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Use of Diabetes Technology in Children: Role of Structured Education for Young People with Diabetes and Families

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INTRODUCTION

The current era is witness to a technological revolution for the management of type 1 diabetes (T1D) in children. Youth with T1D are routinely using advanced diabetes technologies for glucose monitoring and insulin delivery for their day-to-day management, shifting more and more of the meticulous and calculated tasks of T1D self-care from the individual to external systems. The International Society for Pediatric and Adolescent Diabetes (ISPAD) and the American Diabetes Association (ADA) recognize the need for initial and ongoing structured education for youth and families living with diabetes in order to keep them informed and to optimize their chances of attaining benefits from technology use.[1,2]

The goal of this review is to provide an overview of diabetes technologies and the role of structured education in empowering youth and families to succeed with safe and effective use of diabetes technology aimed at optimizing glycemic control and reducing the burden of

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diabetes management. Given deficiencies in achievement of target glycemic control in youth with T1D [3], the diabetes community should utilize the available advanced diabetes technologies to help achieve target glycemic outcomes. To do so, it requires the provision of adequate education and support to avoid unrealistic expectations and increased self-care burden. This review will highlight educational approaches for youth with T1D along with their family members and other child caregivers, highlighting the pivotal roles played by multi-disciplinary members of the diabetes team. We will cover educational approaches regarding continuous glucose monitoring (CGM) devices and advanced insulin delivery systems, mainly insulin pumps with a brief discussion of smart pens and automated insulin delivery systems. Insulin pumps reduce the need for multiple daily injections and continuous glucose monitors (CGM) reduce the need for frequent fingersticks; and thus, both are welcomed by youth with T1D and their families. According to recently published data from the T1D Exchange Registry, the number of youth using technologies has increased substantially.[3] From 2010–12 to 2016–18, insulin pump use increased among children and young teens by about 20% while CGM use increased 10-fold over that time, highlighting the timeliness of this review.

Continuous Glucose Monitoring

Many patients and families seek CGM to optimize glycemic control and detect glycemic excursions.[4–7] In the past, CGM use was not always associated with HbA1c improvement in pediatric samples; however, newer CGM devices with improved performance have yielded increases in CGM uptake and use along with glycemic benefit in pediatric, adolescent, and young adult patients.[8–16] Recent data from Mulinacci et al. (2019) have shown improved glucose control and fewer diabetes-related emergency visits with early CGM initiation during the newonset period.[17] A number of professional organizations support consideration of CGM use for all children and adolescents with T1D, especially since the advent of CGM devices with improved performance and regulatory approval that includes non-adjunctive use.[18–21] Non-adjunctive CGM use allows for insulin dosing and treatment of hypoglycemia based on the CGM values without need for self-monitoring of blood glucose (SMBG) levels. Indeed, it is the non-adjunctive CGM use that reduces substantial burden of diabetes self-care. Recent data from the T1D Exchange and the German/Austrian Diabetes DPV registries show that mean HbA1c is lower among CGM users regardless of insulin delivery method, and CGM users are more likely to achieve the ADA glycemic target of HbA1c <7.5% (56% vs. 43% for DPV and 30% vs. 15% for T1D Exchange, for CGM users vs. non-users, respectively, both $P < 0.001$).[22] As interest and clinical integration in pediatrics accelerate, it is essential to educate the youth and their families about the fundamentals of CGM device components, insertion, skin care, and data interpretation to assure safe and effective use of the increasingly sophisticated systems.

As an introduction to CGM, the youth and family need to learn realistic expectations about how CGM can be incorporated into diabetes management. Patients and their families must understand the instances in which confirmatory SMBG checks must be performed for safety, such as when there is a device issue (e.g. absent number and/or directional arrow) or symptoms are incongruent with displayed value, or rapid confirmation of blood glucose value. Education includes how CGM devices measure interstitial glucose, not blood levels, and that CGM readings may not be identical to a SMBG value. It can be helpful to show the youth and family members a visual graphic of sensor placement that includes location of the sensor tip in the interstitial space (see Figure 1). The concepts of sensor lag, generally 5–10 minutes behind the blood glucose level, and factors that affect CGM accuracy are vital information for the youth and caregivers to make safe decisions regarding management.[23]

Education needs to be supportive and realistic in order to maximize uptake and continued CGM use as glycemic benefit can only be realized if the device is worn consistently. Primary barriers to device uptake and continued use in the pediatric population include cost, nuisance alerts/alarms, concerns with accuracy, discomfort, hassle of wearing devices, among others.[5,24–30] Maximizing adoption and consistent CGM use can be promoted by addressing both youth developmental stage and psychosocial parameters at the time of initiation, as well as identifying individual patient/family needs and potential provider biases.[5] (See Table 1.)

Main teaching point: CGM System Components

Topics to Review: CGM type, physical placement, site issues alerts/alarms.— Education involving device selection and component parts comprise the initial steps towards successful CGM use. A CGM device includes a sensor, which is inserted under the skin, a transmitter that receives the glucose signal, and a receiver that receives the glucose signal wirelessly and then displays the glucose value. There can be a dedicated receiver or the signal can be sent to a mobile phone by Bluetooth transmission. CGM devices are classified by modality of device insertion and timing of data delivery. The primary approach for device insertion is into the subcutaneous, interstitial space by puncturing the skin with a replaceable sensor. This approach is used for CGM devices such as the Medtronic Guardian, Dexcom, and Abbot Libre Flash. They are self-inserted every 7, 10, or, 14 days, respectively. These devices provide glucose data in real-time (rtCGM, for Medtronic and Dexcom) or by intermittent scanning (Abbott Freestyle Libre).[31] The second route for device insertion involves professional placement of an implantable sensor into the subcutaneous space with the Senseonics Eversense™ device.[31] This includes a sensor that lasts for 90 days (per FDA approval) or 180 days (per EMA approval). However, this device does not currently have FDA approval for use in the pediatric population under 18 years of age.

CGM devices are generally inserted on the arms, abdomen, buttocks/hips, or anterior thighs although different devices have received regulatory approval for only certain sites. Nonetheless, in the clinical arena, educators generally work individually with young persons and their families to identify the easiest sites for sensor insertions. Indeed, site selection and insertion can be challenging for pediatric patients, especially for the very young where available ‘real estate’, or space on the body, can be limited, especially given that the CGM device should be separated from areas of insulin delivery by three inches. Unanticipated or accidental sensor removal can be common in children, especially in young children, when the sensor can be knocked off during routine childhood activities. One can often help to ensure durability of the sensor placement with use of additional adhesive products. Occasionally, skin irritations can arise at the sites of sensor insertions. Such skin reactions can generally be handled with topical care or with barrier tapes, which should be managed on an individual basis with the health care team. Continual education and guidance around technique for insertion can help support families overcome challenges with CGM wear.[5,23,28,32]

CGM devices generally have alerts and alarms that can be set for the individual's needs. The alerts and alarms include threshold alarms that are set for high and low glucose levels. There can also be alerts for signal loss and alerts for rapidly changing glucose levels, so-called trend arrow alarms (see below). It is important to avoid too many alerts or alarms as they can be viewed as a 'nuisance' by the youth who may then tend to ignore the signals and the CGM data. Ongoing support and guidance for the youth and family are important.

Main teaching point: Glucometrics and Interpretation

Topics to Review: Data transmission, sensor lag, glucose reports, calibration, sharing data—CGM is a valuable tool for detecting and tracking of glucose levels, trends, and patterns. CGM data generally provide an updated glucose value every 5 minutes, yielding 288 readings daily. CGM data can be nearly 50-times the amount of glucose data provided by SMBG. CGM provides directional information as well as actual glucose levels. CGM data can be taught as offering an understanding of the magnitude (how high or low) as well as the direction (rising, falling, or stable) of the glucose values. Such detailed information allows both the person with diabetes and the provider to better understand cause and effect relationships between glucose values and responsible factors, related to dietary intake or exercise, for example.[23]

CGM data can be viewed in real-time to reflect glucose excursions over the past few hours or can be viewed retrospectively via downloaded reports that can be printed out for ease of review and interpretation. Such reports can be helpful visual aids for teaching youth and families about how medication, physical activity, and food affect glucose levels. Retrospective data can be viewed in multiple, adjustable formats to show daily, weekly, and monthly trends, allowing comparisons of glucose levels over time. Real-time CGM data can help families make appropriate and timely management decisions, especially when glucose levels are rapidly changing (see trend arrow section below).

A number of recent publications have highlighted the use of retrospective CGM data to help both clinicians and people with diabetes along with their family members/caregivers to understand glycemic patterns, including the impact of food, exercise, illness, stress, among other things, on glycemic control.[33,34] As noted above, retrospective CGM data can reviewed over the past few hours to the past few months. A recent publication highlights how 14 days of CGM data provide sufficient information to reflect upon the recent 3-month interval.[35] Further, data from a 2-week interval are easier to review for clinicians as well as for the youth and families. A very recent publication highlights the critical importance of assessing glucose time-in-range, generally accepted as 70–180 mg/dL (3.9–10 mmol/L),[36] which now appears on apps and downloads of most CGM devices. Youth and families can learn how to review glucose time-in-range as well as time below range, time above range, and glycemic variability in their efforts to optimize glycemic control.

Non-adjunctive CGM devices are rapidly becoming the primary source of glucose data. Thus, it is important to teach youth and their families about the potential limitations of CGM and to confirm their ability to perform SMBG when indicated. There may be need to calibrate certain CGM devices, depending upon the recommendations of the manufacturer. For other devices, there may be opportunities to calibrate at times of suspected inaccuracy or when symptoms do not match the CGM reading. SMBG calibrations should be entered into the CGM system generally when the CGM arrow is steady or indicating only modestly changing glucose levels, again according to the manufacturer's recommendations. At the time of this publication, the Dexcom CGM system is the only CGM currently approved by the FDA for treatment decisions without confirmatory SMBG and without calibration for use in the pediatric population.

Some CGM systems offer 'share' features that allow caregivers to receive RT-CGM data. The glucose data are transmitted wirelessly in real-time from the child's CGM device if the youth has a cellular or Wi-Fi-enabled device that sends the data to the 'cloud', which can then be received by others, such as parents, school nurses, or other care providers. This feature offers parents an opportunity to assist in the care of their child. Some parents elect to help with insulin dosing at lunch time during school while others may provide guidance prior to physical education by viewing the glucose trends to determine if additional carbohydrate snacking may be needed.

Generally, secondary caregivers, such as school nurses, babysitters, daycare providers, grandparents, among others, may be unfamiliar with CGM interpretation; therefore, it is prudent that they receive training from parents or by attending school nurse or caregiver classes that are often given by diabetes organizations or large pediatric diabetes centers. Such education generally includes the need for ongoing support and guidance to ensure that the continuous and often fluctuating glucose data along with frequent alerts/alarms does not overwhelm the care providers.[29]

Main Teaching Point: Trend Arrows

***Topics to review: Arrow meaning*, *trend* arrow *dose adjustments*—**As noted, CGM devices display the glucose level along with an arrow that designates the direction and the rate of change of the glucose levels (see Table 2). It is important to note that there is no standardization of the trend arrows from the different CGM devices regarding glucose rate of change. Therefore, youth and families should work with their diabetes educators and consult the manufacturer's guide. CGM devices may also include alert features that allow for alarms for rapidly changing glucose levels.

The trend arrows allow youth and caregivers to understand where the glucose levels have been and predict which direction the glucose is likely headed over the next 30 minutes or so. At meal times, insulin dosages can be adjusted upwards or downwards based upon the arrow's directionality, adding to the dose for upwards arrows and rising glucose levels or subtracting insulin from the dose for downward or falling glucose levels. Recommendations for insulin adjustments based on trend arrows from the Dexcom CGM are based on the youth's correction factor and are outlined in the recent publication by Laffel et al. (2017) in Figure 2.

Continuous Subcutaneous Insulin Infusion

Insulin pumps, or subcutaneous continuous insulin infusions (CSII), have been an important part of the management of T1D for many years. Recent data indicate that insulin pump use is the most common modality of insulin delivery for youth with T1D.[3] In the T1D Exchange registry, 60%, 74%, and 67% of youth ages <6, 6–12, and 13–17 years old, respectively, reported using an insulin pump.[3]

There is potential for benefit with insulin pump therapy, including improved glycemic control, reduced hypoglycemia, and improved quality of life. A recent meta-analysis of 25 randomized controlled trials reported a reduction of 0.32% in children and 0.42% in adults using insulin pump therapy compared with those on multiple daily injections.[37] Severe hypoglycemia is also reduced with insulin pump use compared with injection therapy in youth. [38] Furthermore, insulin pumps offer increased flexibility for the delivery of insulin at various times of the day. Families have reported higher rates of satisfaction and a better perception of their health compared with injections users.[39] Higher diabetes-specific quality of life is reported by pump users along with a decrease in the care burden reported by caregivers.[40]

Topics to Review: Operation, types, placement—It is important to ensure that youth and families understand the fundamentals of insulin delivery with an insulin pump. Specifically that basal insulin is provided continuously while prandial insulin is provided when the user programs the pump to deliver a bolus of insulin according to the planned carbohydrate intake. In addition, correction doses of insulin required at times of elevations must also be programmed for delivery by the user. Thus, it is important that youth and parents understand that while pump use may reduce some of the burdens of self-care related to frequent insulin injections, there remains substantial person input for the bolus insulin delivery. Furthermore, it is critical that the user and/or caregiver be aware of any pump dislodgement as that would prevent basal delivery and could lead to insulin deficiency within a few hours.

Education must include review of the two main types of insulin pumps: a pod pump that resides on the body with a small catheter beneath the skin in the subcutaneous tissue or pumps that utilize an infusion set into the subcutaneous tissue connected via tubing to the actual pump. Both pump types can be placed on the arms, abdomen, buttocks/hips, or anterior thighs.

Structured education can be provided in group classes or one-on-one. It is important that youth and families receive realistic expectations about pump therapy and recognize the ongoing need for substantial self-care behaviors to ensure safe pump use. Understanding insulin action, carbohydrate counting, correction doses, and sick day management is critical for safe pump use. In particular, deficient understanding of insulin action can result in insulin stacking and severe hypoglycemia.

Topics to Review: Potential challenges with pump therapy—Table 1 provides a list of common pump challenges and educational opportunities. Pump use requires families to monitor blood glucose and ketone levels frequently in order to detect pump failure in a timely manner. Most failures are the result of a dislodged infusion site. Insulin pump failure can lead to diabetes ketoacidosis (DKA). Fortunately, recent data from children in England, Wales, Germany, Austria, and the United States did not show higher rates of DKA in those on insulin pumps compared with injection therapy.[41] The cost of insulin pump therapy is another factor that parents may worry about when considering insulin pump therapy.[42] The cost of the insulin pump, infusion sets, and supplies can be expensive for families.[43]

To best prepare youth and families for success and best manage the challenges with CSII, structured education is needed. Healthcare providers' approach to educating families varies around the globe. For example, in France, youth may be hospitalized for a few days to start the pump while in New Zealand, there can be substantial within country variation, including both inpatient and outpatient training.[44] Their approach also varies with timing of the discontinuation of long acting insulin and the use of CGM to assist with dosage changes.

The timing of when to initiate insulin pump use after diagnosis also varies. A recent study has indicated safe and effective use of insulin pump therapy at or shortly after diagnosis.[45] In another recent study that included a randomized controlled trial, there was no clinical difference between pump therapy and injection regimens during the first year of diagnosis.[46] In the United Kingdom, the Dose Adjustment for Normal Eating (DAFNE) trial showed that structured education for adults was beneficial for glycemic control improvement and benefits to quality of life.[47] Specifically, for pump education, after attending the 5-day pump education DAFNE course also yielded a reduction in severe hypoglycemia and improved psychosocial outcomes after 6 months. The DAFNE course covers the topics noted above, including: insulin action, dosing, reducing hypoglycemia risk, sick day management, and insulin pump problem-solving.[47] Specifically for pump education, a 5-day pump education DAFNE course also yielded a reduction in severe hypoglycemia and improved psychosocial outcomes after 6 months. The DAFNE course covers the topics noted above and in the table, including insulin action, dosing, reducing hypoglycemia risk, sick day management, and insulin pump problem-solving. [47] There has been a parallel, structured 5-day education course developed for youth with T1D, called KICk-OFF.[48] This program has been evaluated in a clustered-randomized clinical trial involving teens with T1D.[49] This study demonstrated improved quality of life outcomes in those receiving KICk-OFF compared with usual care 6 and 12 months following the structured education program although there were no differences in glycemic control. Such educational topics are usually covered repeatedly for youth with T1D and their families as refresher education is generally an ongoing requirement during childhood and adolescence, especially when the youth acquires greater self-care responsibility. These topics are usually covered repeatedly for youth with T1D and their families as refresher education is generally an ongoing requirement during childhood and adolescence, especially when the youth acquires greater self-care responsibility.

Next Generation Insulin Pens

Smart pens offer technology integration to youth using pen-based, multiple daily injection therapy. Similar to insulin pumps, smart pens feature dose calculators that incorporate active insulin (insulin on board), record of insulin doses and times of administration, and downloadable report generation. The retrospective reports include calculation of total daily insulin dose, identification of missed doses, and potential to observe glycemic patterns to direct dose changes. Other features include notifications to administer rapid or long-acting insulin doses, low battery alerts, and insulin temperature or insulin expiry warnings. In 2016, the Companion InPen became the first FDA-approved insulin pen delivery device to wirelessly transmit such information by Bluetooth to a dedicated mobile application.[50] To date, there have not been any randomized control studies involving smart pen use in pediatrics. Education to use such devices generally involves one-on-one sessions to set-up the InPen application on a smart phone along with its bolus calculator.

Automated Insulin Delivery Systems:

The current era of advanced diabetes devices includes some automation of insulin delivery that requires use of both a CGM device and an insulin pump with an imbedded or Bluetooth connected algorithm.[31]The algorithm generates insulin dose recommendations based upon the CGM glucose level and trends. The initial step of automation included pump basal rate suspension for low glucose levels, which was followed by predictive low glucose suspension, whereby the basal rate is suspended in anticipation of falling glucose levels. The current era now includes hybrid closed-loop systems that not only suspend basal rate insulin delivery to prevent hypoglycemia but also modulate basal rates upwards for rising or elevated glucose levels to prevent hyperglycemia. Such devices are called hybrid closed-loop systems since the user still has to bolus for carbohydrate intake for meals and snacks and may need to provide or confirm insulin correction doses at times of hyperglycemia.

It is important for the education of the youth and family to be explicit regarding these remarkable advances, as there remains an ongoing need for youth and family input to set-up the systems, to insert the CGM sensor, and to set-up the insulin pump. The first hybrid closed-loop, the MiniMed Medtronic 670G™ pump with the Guardian Sensor™, was approved in the fall of 2016 for youth ages 14 and older.[51] It has since been approved for children ages 7 and older during the summer of 2018. Most recently, the Tandem X2 pump™ with the *Control IQ*™ algorithm has been successfully evaluated in a randomized control trial that included pediatric patients ages 14 and older.[52]

Given the novelty of hybrid closed-loop systems, systematic educational approaches are just being introduced. The CARES paradigm can be used to guide clinicians and educators in practical application and teaching.[53] Another recently published approach suggests use of an in-person group class to review CGM and pump use, followed by a live video conference to teach use of the hybrid closed-loop, which is then followed by three phone calls over the next few weeks.[54] Other approaches will include in-person, one-on-one or group classes to implement the closed loop systems. With any of these approaches, close phone follow-up is needed.

Conclusions: Recognizing and overcoming potential barriers to technology uptake and continued use in youth with T1D

There can be multiple barriers to the uptake, use, and accessibility of diabetes technologies for youth with T1D.[26,55–57] There is need to ensure provision of realistic expectations when beginning any new device. It is as important to review what devices cannot do as much as it is important to ensure understanding of what devices can do. Further, education and support must extend beyond the youth and family as multiple caregivers are generally involved in the care. Caregivers can include daycare providers, school nurses, teachers, babysitters, after-school programs, among others. Structured education and written healthcare plans for all involved caregivers can provide practical guidance to support the successful adoption and use of technologies.[6,58]

Ongoing training and education in the use of diabetes technologies for youth and their families are needed as the technologies are constantly being improved and updated. Such education and support can occur at times of routine follow-up care for youth with T1D, who are expected to maintain frequent contact with the health care team due to their frequent need for insulin dose adjustments, especially during periods of growth and development. The extraordinary advances in diabetes technologies have the potential to improve glycemic control and reduce some of the burdens of diabetes self-care for youth with T1D, especially if implemented and maintained with education and support for the person with diabetes and the family.

Abbreviations:

CGM	Continuous glucose monitoring
CSII	Continuous subcutaneous insulin infusion
EMA	European Medicines Agency
FDA	Food and Drug Administration
HCL	Hybrid closed-loop
HbA1c	Hemoglobin A1c
SMBG	Self-monitoring of blood glucose
T1D	Type 1 diabetes
SAP	Sensor augmented pump

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KEY POINTS

1. The field of advanced diabetes technologies is rapidly evolving and includes continuous glucose monitoring, continuous subcutaneous insulin delivery, and closed-loop insulin delivery systems.

2. Education of young people with diabetes and their family members is a critical cornerstone of care for the proper implementation of advanced diabetes technologies and to identify and overcome barriers to continued use in order to derive maximum benefits with respect to biomedical and psychosocial outcomes.

3. The improved performance of continuous glucose monitoring (CGM) devices has led to a revolution in their use, often eliminating the need for traditional fingerstick glucose monitoring, yielding CGM as the standard of care for glucose monitoring in youth.

4. Closed-loop insulin delivery systems are the newest addition to advanced diabetes technologies in clinical use; safe and effective use of such tools will require substantial education and support for young persons with diabetes and their family members.

SYNOPSIS

Provide a brief summary of your article (100 to 150 words; no references or figures/tables). The synopsis appears only in the table of contents and is often used by indexing services such as PubMed

The current era has witnessed an explosion of advanced diabetes technologies, including continuous glucose monitors, sophisticated insulin pumps, and closed-loop insulin delivery systems. Young people with diabetes and their families require detailed, structured diabetes education in order to optimize use of such devices. First, there is need for youth and their families to participate in the selection of particular devices for personal use. Next, there is need for comprehensive education regarding the safe and effective use of such technologies. Further, it is important that the education process ensure that youth and their families receive realistic expectations of what the advanced technologies can and cannot do in order to avoid disappointment and the premature discontinuation of such systems. Together with education and support, advanced diabetes technologies can help young people with diabetes to achieve target glycemic goals while reducing self-care burden and optimizing quality of life.

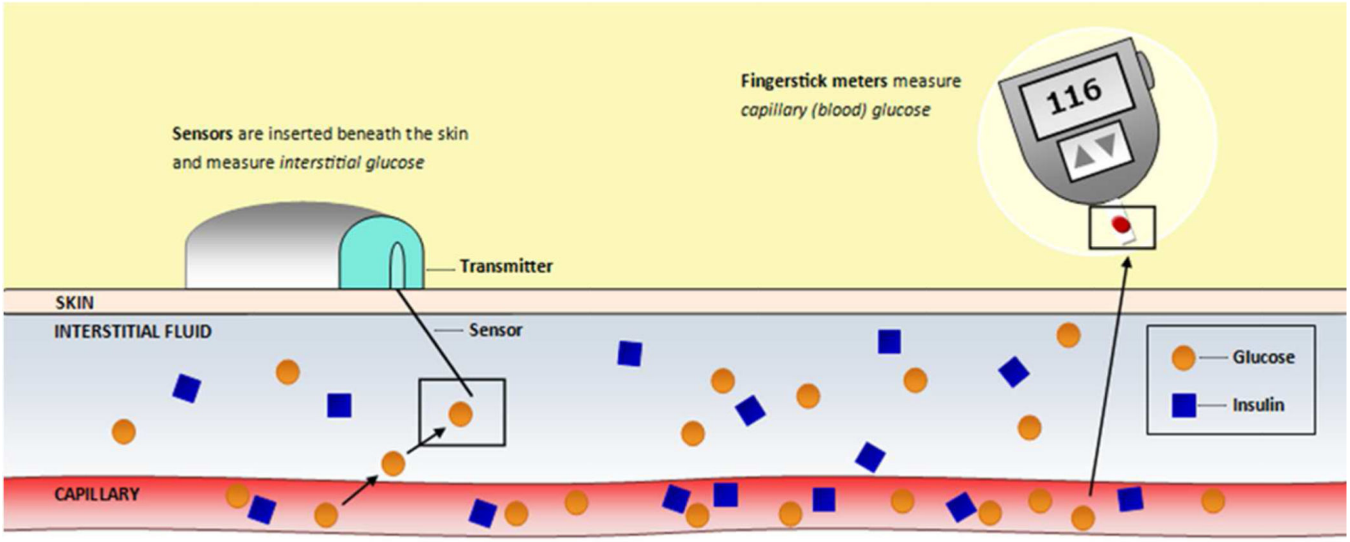

Figure 1.

CGM sensor placement into the interstitial space compared with fingerstick blood glucose monitoring.

Courtesy of Lindsay Roethke, BS, Boston, MA.

Suggested Approach to Adjusting Insulin Dose Using Trend Arrows in Pediatric Patients: Pre-meal and ≥3 Hours Post-meal

Trend Arrows		Correction Factor* (CF)	Insulin Dose Adjustment (U)
Receiver	App		
⬆⬆		<25	+4.0
		25–<50	+3.0
		50–<75	+2.0
		75–<125	+1.0
		≥125	+0.5
⬆		<25	+3.0
		25–<50	+2.0
		50–<75	+1.0
		75–<125	+0.5
		≥125	No adjustment
⬈		<25	+2.0
		25–<50	+1.0
		50–<75	+0.5
		75–<125	No adjustment
		≥125	No adjustment
➡		<25	No adjustment
		25–<50	No adjustment
		50–<75	No adjustment
		75–<125	No adjustment
		≥125	No adjustment
⬊		<25	-2.0
		25–<50	-1.0
		50–<75	-0.5
		75–<125	No adjustment
		≥125	No adjustment
⬇		<25	-3.0
		25–<50	-2.0
		50–<75	-1.0
		75–<125	-0.5
		≥125	No adjustment
⬇⬇		<25	-4.0
		25–<50	-3.0
		50–<75	-2.0
		75–<125	-1.0
		≥125	-0.5

Insulin adjustments using trend arrows do not replace standard calculations using ICR and CF. Adjustments are increases or decreases of rapid-acting insulin in addition to calculations using ICR and CF. Adjustments using trend arrows are an additional step to standard care.

Note on insulin sensitivity with developmental stages in pediatric patients: We provide five insulin sensitivity ranges. Notably, younger patients tend to be more insulin sensitive (higher CF) and older patients tend to be less insulin sensitive (lower CF). Typical decrease in insulin sensitivity is an important consideration in long-term care. Outliers may exist in any group.

Pre-School-Age/Toddlerhood (ages 2–6): often use CF ≥125
School Age/Middle-Childhood (ages 7–12): greatest variability
Adolescence/Young Adulthood (ages 13–22): often use CF 25–50 or <25

Considerations when adjusting for trend arrows:
If sensor glucose is rapidly rising (2 UP arrows; ⬆⬆) at pre-meal, consider administering insulin 15–30 minutes before eating.

If sensor glucose is rapidly falling (2 DOWN arrows; ⬇⬇) at pre-meal, consider administering insulin closer to the meal.

At bedtime, adjustments may be considered; however, use caution when adding insulin at that time. Suggest a bedtime target of 130 mg/dL with FLAT (➡) or ANGLE UP (⬈) arrow.

Approach does not require insulin on board to be set to 3 hours.

*Correction factor (CF) is in mg/dL and indicates glucose lowering per unit of rapid-acting insulin.

Figure 2.

Using trend arrows for dosing at meal times.

From Laffel LM, Aleppo G, Buckingham BA, et al. A practical approach to using trend arrows on the dexcom G5 CGM system to manage children and adolescents with diabetes. *J Endocr Soc*. 2017;1(12):1461–1476; with permission.

Table 1.

Challenges and Potential Strategies for Youth and Families using CGM, CSII, and HCL.

CGM	
Potential Issue	***Educational Opportunity***
Device components	
Adhesive issues	Offer adhesive adjunctive options, symptoms of adhesive reaction
Cost / insurance coverage	Advocate for coverage, complete certificate of medical necessity
Supply and reordering	Support consistent supply options
Receiver and/or mobile device	Review features and options of each, mobile device must employ up-to-date system
Pump integration	Educate patient about HCL options by device
Device Application	
Sensor site selection	Review symptoms of site problems, rotation to area with sufficient subcutaneous tissue for reading
Safety	MRI incompatible, removal often necessary with radiation exposure or security clearances
Fingerstick requirements	Review parameters for fingerstick confirmation (e.g. no number/no arrow, symptoms not matching reading, or glucose rapidly changing or severely low)
Remote treatment and support feasibility	Develop plan for management of severe hypo/hyperglycemia
Data Transmission	
Bluetooth connectivity	Confirm device compatibility, re-connecting Bluetooth if signal lost
WI-FI connectivity for sharing	Data must be received by user in order for share feature; sharing currently only available with Dexcom system
Technological support	Provide access to customer service contact and differentiation between user vs. device errors
Data Interpretation	
Sensor lag	Discuss interstitial vs. blood glucose readings, variability
Trend arrows	Review trend arrow significance, mealtime adjustments
Risk of stacking	Counsel about clinically appropriate correction timeframes
Glucometric report	Assist with patient/family understanding of reports and significance (e.g. Convert TIR from percentage to hours)
Data overwhelm	Encourage meaningful monitoring of glucose information
Data Sharing	
WI-FI connectivity	Dexcom and Share user must be WI-FI connected for data transmission
Privacy rights	Discuss data sharing and report receipt once patient of age
Family communication	Support dialogue around youth-family experience including transitions (e.g. college), stressors and successes

CSII	
Potential Issue	***Educational Opportunity***
Glycemic Excursions	*Review basal-bolus settings, technical application of device, insulin administration timing and use of bolus calculator*
Risk of DKA	
Hyperglycemia	Review importance of frequent glucose monitoring to detect hyperglycemia and pump failures, *administering insulin via injection if pump failure suspected*
Ketosis	Discuss need to monitor ketones during hyperglycemia and illness
Running out of insulin	Encourage families to carry back up insulin and set alarms for low insulin reservoir
Missed boluses	Consider bolus reminders, review parent/child responsibility for boluses
Infusion Site Issues	

CSII	
Potential Issue	***Educational Opportunity***
Site failures	Recommend avoidance of site placement at areas of hypertrophy or scarring, remind family of importance of frequent glucose monitoring
Site disconnections, tubing problem	Offer adjunctive adhesives, recommend frequent visual check of site connection. *Confirm appropriate priming technique, cannula and tubing integrity*
Adhesive site reactions	Encourage use of adhesive barrier, review site rotation
Body image	Review appropriate application areas, consider untethered pumping
Site infections	Discuss proper skin preparation, changing site every 2-3 days, *teaching early signs and symptoms of infection*
Hypertrophy	Counsel on importance of site rotation, avoiding overuse of frequent sites
Misc.	
Travel	Offer heath care provider letter, review need to bring extra supplies and keep in carry-on luggage
School	Confirm school has ketone monitoring supplies, back up insulin/syringes in case of pump failure, assist with education of school staff

HCL	
Potential Issue	***Educational Opportunity***
See 'CSII' and 'CGM' Issues	
Mental burden	
System complexity	Encourage formalized training for initial use to learn systemspecific 'clinical rules', as well as ongoing education, evaluation, and support with diabetes team, updating pump settings for use in open loop mode as needed
Terminology	Define brand-specific terms relating to the individual>s system
Rapid upgrades and changes to systems	Encourage ongoing education and follow-up for both patient and clinicians
Cost	Review insurance benefits, submit Certificate of Medical Necessity, explore participation in clinical trials
Human vs. system conflicts related to automated insulin delivery	Assess user comprehension with system, especially automation vs. manual modes; review fundamental concepts of diabetes management routinely; encourage prompt reporting and resolution of device-related issues
Diabetes burnout	Teach benefits of system, reiterate diabetes goals, share and interpret glucometrics
Technology vacation	Assess and review fundamental diabetes management, manual pump use guidelines
Physical activity	Encourage use of system tools (e.g. temp target, basal suspension), hypoglycemia and hyperglycemia treatment recommendations by exercise type and duration

Table 2.

Trend arrow significance by device

Dexcom G5®/ Dexcom G6®

Trend Arrow	Glucose Direction	Change in Glucose
↑↑	Increasing: Glucose is rapidly rising	Increasing >3mg/dL/min or >90mg/dL in 30 minutes
↑	Increasing: Glucose is rising	Increasing 2–3mg/dL/min or 60–90 mg/dL in 30 minutes
↗	Increasing: Glucose is slowly rising	Increasing 1–2 mg/dL/min or 30–60 mg/dL in 30 minutes
→	Increasing or decreasing: Glucose is steady	Not increasing or decreasing >1mg/dL/min
↘	Decreasing: Glucose is slowly falling	Decreasing 1–2 mg/dL/min or 30–60 mg/dL in 30 minutes
↓	Decreasing: Glucose is falling	Decreasing 2–3mg/dL/min or 60–90 mg/dL in 30 minutes
↓↓	Decreasing: Glucose is rapidly falling	Decreasing >3mg/dL/min or >90 mg/dL in 30 minutes

Medtronic MiniMed Guardian® 3

Trend Arrow	Corresponding SG rate per minute
↑	Rising at a rate of 1mg/dL but less than 2mg/dL
↓	Falling at a rate of 1 mg/dL but less than 2mg/dL
↑↑	Rising at a rate of 2 mg/dL but less than 3 mg/dL
↓↓	Falling at a rate of 2mg/dL but less than 3 mg/dL
↑↑↑	Rising at a rate of 3 mg / dL or more
↓↓↓	Falling at a rate of 3 mg /dL or more

Freestyle Libre™

Trend Arrow	Glucose Direction	Change in Glucose
↑	Rising quickly	Increasing >2mg/dL/minute or >60 mg/dL in 30 minutes
↗	Rising	Increasing 1–2mg/dL/minute or 30–60 mg/dL in 30 minutes
→	Changing slowly	Not increasing or decreasing >1mg/dL/minute
↘	Falling	Decreasing 1–2mg/dL/minute or 30–60 mg/dL in 30 minutes
↓	Falling quickly	Decreasing >2mg/dL/minute or >60 mg/dL in 30 minutes

Eversense®

Trend Arrow	Glucose Direction and Velocity
→	Gradually rising or falling at a rate between 0.0 mg/dL and 1.0 mg/dL per minute
↗	Moderately rising glucose level, rising at a rate between1.0 mg/dL and 2.0 mg/dL per minute
↘	Moderately falling glucose levels, falling at a rate between 1.0 mg/dL and 2.0 mg/dL
↑	Very rapidly rising glucose levels, rising at a rate more than 2.0 mg/dL per minute
↓	Very rapidly falling glucose levels, falling at a rate more than 2.0 mg/dL per minute