians to initiate a conversation on engagement with care. With information on the number of boluses per day or the average amount of carbohydrates entered per day, more structured instruction on meal bolusing is possible. Further, records regarding the frequency of infusion set changes helps providers broach the conversation on recommendations regarding infusion set changes and the importance of rotating sites. For more information on care delivery, see ISPAD 2022 Consensus Guidelines Chapter 7 on The delivery of ambulatory diabetes care to children and adolescents with diabetes.

6 | SENSOR AUGMENTED PUMP THERAPY

Sensor Augmented pump (SAP) therapy is defined as the combination or augmentation of a conventional insulin pump with CGM

(Figure 1). For more details on CGM, please see ISPAD 2022 Consensus Guidelines Chapter 16 on Diabetes technologies: glucose monitoring. With CGM values viewed either on a separate reader or smartphone or through direct integration of sensor glucose values on the insulin pump, SAP therapy provides the data that a person with diabetes can choose to act upon instead of relying on fingerstick glucose measurements at specific time points. For example, if a sensor glucose value reaches a high alert threshold, a correction bolus can be delivered. Thus, while SAP does not allow for automation of insulin dosing, it provides the framework on which integrated systems are built.

6.1 | A single platform: The beginnings of SAP therapy

The first 6 month RCT comparing SAP to insulin pump therapy conducted in 12–72 year old participants showed similar reductions in HbA1c, but this was associated with significantly increased hypoglycemia exposure in those randomized to the insulin pump with SMBG group.¹³³ For those in the SAP group, sensor utilization more than 60% of the time was associated with HbA1c reduction.¹³³

The Sensor-Augmented Pump Therapy for A1c Reduction (STAR) 3 study compared SAP with MDI and SMBG checks over a 1-year study period in device naïve participants with T1D, including 74 adolescents (age 13–18) and 82 children (aged 7–12).^{134–136} The SAP group had a sustained greater reduction in HbA1c, less time in hyperglycemia, and reduced glucose variability.¹³⁶ Rates of SH and DKA were relatively low and did not differ between groups. Importantly target achievement was directly linked to sensor wear duration and was more prominent in the children's cohort (aged 7–12 years) who had sensor use that was 1.5 times higher than adolescents (aged 13–18 years).¹³⁶ The crucial impact of regular sensor use has been echoed in other trials.¹³⁷ Recent data demonstrate every 10% increase in sensor use frequency is associated with a 1.1% increase in TIR and a 1.0% decrease in TAR >10 mmol/L (180 mg/dl).¹³⁸

Although SAP is more expensive than conventional insulin pump therapy, the additional clinical benefits and quality-adjusted life years they afford provide justification for considering this treatment a good value for the money spent, provided sensor use is persistent.^{139,140}

SAP generates a wealth of information upon which insulin doses can be optimized. Yet, glycemic improvement relies on the user or a caregiver responding to the sensor glucose data to adjust insulin or other aspects of care. Classically, this has been done with the assistance of a health care provider; however, more recently automated algorithms to adjust pump settings have been employed. ADVICE4U was a RCT assessing the use of automated artificial intelligence-based decision support system that showed non-inferiority of the decision support tool when compared to provider-driven insulin dose titrations in a cohort of 108 participants aged 10–21 years.¹⁴¹

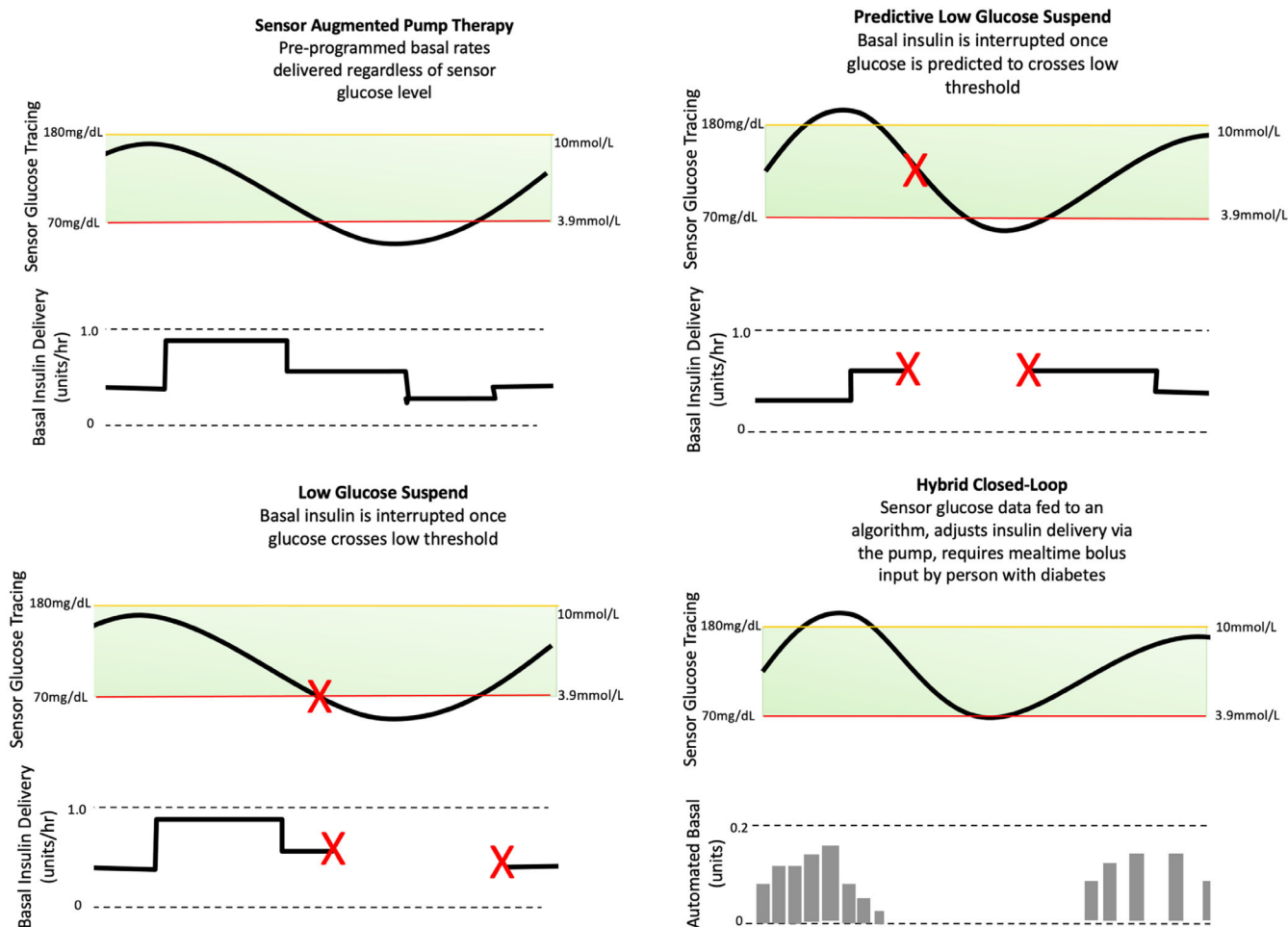


FIGURE 1 The evolution of insulin delivery technologies used in clinical care. Sensor glucose tracings are represented in black with time in target range 3.9–10 mmol/L (70–180 mg/d) represented in green. Discrete basal insulin delivery in units/h is noted in the bottom panel for each technology, except for hybrid closed loop where there is automated basal insulin delivery represented with the gray spikes. Red Xs mark both the glucose level when insulin suspension occurs as well as the start and stop of the suspension period on the basal insulin delivery graphs

7 | LGS SYSTEMS

7.1 | Reducing the severity and duration of hypoglycemia

With CGM data integrated into an algorithm on an insulin pump, altering insulin delivery based on sensor glucose readings is possible. The LGS system can suspend insulin delivery when the sensor glucose reaches a programmed low threshold (Figure 1). The insulin pump suspension lasts for 2 h in the absence of user intervention although the pump can be manually restarted at any time. The LGS feature is optional, and the pump functions normally if the feature is switched off, if sensor glucose data are not available, or if the sensor glucose value is above the predetermined threshold value.^{142,143} Feasibility data on the efficacy and safety of LGS from early closed loop studies demonstrated that insulin suspension mitigated hypoglycemia risk.^{135,144} LGS systems reduce risk of hypoglycemia, which may facilitate user engagement with bolusing.

LGS system benefits were first demonstrated in the real-world setting through the Automation to Simulate Pancreatic Insulin Response (ASPIRE) in-home study that enrolled participants with T1D aged 16–70 years. Sensor readings of <3.9 mmol/L (<70 mg/dl), <3.3 mmol/L (60 mg/dl), and <2.8 mmol/L (50 mg/dl) were significantly reduced without any deterioration in glycemia as measured by HbA1c with use of the LGS system.¹⁴⁵ Additionally, glucose levels remained stable even 2 h post nocturnal insulin suspension.¹⁴⁵ Another RCT that included younger people with T1D (mean age of pump users was 19.7 years vs 17.4 years in the LGS group) who had impaired hypoglycemia awareness also showed that LGS reduced the rate of severe and moderate hypoglycemia.¹⁴⁶ While the control group using insulin pumps and SMBG had 6 SH events, the LGS arm had none.¹⁴⁶ Nocturnal hypoglycemia was reduced without increases in HbA1c or episodes of DKA.¹⁴⁶ Real world observational studies leveraging data uploaded to CareLink, where age was self-reported and more than half of the participants were <15 years old, have substantiated the RCT findings showing benefits of LGS over SAP.¹⁴⁷

The possible risk of hyperglycemia or DKA occurring due to insulin suspension in response to inaccurate sensor readings had been a concern prior to approval of LGS devices. This concern was addressed in a study that suspended insulin for 2 h overnight in a preprogrammed fashion for people at home, provided that pre-bedtime blood glucose was <16.7 mmol/L (300 mg/dl) and beta hydroxybutyrate was <0.5 mmol/L.¹⁴⁸ A total of 118 suspend nights and 131 non-suspend nights were included.¹⁴⁸ There was wide variation in the fasting blood glucose, but the mean fasting glucose levels on suspend nights was only 2.8 mmol/L (50 mg/dl) higher than non-suspend nights. Blood beta hydroxybutyrate levels were slightly higher in the morning after suspension of insulin but the difference was not statistically significant.¹⁴⁸ This suggests that LGS is safe even in the face of potentially inaccurate sensor glucose readings.¹⁴⁸

While more advanced insulin pump therapies are now available and include PLGS and AID systems described below, one should be aware that advanced pumps are not available in all countries and may not be covered by certain health/insurance plans. In such circumstances, where LGS insulin pumps are available this insulin delivery modality is strongly recommended over other types of pumps. Studies have shown that LGS is cost-effective and should be particularly considered where there is a high risk of hypoglycemia, impaired hypoglycemia awareness or fear of hypoglycemia, which may lead to difficulty with achievement of glycemic targets.¹⁴⁹⁻¹⁵¹

8 | PLGS SYSTEMS

8.1 | Mitigating hypoglycemia: the benefits of predictive low glucose suspend

PLGS systems interrupt basal insulin delivery to prevent hypoglycemia (Figure 1). Different systems are available; however, not all provide published evidence for successful use and therefore only systems with published peer reviewed data are recommended for use.¹⁵² Early prototype PLGS systems requiring a bedside laptop showed the benefits of predictive insulin interruptions¹⁵³⁻¹⁵⁵ and highlighted the safety of a PLGS system, as frequency of morning ketosis, defined as BHB >0.6 mmol/L, was not different between the PLGS and SAP.^{156,157} This supports that there is no need for daily assessment of ketones for people using PLGS systems. Instead, ketones should be measured when glucose is persistently elevated or in the setting of illness, which is the same advice given to anyone on pump therapy.

The MiniMed™ 640G, 670G, 770G, and 780G systems (Medtronic, Northridge, CA) all offer the PLGS, which in these systems interrupts insulin delivery if the sensor glucose is predicted to reach 1.1 mmol/L (20 mg/dl) above the pre-set low glucose limit within 30 minutes. The system automatically resumes basal insulin delivery after recovery from hypoglycemia, with suspension duration ranging from a minimum of 30 minutes to a maximum of 120 minutes. Under experimentally-induced hypoglycemia through increased basal rates in an in-clinic setting, the system avoided hypoglycemia most of the time.¹⁵⁸ Two RCTs have been conducted with this system: one study

($n = 100$) showed a reduction in hypoglycemia events with PLGS use, but this group had a concomitant rise in the time spent in the hyperglycemia range, while the other trial ($n = 154$) showed a reduction in time spent <3.5 mmol/L (<63 mg/dl), with no deterioration in glycemia, as measured by HbA1c, in the PLGS group.^{159,160}

Using data uploaded to CareLink, a real-world assessment of children <15 years, demonstrated that those on PLGS spent less time per day with sensor glucose in level 1 [<3.9 mmol/L (<70 mg/dl)] and level 2 hypoglycemia [<3.0 mmol/L (<54 mg/dl)] when compared to those on either SAP or LGS.¹⁴⁶ A subset of participants who switched from SAP to PLGS decreased monthly rate of sensor hypoglycemic events <3 mmol/L (<54 mg/dl) and <3.9 mmol/L (<70 mg/dl) by 49% and 32%, respectively.¹⁴⁷

The Tandem t:slimX2 insulin pump with Basal IQ™ Technology (Tandem, San Diego, CA), is another PLGS which integrates the Dexcom sensor. While the suspension threshold is fixed to 4.4 mmol/L (80 mg/dl), the minimal duration of interruption is 5 minutes and insulin delivery will resume after any rise of sensor glucose values. A RCT of this system found that PLGS use led to a 31% reduction in sensor time <3.9 mmol/L (<70 mg/dl).¹⁶¹ Real world registry data from adults using the Tandem systems show a significant reduction in time below range after PLGS start¹⁶² and a 45% risk reduction for sensor time <3.9 mmol/L (<70 mg/dl) with no change in mean glucose.¹⁶³ After starting on the system, adults with T1D/caregivers of minors reported more device satisfaction and less diabetes impact on life with these findings sustained over 6-months of follow up.¹⁶⁴

A meta-analysis including data on 493 children in 5 RCTs concluded that there is high quality evidence that PLGS is superior to SAP in decreasing time spent in hypoglycemia and nocturnal hypoglycemia.¹⁵² This was accomplished without increasing percentage of time spent in hyperglycemia or episodes of DKA.¹⁵² Another meta-analysis concluded use of PLGS during the overnight period was associated with an 8.8% lower risk of hypoglycemia when compared with non-PLGS overnight.¹⁶⁵

8.2 | Practical considerations for SAP, LGS, and PLGS

Critical to the integration of SAP, LGS, and PLGS is successful adoption of sensor therapy. For evidence on sensor therapy, please refer to the ISPAD 2022 Consensus Guidelines Chapter 16 on Diabetes technologies: glucose monitoring. Topics that should be considered when initiating these therapies may include expected frequency of sensor use, and how treatment may vary when breaks from sensor therapy may occur.¹⁶⁶ This may be especially important in those utilizing systems that suspend insulin delivery as behavioral changes may be needed to mitigate the risk of hypoglycemia when the system is not being used.

With both LGS and PLGS system, alarms can be set for when pump suspensions occur. Yet, the usefulness of these alarms should be considered. For example, with PLGS systems that are designed to mitigate hypoglycemia, an insulin suspension alert would not indicate

the need for user intervention and thus it could be viewed as disruptive or burdensome to the person with diabetes. Instead, setting actionable alerts and alarms is critical, like setting a low alert threshold so rapid-acting carbohydrates can be used to treat hypoglycemia. Furthermore, with LGS systems people with diabetes should be encouraged to allow the system to work overnight, but if an alert occurs during the day they should consume carbohydrates and resume basal insulin delivery. With a PLGS system, should a hypoglycemic event occur despite insulin suspension, carbohydrate intake may need to be decreased to 5–10 g as compared to usual treatment strategies to prevent rebound hyperglycemia. Access to data from diabetes devices is essential to providers; these reports allow for more refined analyses, which can be used to determine insulin suspension frequency and whether changes in insulin doses and/or treatment for hypoglycemia are required.

9 | AID

AID systems, also referred to as closed loop (CL) or artificial pancreas systems, adjust insulin delivery in response to sensor glucose data. AID is safe and effective at reducing HbA1c and increasing TIR in children and is strongly recommended. With AID use quality of life improvements have also been noted in children with diabetes and their caregivers.

9.1 | AID approaches

AID systems consist of three components: an insulin pump, a CGM sensor, and an algorithm that determines insulin delivery. Several algorithms have been widely tested: proportional integrative derivative (PID),^{167,168} model predictive control (MPC),¹⁶⁹ and fuzzy logic.¹⁷⁰ PID alters insulin delivery according to the difference from target glucose (proportional), the area under the curve between measured and target glucose (integral), and the rate of change of measured glucose (derivative).^{171,172} MPC predicts glucose concentrations over a predetermined time horizon to inform insulin delivery.¹⁷³ The fuzzy logic controller modulates insulin delivery based on a set of rules that imitates the reasoning of diabetes practitioners, which in turn are based on common medical knowledge and the experience of traditional treatment.¹⁷² Currently there is no “optimal” algorithm; comparisons among different control algorithms^{174–176} have been hindered by heterogeneous experimental designs.¹⁷⁴

Besides control mechanisms, AID systems have other differentiating features. Early, fully CL studies demonstrated significant postprandial glycemic excursions and led to the use of a “hybrid” approach, meaning the user needs to manually bolus for carbohydrate intake.¹⁶⁸ With hybrid closed loop (HCL) only basal insulin delivery is adjusted based on sensor glucose values. Building on this, advanced hybrid closed loop (AHCL) systems incorporate automated correction boluses as part of the algorithmically modulated insulin delivery. Therefore, the differentiation between manual, or user initiated, and automated

insulin delivery may be more meaningful than the classic categorization of insulin delivery as being either basal or bolus.

System targets are set in one of two ways; a treat-to-target approach with a single target glucose [e.g., 5.8 mmol/L (105 mg/dl)] or treat-to-range approach [e.g., 6.2–8.9 mmol/L (112–160 mg/dl)].¹⁷²

9.2 | Benefits of AID

AID performance has been explored in controlled highly supervised in-clinic or transitional environments like hotels and camps.^{177,178} These trials clearly demonstrated increased TIR and a concomitant reduction in time below range and led to home setting assessments.

Some outpatient trials of these devices have been conducted using an RCT design,^{179–187} while others have been single arm trials.^{188–194} The RCTs have demonstrated the efficacy of both HCL and AHCL to achieve ~10%–15% increase TIR (3.9–10 mmol/L, 70–180 mg/dl) when compared to conventional pump therapy, SAP, PLGS, or HCL to ACHL.^{179–187} Similar findings in change in TIR from baseline data collection periods have been noted in the single-arm trials.^{188–194} (Table 3). These findings hold true regardless of the age of participants; importantly AID benefits have been demonstrated in very young children aged 2–5 years, children aged 6–13 years, adolescents, and young adults (Table 3). In addition to the increased TIR, longer outpatient studies have also demonstrated that AID use has led to a concomitant reduction in HbA1c by 0.3%–0.7%.^{179,181–185,187–194}

A post-hoc analysis conducted on data from the Diabetes Control and Complications Trial (DCCT), demonstrated that a 10% lower TIR was strongly associated with risk of retinopathy progression and development of microalbuminuria (hazard rates of 64% and 40%, respectively).³⁰ Importantly, this data was derived from 7-point finger-stick testing conducted during daytime hours in the DCCT, and so it may underestimate the true TIR. Yet, it would imply that the observation of ~10% increase in TIR in recent clinical trials of AID systems will decrease rates of microvascular complications in youth using these systems.

9.3 | Initiating AID and persisting with system use

Historically, determining ideal candidates for initiating diabetes technology use has often been based on how engaged a person with diabetes, or for children their caregivers, are with diabetes management. Engagement could be demonstrated by performing a minimum number of glucose checks per day, attending a certain threshold of medical visits per year, or achieving a target HbA1c level as a crude proxy estimate for treatment adherence.¹⁹⁵ Yet, these criteria are not evidence-based, may introduce substantial bias into determining who would be suitable candidates, and deny access to technology for children who could benefit greatly. This bias could contribute to disparities noted in device access. Data from the Control IQ pivotal trial demonstrated

TABLE 3 Automated Insulin Delivery (AID) studies that have enrolled very young children, children, and adolescents

AID system	Study duration and design	Comparison group/ baseline data collection on	Population	Baseline	Glycemic outcomes assessed	Difference [between groups or from baseline]
Very young children						
Medtronic 670 G ¹⁸⁸	3-month, single arm- study	Baseline pump or SAP	N = 46 Age 4.6 ± 1.4 years	HbA1c 8.0 ± 0.9% TIR 55.7 ± 13.4	HbA1c 7.5 ± 0.6% TIR 63.8 ± 9.4%	ΔHbA1c -0.5% ΔTIR +8.1%
CamAPS ¹⁷⁹	16-week per treatment, two period, randomized crossover trial	HCL SAP	N = 74 [N = 39 HCL and N = 35 SAP first group] / Age 5.6 ± 1.6 years	HbA1c 7.3 ± 0.7% TIR 61.2 ± 10.1%	HbA1c 6.6 ± 0.6% TIR 71.6 ± 5.9% HbA1c 7.0 ± 0.7% TIR 62.9 ± 9.0%	ΔHbA1c -0.4% ΔTIR +8.7% [paired differences]
Medtronic 670G ¹⁸⁷	8-week per treatment, randomized, controlled, crossover trial	HCL SAP	N = 18 Age 5.4 ± 1.1 years	HbA1c 7.0 ± 0.7% TIR 65.9 ± 12.6%	HbA1c 6.7 ± 0.3% TIR 72.7 ± 6.1% HbA1c 6.8 ± 0.3% TIR 67.5 ± 9.6%	ΔHbA1c -0.3% from baseline ΔTIR +6.8% from baseline
Omnipod 5 ¹⁹⁴	3-month single arm-study	Baseline MDI, pump, SAP, HCL	N = 80 Age 4.7 ± 1.0 years	HbA1c 7.4 ± 1.0% TIR 57.2 ± 15.3%	HbA1c 6.9 ± 0.7% TIR 68.1 ± 9.0%	ΔHbA1c -0.55 ΔTIR +10.9%
Children (6–13 years)³						
Medtronic 670 G ¹⁹³	3-month single arm-study	Baseline pump or SAP	N = 105 Age 10.8 ± 1.8 years	HbA1c 7.9 ± 0.8% TIR 56.2 ± 11.4%	HbA1c 7.5 ± 0.6% TIR 65.0 ± 7.7%	ΔHbA1c -0.4% ΔTIR +8.8%
Medtronic 670G ¹⁸⁷	8-week per treatment, randomized, controlled, crossover trial	HCL SAP	N = 20 Age 11.6 ± 1.7 years	HbA1c 7.7 ± 0.9% TIR 55.1 ± 11.6%	HbA1c 7.1 ± 0.5% TIR 69.1 ± 7.8% HbA1c 7.5 ± 0.7% TIR 53.9 ± 14.1%	ΔHbA1c -0.6% from baseline ΔTIR +14%
Omnipod 5 ¹⁸⁹	3-month single arm-study	MDI, pump, SAP, HCL	N = 112 Age 10.3 ± 2.2 years	HbA1c 7.67 ± 0.95% TIR 52.5 ± 15.6%	HbA1c 6.99 ± 0.63 TIR 68.0 ± 8.1%	ΔHbA1c -0.71% ΔTIR +15.6%
DiabeLoop Generation 1 (DBLG1) ¹⁸⁶	6-week cross-over study [outpatient phase]	HCL SAP	N = 17 Age 8.2 ± 1.6 years	HbA1c 7.2 ± 0.5% TIR n/a	HbA1c n/a TIR 66.2 ± 1.5% HbA1c n/a TIR 58.7 ± 1.5%	ΔHbA1c n/a ΔTIR +7.5%
Tandem Control IQ ¹⁸³	16-week RCT, parallel group	AHCL SAP	N = 78 Age 11.3 ± 2.0 years N = 23 Age 10.8 ± 2.4 years	HbA1c 7.6 ± 1.0% TIR 53 ± 17% HbA1c 7.9 ± 0.9% TIR 51 ± 16%	HbA1c 7.0 ± 0.8% TIR 67 ± 10% HbA1c 7.6 ± 0.9% TIR 55 ± 13%	ΔHbA1c -0.4% ΔTIR +11%
Adolescents and adults (>14 years)						
Medtronic 670G ^{191,192}	3-month single arm-study	Pump or SAP	N = 124 Age 21.7 years Adolescent cohort N = 30 Age 16.5 ± 0.9 years	HbA1c 7.4 ± 0.9% TIR 66.7% ± 12.2% Adolescent cohort HbA1c 7.7 ± 0.84% TIR 60.4% ± 10.9%	HbA1c 6.9 ± 0.6% TIR 72.2% ± 8.8% Adolescent cohort HbA1c 7.1 ± 0.6% TIR 67.2% ± 8.2%	ΔHbA1c -0.5% ΔTIR +5.5% From baseline Adolescent cohort ΔHbA1c -0.6% ΔTIR +6.8% From baseline

(Continues)

TABLE 3 (Continued)

AID system	Study duration and design	Comparison group/ baseline data collection on	Population	Baseline	Glycemic outcomes assessed	Difference [between groups or from baseline]
Medtronic 670G vs AHCL ¹⁸⁴	12-week per treatment, two period, randomized crossover trial	AHCL	N = 113 Age 19 ± 4 years	HbA1c 7.9 ± 0.7% TIR 57% ± 12%	HbA1c 7.4 ± 0.8% TIR 67% ± 8%	ΔHbA1c -0.5% ΔTIR +10% From baseline
Medtronic 780G ^{190a}	4-week per treatment, two period, randomized crossover trial	AHCL	N = 60 Age 23.5 years	HbA1c 7.6 TIR 59.0 ± 10.4	HbA1c n/a TIR 70.4 ± 8.1%	ΔHbA1c n/a ΔTIR +14.4% [paired difference]
Medtronic 780G A- HCL ¹⁹⁰	3-month single arm-study or HCL	PLGS	N = 39 Age 16.2 ± 2.1 years	HCL (Medtronic 670G)	HbA1c n/a TIR 57.0 ± 11.7%	
Medtronic 780G A- HCL ¹⁹⁰	3-month single arm-study or HCL	Baseline with pump, SAP, or HCL	N = 157 Age 38.3 ± 17.6 years Adolescent cohort	HbA1c 7.5 ± 0.8% TIR 68.8 ± 10.5% Adolescent cohort	HbA1c 7.0 ± 0.5% TIR 74.5 ± 6.9% Adolescent cohort	ΔHbA1c -0.5% ΔTIR +5.7% Adolescent cohort
Cambridge MPC (Medtronic 640G pump and Enlite 3 sensor) ¹⁸¹	3-month, two-arm randomized controlled trial	SAP	N = 39 Age 16.2 ± 2.1 years	HbA1c 7.6 ± 0.8% TIR 62.4 ± 9.9%	HbA1c 7.1 ± 0.6% TIR 72.7 ± 5.6%	ΔHbA1c -0.5% ΔTIR +10.4%
Tandem Control IQ ¹⁸²	6-month randomized controlled trial	SAP	N = 46 Age: 22 (range 13–36) years	HbA1c 8.0 ± 0.6% TIR 52 ± 10%	HbA1c 7.4 ± 0.6% TIR 65 ± 8%	ΔHbA1c -0.36% ΔTIR +10.8%
Ornipod 5 ¹⁸⁹	3-month single-arm study	SAP	N = 40 (control) Age: 21 (range 11–36) years	HbA1c 7.8 ± 0.6% TIR 52 ± 9%	HbA1c 7.7 ± 0.5% TIR 54 ± 9%	
Tandem Control IQ ¹⁸²	6-month randomized controlled trial	AHCL	N = 112 Age 33 ± 16 years	HbA1c 7.4 ± 0.96% TIR 61 ± 17%	HbA1c 7.06 ± 0.79% TIR 71 ± 12%	ΔHbA1c -0.33% ΔTIR +11%
Ornipod 5 ¹⁸⁹	3-month single-arm study	SAP	N = 56 Age 33 ± 17 years	HbA1c 7.4 ± 0.76% TIR 59 ± 14%	HbA1c 7.39 ± 0.92% TIR 59 ± 14%	
Diabeloop Generation 1 (DBLG1) ¹⁸⁵	12-week per treatment, two period randomized crossover trial	MDI, pump, SAP or HCL	N = 128 Age 36.9 ± 13.9 years	HbA1c 7.16 ± 0.86% TIR 64.7 ± 16.6%	HbA1c 6.78 ± 0.68% TIR 73.9 ± 11.0%	ΔHbA1c -0.38% ΔTIR + 9.3%
Diabeloop Generation 1 (DBLG1) ¹⁸⁵	12-week per treatment, two period randomized crossover trial	HCL	N = 63 Age 48.2 ± 13.4 years	HbA1c 7.6 ± 0.9% TIR n/a	ΔHbA1c from baseline -0.29% TIR 68.5 ± 9.4%	ΔHbA1c -0.15% ΔTIR +9.2% [paired difference]
		SAP			ΔHbA1c from baseline -0.14% TIR 59.4 ± 10.2%	

Note: ΔHbA1c and ΔTIR indicates the difference from baseline or between groups of HbA1c and time in range 3.9–10 mmol/L (70–180 mg/dl), respectively.

Abbreviations: A-HCL, advanced hybrid closed loop; AID, automated insulin delivery; HbA1c, hemoglobin A1c; HCL, hybrid closed loop; MDI, multiple daily injections; SAP, sensor augmented pump; PLGS, predictive low glucose suspend; TIR, time in range 3.9–10 mmol/L (70–180 mg/dl).

^aFor studies including those age 6–13 years but limited data by age group they are included in the table under adolescent/adult data.

that, while all participants in the 14–71 year old cohort had improved TIR, those with baseline HbA1c $\geq 8.5\%$ had the greatest reduction in time above range, while those with HbA1c $< 6.5\%$ primarily benefited from reductions in time below range.¹⁹⁶ Recently, real-world Control IQ system data from those age ≥ 6 years have demonstrated that those with a higher initial glucose management index (GMI), which estimates average HbA1c concentration based on mean sensor glucose values, showed substantial improvement over time.¹⁹⁷ Real-world use analyses of 670G use in 14,899 users (no age demographics provided), demonstrated that for those with a GMI $< 7\%$, TIR improved slightly from 76.1% to 78.7%, while for the group whose GMI was $> 8\%$, improvement was more substantial from 34.7% to 58.1%.¹⁹⁸ These data provide compelling evidence that all with diabetes can benefit from advanced diabetes technologies and providers should not limit access to this therapy. Additionally, they should seek to advocate for their safe incorporation into the management plan and provide education and support to help children and families use the devices consistently and as intended.

Once technology use has begun, persistent use is essential for success. Users have reported that system-mandated exits (user has to revert to using conventional pump settings because automation is unavailable) can lead to user frustration and ultimately discontinuation of device use.^{199,200} A real-world prospective trial with the first HCL system with 80 participants, of whom 30% were < 18 years old, noted more than half of the participants, despite endorsing adequate training on the system, experienced sleep interruption due to alarms and 40% did not like the frequency of system-initiated reversion to open loop insulin.²⁰¹ Next generation systems have benefited from continued evolution, incorporate factory calibrated sensors and have eliminated numerous mandated exits. The need to revert to open loop is primarily dictated by times when sensor data are not available. Real-world assessment of device use has shown increased wear times with both the Tandem t:slim X2 with Control-IQ™ (Tandem, San Diego, CA) and the MiniMed™ 780G system (Medtronic, Northridge, CA).^{202–204} Yet, it is imperative that people with diabetes, and their families, have realistic expectations of what devices can and cannot do and receive training on system use. This is reviewed further below in the behavioral section.

9.4 | Questioning the need for alternative approaches: Diluted insulin and do-it-yourself (DIY) systems

9.4.1 | Diluted insulin

Prior to recent trials, consideration had been given to the use of diluted rapid-acting insulin analogs in AID for very young children to reduce mechanical delivery errors and enable more consistent absorption due to the larger volume of the subcutaneous insulin depot. Although early studies performed in controlled settings^{125–127} showed reduced glycemic variability and lower risk of time below range with diluted insulin¹²⁵ a subsequent 3-week outpatient RCT conducted in children aged 1–7 years, did not demonstrate any benefit of diluted insulin when compared to a standard U100 rapid-acting

analog.²⁰⁵ Importantly, this study also highlighted that, compared to other age cohorts, very young children have higher day-to-day variability in insulin requirements.²⁰⁶ This supports the recommendation for rapid adoption of AID in this population as other insulin delivery modes cannot respond to the constant changes in insulin needs.²⁰⁶

9.4.2 | Open-source systems

Recognizing the inherent delays in conducting clinical trials and obtaining regulatory approval for new technologies, the past decade has seen the creation of open-source automated insulin delivery systems. Through an online community, the DIY approach has been adopted by several thousand people with diabetes and their families. In silico studies have demonstrated the relative safety of the system through simulations with both meal bolus over- and underestimation as well as what might occur with delayed bolusing.²⁰⁷ Additionally, a real-world prospective observational study in 558 users, with more than half being < 25 years old, showed improvement in TIR and reductions in the incidence of severe hypoglycemic events with system use, suggesting these systems can be used safely and effectively.²⁰⁸ As these systems do not have regulatory approval, health care professionals should be cautious about recommending these devices in preference to commercially available systems. Yet, when people with diabetes choose to use an open-source system, a consensus statement suggests that providers should support them.²⁰⁹ Recently, an RCT in those aged 7–70 years comparing use of an open-source AID to a control group using CGM showed an increase in TIR of 10% in the AID group leading to an adjusted difference between groups of 14%.²¹⁰

9.5 | Additional strategies to improve automated insulin delivery

People using AID often experience postprandial hyperglycemia. Several mitigation strategies have been tried. Ultra fast-acting insulin analogs have not demonstrated clinical benefits in short duration trials.^{211–213} Intraperitoneal insulin delivery has also been proposed^{214,215} with short duration studies showing increased TIR of 4.4–7.8 mmol/L (80–140 mg/dl).²¹⁶ Additionally, inhaled insulin has been tested in conjunction with AID during meals and led to reduced glycemic excursions and improved postprandial glucose levels; further exploration of this strategy may be warranted.²¹⁷ In addition to optimizing glycemia, this approach could reduce the peripheral hyperinsulinemia of subcutaneous insulin delivery, which may also lower risk of macrovascular complications.^{218–220} For both intraperitoneal and inhaled insulin delivery, longer and larger scale studies are needed.

Adjunctive non-insulin therapies have also been tested with AID to mitigate post-meal glucose excursions. These proof-of-concept or short feasibility trials, lay the groundwork for potential use of agents like pramlintide, glucagon like peptide-1 (GLP-1) analogs, and sodium glucose cotransporter inhibitors.^{221–223} Finally, the use of a bi-hormonal AID system that integrates both insulin and glucagon infusions has

TABLE 4 Modified CARES approach to understand and optimize AID use²³⁶

	Questions	Potential Implications
<u>C</u> alculate	<p><i>How does the system CALCULATE insulin delivery?</i></p> <p>Identify the key features of insulin delivery algorithm (e.g., treat to target vs. treat to range)</p> <p>Which components of insulin delivery are automated?</p>	<ul style="list-style-type: none"> • Basal rate modulation • Automated Correction boluses • Meal identification
<u>A</u> adjust	<p><i>How can the user ADJUST insulin delivery?</i></p> <p>Which parameters can be ADJUSTED to individualize insulin delivery during automation (e.g., setting optimization for each system and age group)?</p> <p>Which parameters are fixed?</p>	<ul style="list-style-type: none"> • Insulin to Carbohydrate Ratios • Correction factors/Sensitivity Factors • System targets/setpoints • Duration of insulin action • Basal rates <p>Review settings that do not impact or cannot be altered during automation</p>
<u>R</u> ever	<p><i>When does (should) the system REVERT to open loop insulin delivery?</i></p> <p>When should the user choose to REVERT to open loop/no automations?</p> <p>When will the system default to open-loop/no automation?</p>	<p>Identify times when the user should <i>choose to revert to open loop</i> (ketosis, steroid use)</p> <ul style="list-style-type: none"> • Identify reasons for <i>system mandated exits</i> to open-loop • Seek to minimize frequency of these events
<u>E</u> ducate	<p><i>What are important factors in regard to EDUCATION about the system and setting appropriate EXPECTATIONS?</i></p> <p>What are the key EDUCATION points for the advanced diabetes device?</p> <p>What are the user expectations?</p> <p>Where can users and clinicians find additional EDUCATION?</p>	<p>Essential training (tips and tricks, best practices, necessary skills)</p> <ul style="list-style-type: none"> • Discuss frequency of sensor wear and time anticipated in automation • Create individualized goals for HbA1c targets and TIR • Identify system limitations (e.g., postprandial glycemia) <p>Identify verified source of education, which may include those developed by</p> <ul style="list-style-type: none"> • Manufacturers • Professional societies • Academic groups • Diabetes Advocacy Groups/Online communities
<u>S</u> ensor/ <u>S</u> hare	<p><i>What SENSORS pair with the system? What are the SHARE capabilities?</i></p> <p>What are the relevant SENSOR characteristics for each paired sensor?</p> <p>What are the system capabilities for remote monitoring and cloud-based data sharing?</p>	<p>Identify the need for calibration and therapeutic blood glucose requirements, duration of sensor wear, transmitter characteristics</p> <ul style="list-style-type: none"> • Review options for data sharing • Strategize the use of sharing options according to individual needs • Identify privacy options (if any)

been an area of intense interest with promising findings from initial trials.^{224–228} With the advent of stable liquid glucagon, testing of systems for commercial approval is now underway.²²⁹

Adapting for physical activity also remains problematic. Studies have explored bi-hormonal systems, reduction of pre-meal boluses prior to exercise, administration of a snack just prior to exercise, and integration of alternate signals like heart rate monitors to detect exercise.^{230–234}

9.6 | Practical considerations for AID

To ensure success with adoption of AID technology, it will be important for clinicians to have a framework to integrate its use. The

“CARES” strategy has been suggested to help clinicians conceptualize the differences between AID systems.^{235,236} CARES can assist clinicians by posing five fundamental questions related to the person with diabetes and the proposed device (Table 4).

Tools to assist people with diabetes compare devices with their clinicians will be of great benefit. Some resources include the American Diabetes Association consumer guide (<https://consumerguide.diabetes.org>), Diabetes Wise (<https://diabeteswise.org/>), and the Panther Program (<https://www.pantherprogram.org>).

Systematic training of people transitioning to hybrid closed loop and advanced closed loop therapy is essential.^{237–239} People with diabetes should be guided on methods to manage exercise. See ISPAD 2022 Consensus Guidelines Chapter 14 on Exercise in children and

adolescents with diabetes. Carbohydrate intake required for treatment of mild hypoglycemia often only requires 5–10 g with AID systems and may need to be reduced in the context of prolonged basal insulin suspension with other devices.

10 | BEHAVIORAL, PSYCHOSOCIAL, AND EDUCATIONAL CONSIDERATIONS OF INSULIN DELIVERY DEVICES

Uptake and sustained use of insulin delivery devices are associated with behavioral and psychosocial factors, including self-management demands, emotional considerations, family experiences, and social variables. Such factors may promote (e.g., supportive family involvement) or be barriers (e.g., diabetes distress) to optimal engagement in self-management behaviors. ISPAD 2022 Consensus Guidelines Chapter 15 on Psychological Care of children and adolescents with type 1 diabetes and the American Diabetes Association³² highlight the importance of attending to the psychosocial needs of youth with diabetes and their families, which has implications for optimal use of diabetes technologies including insulin delivery devices.

Youth with T1D who use insulin pumps tend to experience benefits in health-related quality of life compared to MDI.^{240–242} Parents may also experience improved quality of life.²⁴³ Specific perceived benefits of pump therapy include increased autonomy in diabetes management, decreased diabetes burdens, and greater flexibility in eating.^{241,244,245} However, psychosocial factors, such as depressive symptoms, may increase the risk for discontinuation of pump use.⁹⁸

Fear of hypoglycemia is a common concern for people with diabetes and their caregivers.¹¹ LGS systems may reduce this fear, although data are limited. The CGM Timing of Initiation of continuous glucose Monitoring in Established pediatric diabetes (TIME) trial was a multicenter RCT whose primary aim was to assess the impact of CGM initiation in comparison to starting pump therapy.²⁴⁶ An exploratory sub study assessed fear of hypoglycemia using the Hypoglycemia Fear Survey.²⁴⁷ Parents and children >10 years old had significantly reduced fear of hypoglycemia after 1 year of follow up; yet this was not related to CGM adherence nor were data obtained about whether participants were using the LGS feature.²⁴⁷

Early research found youth who were potential AID system users felt trusting the system was critical for uptake; children and adolescents emphasized concerns related to use at school and with peers, while parents' concerns prioritized accuracy and ensuring that systems stabilize glucose levels and reduce risk for long-term complications.²⁴⁸ Studies of HCL systems in clinical and real-world settings suggest benefits for quality of life and well-being, including lower diabetes burden/distress (especially around meals), reduced fear of hypoglycemia and worries about glycemic excursions, less time spent thinking about diabetes, and improved treatment satisfaction.^{241,249–253} There are also indications of perceived improvements in sleep for both youth and parents.^{253,254}

However, AID device discontinuation has been estimated to occur in up to 30% of youth.^{199,200} Psychosocial and behavioral

barriers to use have been identified, including devices not being as “hands-off” as anticipated, perceived high workload required to maintain AID function, concerns about accuracy and distrust of the devices, dissatisfaction with the size/appearance of wearing multiple devices, physical discomfort, limitations to their use during physical activity or while bathing, limitations in remote monitoring access for parents, frustrations with technical glitches, and difficulties with required calibration of some devices.^{251,255,256} AID devices that use factory calibrated CGM, which eliminate/minimize the need for BG checks with a glucometer, may reduce the burden associated with AID devices and improve sustainability of use, especially in youth.²⁵⁷

Evidence from qualitative research and self-report surveys suggests that caregivers are motivated for their children to use AID systems primarily to improve glycemic outcomes, reduce diabetes care burdens, and improve sleep.^{209,258} As such, caregivers and youth may have high expectations of AID systems to drastically reduce or eliminate the need for diabetes self-management behaviors. To date, this is an unrealistic expectation, as all available AID systems require users to announce carbohydrate intake, deliver meal boluses and respond to system alerts. Evidence suggests that those youth with higher HbA1c and greater negative affect around diabetes self-management may have more positive expectations for AID device use.²⁵⁹ Additionally, less knowledge about AID devices may result in overly optimistic expectations and greater risk of dissatisfaction with the device.²⁵¹ Thus, it is critical that diabetes care teams assess expectations, educate youth and caregivers about realistic expectations for these systems, and provide referrals for any psychosocial need that may be a barrier to optimal device use.

Education and device training are important to ensure effective use of insulin pump devices and to promote sustained device use and ongoing success.^{238,239,260,261} For AID devices, a structured training program with frequent follow-up for new users is recommended to optimize device use. The training program should emphasize education on the basics of CGM use, required diabetes self-management tasks to optimize the device (i.e., pre-meal bolusing), and common troubleshooting for the specific device. It is imperative that users understand the safety principles of managing persistent hyperglycemia and infusion site failure (i.e., when to check ketones, change infusion site, and/or give insulin by injection). These principles are vital for safe use of any insulin pump therapy to prevent DKA and are equally applicable with use of advanced insulin delivery technologies. Users who discontinue HCL/AID devices are most likely to discontinue within the first 1–3 months of use.^{199,200} Therefore, follow-up within the first month of use is helpful to assess system use and glucose trends, to allow the provider or diabetes educator an opportunity to identify early any challenges the user may be experiencing, and to provide an opportunity for targeted re-education to help the user overcome challenges and improve outcomes. Further, youth may benefit from adjustments to any modifiable pump settings (i.e., insulin to carbohydrate ratios) to improve glycemic outcomes when transitioning from MDI or a conventional insulin pump to AID, and a follow-up call in the first month provides the opportunity for the clinician to make these changes.

In sum, the current evidence base points to psychosocial and quality of life benefits from using insulin pumps, including conventional insulin pumps, SAP, LGS, PLGS, and AID systems. As insulin pump technologies continue to advance and offer opportunities for improved glycemic outcomes, interventions to reduce barriers to technology use are actively being investigated.³⁴ However, more clinically translatable research targeted to the needs and experiences of pediatric populations is needed on the best ways to break down barriers to uptake of insulin delivery devices and technologies and to prevent discontinuation.

10.1 | Practical considerations for behavioral, psychosocial, and educational considerations of insulin delivery devices

When integrating diabetes technology into the care of youth with diabetes, families of all backgrounds should be informed about the spectrum of insulin delivery devices from conventional pumps to AID systems. Clinicians should portray the use of insulin delivery devices and technologies as an option that can be a good fit for many youth and families, provide education and encourage youth and families to review vetted websites and device informational materials. Further, it is critical for the diabetes team to recommend the most advanced device technology that the person with diabetes is interested in and to not make assumptions about interest or capability. Clinicians should refrain from having youth and families “earn” the right to use devices (i.e., achieve a certain HbA1c before considering starting a device). If payers/insurance companies require logging or other documentation prior to device approval, convey that directly to the family and advise this is not a requirement of the diabetes care practice.

Assessing barriers to device uptake and use should be part of routine clinical practice. Providers should seek to work with the youth and their family on ways to break down barriers and increase facilitators of device use. This may require referral to a psychological care provider, who can teach problem-solving skills and other behavioral strategies to support device uptake and sustained use.²⁶²

10.1.1 | Setting realistic expectations

With integration of any diabetes technology, it is critical for people with diabetes and their families to understand what devices can and cannot do. Ensuring realistic expectations for glycemic outcomes and the effort required for successful use of technologies is essential. This may be especially important in those who have suboptimal glycemia, those who have had challenges with engagement with the current treatment plan, and/or those with higher burnout/mood concerns in the past.

When transitioning to an AID system, people with diabetes and their caregivers should be advised that although glycemia will improve they should expect to experience some variability. As evidenced in the clinical trials, improvements in nocturnal glycemia are

anticipated to be the greatest. Youth with diabetes and their families must understand that glucose fluctuations will still occur, especially after meals and that people with diabetes will need to receive meal boluses to attain glycemic targets. Finally, with the transition to new devices, users should be prepared to allow at least a 1 month adjustment period. In addition to the person with diabetes and their caregiver(s) acclimating to using the new insulin delivery system, changes in the total daily insulin dose may influence how the algorithm functions; that is, the parameters for insulin delivery are linked to the total daily dose for some systems, and alterations in insulin requirements will seamlessly impact automation for systems with adaptivity. Further, adjustments to modifiable pump settings, especially insulin to carbohydrate ratios, are generally needed to optimize glycemic outcomes.

10.1.2 | Critical components of training

Standardized training is critical. Three overarching themes should be reviewed: 1. basics of device use, 2. CGM education, 3. hyperglycemia and other troubleshooting strategies. With each insulin delivery device, people with diabetes and their families should be trained on the basics of device use as well as unique features of the device (i.e., sleep or exercise features for AID systems or temporary basal rates for pumps and SAP). With any system that can alter insulin delivery based on sensor glucose values, CGM education will be a cornerstone of care. For success, with SAP, LGS, PLGs, and AID systems consistent CGM use is required. Discussing any identified challenges to CGM wear (i.e., alarm fatigue, skin irritation, inconsistent wear) and problem-solving solutions will be crucial to minimize the risk of device discontinuation. As with all subcutaneously infused insulin, there is a risk of infusion set failure, which may lead to persistent hyperglycemia and DKA. To minimize this risk, users should be advised to check for ketones if they have persistent hyperglycemia, change their infusion set, and give an insulin injection with a pen or syringe. See ISPAD 2022 Consensus Guidelines Chapter 12 on Sick day management in children and adolescents with diabetes. Clinicians should review the most common issues youth and families are likely to face and provide a framework for troubleshooting. Additionally, users should be able to call device manufacturers for additional technical assistance. This requires manufacturers to employ trained personnel to answer such calls and work with users who may have varying degrees of numeracy and literacy skills.

Clinicians should encourage families to use the AID as intended to obtain optimal outcomes. Users should be advised to avoid “tricking” the system and encouraged to “work with it, not against it”. For example, youth with diabetes and their families should only announce food intake by entering carbohydrate amounts if the person with diabetes will really eat them and follow the bolus calculator recommendations. Increases in insulin delivery by AID algorithms are incorporated into insulin on board calculations and subtracted from bolus dose calculations. Overriding the bolus calculator to give more insulin than is recommended may result in

hypoglycemia because the user may be unaware that there may be a lot of insulin on board from automated insulin delivery. Families should be counseled to trust the system; ensuring they are equipped with skills to manage unanticipated hyper- or hypoglycemia will help them feel comfortable as they develop this trust. Finally, families should be encouraged to talk to their diabetes team if they have concerns about how the algorithm is working or observe high or low blood glucose patterns that may signal needed adjustments to modifiable parameters in the pump (i.e., insulin to carbohydrate ratios, correction factor) or behavioral modifications (e.g., bolus prior to eating) to improve glycemic outcomes.

If psychosocial needs are reported or identified, refer to psychological care provider.²⁶³ For further information, see the ISPAD 2022 Consensus Guidelines Chapter 15 on Psychological Care of children and adolescents with type 1 diabetes.

11 | CONCLUSION

Just as our everyday lives have vastly changed with integration of new technologies including computers, smartphones, and the increased connectivity of devices, the technological revolution has had an enormous effect on the management of diabetes and especially modes of insulin delivery. It is reasonable to expect that in the years ahead there will be significant growth in this aspect of diabetes care and that these mechanical solutions will afford people with diabetes, and their families, improved ability to attain glycemic targets while reducing the burden of diabetes care. With integration of more physiologic insulin delivery afforded by AID systems, it is possible that the range of glucose levels that currently define target range, specifically 3.9–10 mmol/L (70–180 mg/dl) may be further tightened [e.g., 3.9–7.8 mmol/L (70–140 mg/dl)]. Data from people without diabetes highlight the exquisite regulation afforded by endogenous insulin production, with mean glucose being 5.4–5.5 mmol/L (98–99 mg/dl) and 96% of time spent in this tighter target range.²⁶⁴ The true test of new technologies will be to see how they can reduce glycemic variability while achieving greater TIR and improve quality of life. Clinicians must seek methods to remain abreast of new technology developments to optimize uptake and use. Integration of technology into clinical care will also require understanding of the cost–benefit of therapies to justify payer coverage. Indeed, as many of these technologies are expensive, further understanding of the health economics and relevant policies/regulations will provide valuable information for people with diabetes, clinicians, as well as payers.

This chapter has reviewed evidence on insulin delivery devices in children, adolescents, and young adults with the aim of providing practical advice and approaches to their use. Updates are anticipated in this rapidly evolving area of research and practice.

CONFLICT OF INTEREST

J.L.S. reports having received speaker honoraria from Eli Lilly, Insulet, Medtronic, and Zealand and serves on advisory boards of Bigfoot

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PEER REVIEW

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AUTHOR CONTRIBUTIONS

JLS reviewed the literature, drafted sections of the guidelines, oversaw completion of the first draft of the guidelines, and edited the manuscript. MS, TD, LR, TB, AG, JV, MEH and CB reviewed the literature, provided drafts of sections and edited the manuscript. LAD outlined the guidelines, reviewed the literature, edited the manuscript, and served as the senior author. The authors gratefully acknowledge the editorial assistance of Dr. Leena Priyambada.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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