HHS Public Access

Author manuscript

Diabet Med. Author manuscript; available in PMC 2022 October 01.

Published in final edited form as:

Diabet Med. 2021 October ; 38(10): e14492. doi:10.1111/dme.14492.

Innovative Features and Functionalities of an Artificial Pancreas System: What Do Youth and Parents Want?

P.V. Commissariat, PhD[1,2], **L.K. Volkening, MA**[1], **D.A. Butler, MSW**[1,2], **E. Dassau, PhD**[1,3], **S.A. Weinzimer, MD**[4,5], **L.M. Laffel, MD, MPH**[1,2]

[1]Joslin Diabetes Center, Boston, MA

[2]Harvard Medical School, Boston, MA

[3]Harvard John A. Paulson School of Engineering and Applied Sciences, Cambridge, MA

[4]Yale University School of Medicine, New Haven, CT

[5]Yale University School of Nursing, New Haven, CT

Abstract

Aims: Participant-driven solutions may help youth and families better engage and maintain use of diabetes technologies. We explored innovative features and functionalities of an ideal artificial pancreas (AP) system suggested by youth with type 1 diabetes and parents.

Methods: Semi-structured interviews were conducted with 39 youth, ages 10–25 years, and 44 parents. Interviews were recorded, transcribed, and coded using thematic analysis.

Results: Youth (72% female, 82% non-Hispanic white) were (M±SD) ages 17.0±4.7 years, with diabetes for 9.4±4.9 years, and HbA1c of 68±11 mmol/mol (8.4±1.1%); 79% were pump-treated and 82% were CGM users. Of parents, 91% were mothers and 86% were non-Hispanic white, with a child 10.6±4.5 years old.Youth and parents suggested a variety of innovative features and functionalities for an ideal artificial pancreas system related to: 1) enhancing the appeal of user interface, 2) increasing automation of new glucose management functionalities, and 3) innovative and commercial add-ons for greater convenience. Youth and parents offered many similar suggestions, including integration of ketone testing, voice activation, and location-tracking into the system. Youth seemed more driven by increasing convenience and normalcy, while parents expressed more concerns with safety.

Corresponding Author: Lori M. Laffel MD, MPH, Joslin Diabetes Center, One Joslin Place, Boston MA 02215, Lori.Laffel@joslin.harvard.edu.

Author Contributions. P.V.C. trained study staff in data collection, analyzed and interpreted the data, and wrote the manuscript. L.K.V. analyzed the data, and edited the manuscript. D.A.B. trained and supervised study staff in data collection, interpreted the data, and edited the manuscript. E.D. conceptualized and designed the study, interpreted the data, and edited the manuscript. S.A.W. conceptualized, designed, and implemented the study, interpreted the data, and edited the manuscript. L.M.L. conceptualized, designed, and implemented the study; interpreted the data; and reviewed and edited the manuscript. L.M.L. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Prior Presentations. Parts of this study were presented at the 79th Annual Scientific Sessions of the American Diabetes Association in San Francisco CA in June 2019; the 45th Annual Meeting of the International Society of Pediatric and Adolescent Diabetes in Boston MA in October 2019; and virtually at the 80th Annual Scientific Sessions of the American Diabetes Association in June 2020.

Conclusions: Youth and parents expressed creative solutions for an ideal artificial pancreas system to increase ease of use, enhance normalcy, and reduce burden of management. Designers of artificial pancreas systems will likely benefit from incorporating the desired preferences by end users in order to optimize acceptance and usability by young persons with diabetes.

Keywords

type 1 diabetes; patient preferences; artificial pancreas; automated insulin delivery; devices; children and adolescents; young adults; parents; system design

INTRODUCTION

In an era of rapidly advancing diabetes technologies, a wide range of treatment options are now available to people with type 1 diabetes. Insulin pumps and continuous glucose monitors (CGM) have been associated with improved glycemic control. When comparing technology users vs non-users, data from the Type 1 Diabetes Exchange Registry found that non-users under age 25 had the highest HbA1c, while those using both pump and CGM had the lowest HbA1c levels [1]. Data have also demonstrated substantial increases in technology use (from 2010 to 2018): 7–10% more insulin pump use and 5–12 times more CGM use in young people ages 6–26 years [2]. Recent years have heralded a new phase of advances in diabetes technologies related to "artificial pancreas" systems, which integrate an insulin pump, CGM, and control algorithm that calculates and directs insulin delivery through partial automation to increase glucose time-in-range [3].

Despite recent advances and increased technology use, the majority of young people with type 1 diabetes still do not achieve recommended glycemic targets [2]. Discrepancies between device or system functionalities and the expectations and perceived needs of persons with diabetes likely influence effective use. As new systems advance in their abilities to manage glucose levels, user-perceived needs for an ideal artificial pancreas system will likely extend beyond improving glycemia to include features that enhance ease of use and engagement.

In previous research, users and family members have suggested ideal systems would function like a pancreas, utilizing small, discreet devices and adaptive learning to reduce burden and responsibility for management [4, 5], and reduce psychosocial burden by lessening daily stress and improving family relationships [6]. A study of hybrid closed-loop users suggested that individuals are willing to compromise on limitations and abilities of the system if they perceive greater benefits to their health and quality of life than their current treatment provides [7]. Presently, less research in this arena gathers concrete solutions from participants, such as a recent study that explored participant suggestions for improving system design and functionality, and gathered specific suggestions to combine pump and CGM into one device and offer customizable alert sounds and settings [8]. Participant-driven features are more often found in Do-It-Yourself (DIY) systems, but setup, usage, and support for these systems may be a barrier to use. Participant solutions in commercial, approved systems may help youth and families engage and maintain use of diabetes technologies.

Recognizing the importance of exploring participant-driven solutions, we used qualitative methods to explore suggestions from youth and parents for specific features and functionalities of an "ideal" artificial pancreas system, focusing on those not currently available in commercial hybrid closed-loop systems. The findings in this paper are part of a larger interview exploring specific preferences regarding physicality and efficacy of a hypothetical, ideal system for the purpose of informing future artificial pancreas system design.

METHODS

Participants and Procedures

Semi-structured interviews were conducted in person from August 2018 to November 2019 with 39 children, adolescents, and young adults with type 1 diabetes and 44 parents at two diabetes centers in the U.S. (Joslin Diabetes Center and Yale School of Medicine). Youth were eligible to participate if they were 8–25 years old and had type 1 diabetes for at least one year. Parents were eligible to participate if they had a child of any age with type 1 diabetes. Youth and parents were not required to participate together, and parent-child dyads were interviewed separately to not bias responses. Participants were identified through providers at each site or by participants contacting study personnel in response to recruitment posters. Recruitment was stratified by age (ages 8–12, 13–17, 18–25) to ensure adequate representation of different ages in the study sample; each site aimed to continue recruitment until there were approximately 15 youth per age group across both sites to ensure adequate representation and saturation of data. Interested youth and parents met with study staff to learn about the study. Before the start of any study procedures, parents and youth ages 18 and older provided written informed consent, and youth under age 18 provided written assent. Youth and parents completed semi-structured qualitative interviews, lasting 20–45 minutes, and demographic surveys; clinical data were collected from the medical record. The protocol was approved by the Institutional Review Boards at both sites.

Qualitative Data Collection

Questions on the semi-structured interviews were consensus-derived from a multidisciplinary team of experienced diabetes care providers and researchers at the participating sites (Table 1). Interview questions broadly explored youth and parent preferences for an ideal system's appearance, functionality and performance for meals and exercise, and any unique features that would increase perceived benefit to using the system. A psychologist on the study team trained research staff at both sites in interviewing techniques to ensure consistent methods across sites. Initial interviews were reviewed by senior staff for quality and training purposes, and feedback was provided. All interviews were audio-recorded, transcribed by a HIPAA-compliant transcription service (Hoffman Transcription), and coded using NVivo software version 11.2 [9].

Data Analysis

Three coders (1 psychologist, 2 research assistants) analyzed the transcripts using an inductive approach to thematic analysis. Research assistants received training in coding by a psychologist (PVC) versed in qualitative methodology. Coders reviewed three transcripts together and received instructions and feedback before coding independently. Thematic analysis, a flexible, active, data-driven method of identifying themes within the data without being tied to pre-existing theory, was used to analyze transcripts [10]. Coders open-coded transcripts, analyzing each line to uncover as many ideas in the data as possible [11]. This data-driven approach was used to analyze transcripts for specific ideas related to desired features and functionalities of an ideal artificial pancreas system. In order to reduce bias, coders did not analyze transcripts of interviews that they conducted. Coders met weekly to discuss their respective analyses and formulate and refine a comprehensive codebook. New codes were generated until saturation was achieved and no new ideas emerged. Approximately 75% of transcripts were double-coded to ensure data saturation, interrater reliability (calculated using Cohen's kappa), and agreement. Inter-rater reliability indicated very good agreement, with a Cohen's kappa of K=0.81 and 95% agreement. Coders discussed all discrepancies until consensus was reached. The coding team analyzed final individual codes for overarching themes. Triangulation was performed with the multidisciplinary team of investigators, who reviewed the codebook at regular intervals and reviewed final themes to reduce potential interpretation bias and further corroborate the findings [12].

RESULTS

Characteristics of the 39 youth and 44 parents are shown in Table 2. Youth and parents suggested a variety of unique features and functionalities of an ideal artificial pancreas system related to user interface, greater automation, and commercial add-ons. Within each themes, we describe the similarities between youth and parent suggestions, followed by the differences. Table 3 provides a detailed list of youth and parent suggestions organized by theme.

Enhancing Appeal of User Interface

Similarities: Convenient Interactions with System.—Youth and parents reported a number of similar features to streamline the user-interface of an artificial pancreas system. Many suggested that voice activation would ease use of the system, similar to current voice-activated, interactive systems like Siri or Alexa. Both youth and parents offered examples of verbally telling the system specific foods or carbohydrate counts to direct insulin delivery, or asking the system for an estimate of carbohydrates. Some suggested that the system should link to a Siri- or Alexa-capable device to give reminders for diabetes care.

- "I'd like it to be kind of like Siri. Like, 'I'm eating an apple' and then it would give me that, and then, 'Siri, I'm having 25 carbs,' and it would give me that."

(10-year-old female)

Youth and parents also suggested a single button press required to inform the system to adjust for "food", "exercise", "stress", "weather", and "illness" to minimize user efforts.

- "It would be like a 'Munch' button. Hit 'Munch' and then it understands the increase [in glucose] it's going to track and would then compensate

[…] You could probably inform it that you're about to have increased activity based on another button that says 'Exercise' or 'Activity' or something, right? And you hit that, and then it's programmed to understand to stop giving insulin at this time."

(25-year-old male)

Differences: Appearance of System and Remote System Access.—Youth and parents provided various suggestions for the appearance of the system. Some younger children suggested choosing their own "fun" and "cool" colors and decorating their devices with stickers. However, some teens, young adults, and parents suggested skin-colored devices to minimize noticeability or black/gray for a "sleek" appearance.

- "I want a sticker that can go on top of it instead of being the sticker that goes around the pump to make sure it sticks to your skin. And then you could decorate it or color, something like that. Maybe it could have cool designs on it."

(10-year-old female)

But while children were open to eye-catching design, parents more often suggested the size and color of the system should make it less noticeable.

- "Definitely something flush to the skin and not noticeable, that would kind of blend in with your regular skin tone, would be good."

(mother of a 5-year-old male)

Youth and parents also discussed distinct features that would help them interact with each other to manage diabetes. Youth suggested the system could text glucose levels to a parent when prompted, allowing the parent to stay informed and/or offer advice.

- "Textable features. Like you can say 'text someone this, this, and this' so you can send your sugars."

(10-year-old female)

Parents similarly expressed a desire to be more informed of management, but wanted to increase their own interaction with the system, including unlimited access to glucose levels, auto-rotation of alert sounds to avoid alert fatigue, and even ability to remotely dose their child.

- "It would be awesome if I could just say, 'Well she's a little high, I'm going to bolus her from my phone.' Or the nurse could bolus her from her office, or I could bolus her at home and not go on the field trip."

(mother of an 8-year-old female)

Steps Toward Automation

Similarities: Reduced User Responsibility in Managing Glucose Levels.—All youth and parents reported that an ideal artificial pancreas system should function autonomously to some degree for meals and exercise. Many suggested a dual-hormone system, with a form of glucose or glucagon included to treat and prevent hypoglycemia faster than insulin reduction.

- "I would really, really like it if it also had glucagon, so I could do glucagon before a workout. Or during a workout if I were to be going low, it would sense it and it would give me glucagon, and I wouldn't have to eat."

(23-year-old female)

Youth and parents also provided features that could minimize their management responsibilities without directly affecting glucose levels. Suggestions included automatic ketone testing for high glucose levels, or the use of faster-acting insulin or quicker bolus delivery mechanism to eliminate pre-bolusing.

- "You could integrate a ketone blood monitor with a CGM and get alerts to that, instead of having to do a separate test when your child is sick for ketones, where the alarm would say 'hey, you've got moderate ketones' and then you could act. Sometimes you don't know they're sick or they have ketones, so that would be beneficial."

(mother of a 5-year-old male)

Despite the desire to reduce responsibility and increase automation, the vast majority of youth and parents said they would not be willing to limit carbohydrate intake to less than 50g per meal in exchange for if fully automated insulin coverage, with many stating they did not want to feel restricted and would rather manually bolus.

- "If you had up to 50 carbs to be automatically bolused, then you could add the extra in, yeah, go for it. I don't mind doing extra carb counting, but if you have to be meticulous about eating less than 50 carbs every meal, that would be too limiting for me."

(19-year-old male)

Differences: Feedback from the System.—Youth and parents both suggested feedback from the system, but expressed differences in the type of feedback desired. Youth suggested the system offer unsolicited advice on dose adjustments to improve glucose levels, or feedback through validation and acknowledgment of efforts.

- "Something that congratulates you, because I'm a big validation person. Like if my blood sugars have been going really well recently, I just want something to say 'Hey, good job for having your blood sugars in a good place.'"

(19-year-old male)

Parents also found value in getting advice from the system, though they wanted advice on how to manage glucose levels before they went out-of-range, rather than suggestions post-glycemic excursion.

- “When he eats, if you could do the voice activation, ‘Hey, I’m eating, I’m going to have some ice cream tonight, what do you estimate the carb?’ [it could] give you advice on what it would suggest to do.”

(mother of a 5-year-old male)

Innovative and Commercial Add-Ons for Greater Convenience

Similarities: Integrating Commercial Features.—Youth and parents frequently referenced two commercial functionalities to incorporate into an ideal system: food libraries and exercise trackers. Food libraries would be built into the system and linked to barcode scanners to aid in carbohydrate counting. Step trackers and heart rate monitors were suggested to help the system recognize exercise and prepare for potential basal dose adjustments.

- “Do you know how with a Fitbit, it can recognize you’re running because your steps are faster and your heart rate’s going up? That would be cool if that [artificial pancreas] system could recognize that and then just shut off.”

(13-year-old female)

Participants also suggested commercial features that would make the system more enjoyable to wear: for example, the use of popular songs and emojis as alerts or a gaming model of incentives/prizes for effective management and use of the system.

- “I would have emojis myself, like [instead of] sounds. I think it would make it fun for people just to be like ‘oh, I’m going to switch out my sound today.’ With diabetes, it’s so hard some days to manage and it’s so depressing some days that anything that’s fun, I would try and add it on, just to make somebody smile.”

(mother of a 10-year-old female)

Differences: Innovative Solutions.—Youth were the main source of creative features and functionalities. For example, some suggested features to aid in the detection of food. One participant suggested automatic pre-bolusing by detection of food aromas. Others suggested the system could detect stomach activity or salivation before pre-bolusing for food.

- “I’m trying to think of how this could mimic the pancreas, right? But even the pancreas, before you even eat, it’s receiving signals from the smell and sight and the fact that you’re salivating, and it’s already producing insulin. Maybe you can make a machine with smell-o-vision.”

(18-year-old female)

Youth suggested location-tracking could help in locating an accidentally lost device, send Emergency Medical Services to their location if needed, and automatically search the immediate area for food or restrooms if glucose was out-of-range.

- "What if it sensed that you were low, but then it scanned your area to see if there was any food places near you if you needed to go to them? Or say you didn't like doing all this stuff in public, maybe it could tell you if there were any nearby bathrooms."

(19-year-old male)

DISCUSSION

Even in an era of rapidly advancing diabetes technologies, many youth and parent preferences for an ideal artificial pancreas system discussed in the current manuscript are innovative in nature, to the extent that they are not integrated nor minor modifications to current commercial diabetes technologies. Suggested features appear to stem from a need for greater convenience and enjoyment in wearing the system rather than a need for better glucose control, suggesting that participants either felt existing technologies provided sufficient glycemic control when used properly, or that other factors beyond glycemic control were more salient for them. As perceived usefulness and ease of use contribute to intent to use technology, it is imperative for clinicians and developers to understand and manage the expectations of users for future artificial pancreas systems [13].

User interface modifications from youth and parents highlighted the need for a more convenient, streamlined interaction with the system through use of voice activation and singular buttons to announce food vs exercise. These "shortcuts" may enhance usage, particularly if users feel less burdened by the efforts they put in to diabetes management. Interestingly, though parents acknowledged the need for an easier way to announce meals or exercise to the system, parents also wanted to take responsibility of remote dosing capabilities. Past research has shown that parents can feel particularly stressed around mealtimes [6] and when their child is away from them, as they worry about depending on other caregivers [14]. Parents appear willing to accept the additional work of remote insulin dosing in exchange for less worry. Additionally, the need for a personalized appearance is resoundingly important to youth and families. Younger children described bright colors and designs as "fun" or "cool", while older youth and parents suggested neutral colors were "sleek" and not noticeable; this is likely appropriate for their developmental stages, as younger children may be drawn to designs and colors as a means of expressing themselves while older youth are more inclined to want to "fit in" with a system that does not draw attention. Youth may prefer a personalized appearance in their diabetes devices as a means to express their individual personalities [4] or exert control over the visibility of their diabetes.

Youth and parents also had multiple ideas for how an artificial pancreas system could ease glucose management, including glucagon in the system, automatic ketone testing, faster peaking insulin, and feedback from the system. Interestingly, these features do not necessarily presuppose a desire for a fully automated system; many even spoke about their roles in managing their ideal system. For example, a need for hypoglycemia treatment or ketone testing suggests an out-of-range glucose level that was not successfully prevented by full automation. Feedback from the system suggests the user has already put in efforts that require feedback, and will make additional efforts based on feedback. A qualitative study similarly found that hybrid closed-loop users initially wanted less responsibility in management and ended up desiring more collaboration with the system to optimize glucose levels [15]. In our study, even when participants were given the option of full system automation if they would be willing to limit their carbohydrate intake, many stated that they would rather manually bolus than feel “restricted” or “limited”. The adverse reaction to feeling “restricted” appears powerful. It is possible that in this age group, youth have experienced some sort of restriction related to their diabetes already, whether it be food-related (e.g., “You can’t eat that because you’re high”) or activity-related (e.g., “You have to stop playing because you’re low”). The aversion to food restrictions seems to overpower the desire for a system that independently manages glucose levels and reduces workload. This is an important finding for developers, as aversion to carbohydrate restrictions will likely affect uptake and usage of future artificial pancreas systems.

Finally, youth and parents discussed novel design features for the system. Many of the suggested features appear inspired by other technologies, such as barcode scanners, heart rate monitors, emojis, songs, and location-tracking. These technologies provide familiarity and convenience that youth enjoy, as many can already be accessed by smartphone. This may be why participants wanted to integrate these technologies of convenience into their diabetes devices in ways that would reduce workload (barcode scanner for carbohydrate counting), help the system adjust for activity (heart rate monitor), and reduce negative emotional responses (emojis instead of sounds). Interestingly, youth considered both convenience and safety by suggesting location-tracking as a supplemental feature to be utilized prior to an actual emergency by offering locations for restrooms or local food options to treat glucose levels. Perhaps the most unique suggestion was for a system to detect food through scent or salivation, again highlighting the desire for convenience by eliminating pre-bolusing and enhancing normalcy by mimicking the automatic way a real pancreas works.

Participants offered feasible (e.g., auto-texting of bolus doses to parents), as well as unrealistic suggestions (e.g., identifying food via scent). An important underlying thread of the features discussed is how they broadly offer some normalization of diabetes self-management and increased convenience. It has been suggested that the process of normalizing diabetes involves the realization that self-management include tasks that everyone must do, such as healthy eating or exercise [16]. This has the potential to improve engagement with diabetes care if diabetes feels like part of one’s self and one’s routine [17]. While many of these design features are already available (e.g., step counters, barcode scanners, colored skins to decorate devices, etc.), they have not been seamlessly integrated into diabetes technologies; rather they are separate apps or products that can also be purchased or used in parallel with diabetes technologies. Future commercial systems should consider the integration of these consumer features. Past research has suggested psychosocial benefit in the ability to operate diabetes devices from a smartphone by reducing embarrassment and offering more seamless integration of care into daily routine [18]; Similarly, wearing diabetes devices may be better accepted and not feel so differentiating if a system utilizes the same functions as one’s watch or phone. However, some suggested features are simply not feasible or cause burdens that are difficult to accept or ignore. For example, safety issues arise from a system that functions off of smell/

salivation or singular buttons for food and exercise announcements. The system will not be able to differentiate proximity or hunger from intent to eat: an automated pre-bolus for the latter would be appropriate, while for the former would increase the risk of hypoglycemia. Furthermore, while single buttons may ease use, they increase the possibility of accidental pressing, and may not necessarily eliminate the need to pre-bolus. Similarly, voice activation could be dangerous without a mechanism to ensure the user was the only one giving commands. Remote parent bolusing brings up concerns of safety if a parent is not fully aware of their child's activity or previous dosing. Additionally, there is potential for remote dosing to be a barrier to youth's independence and instigate family conflict around privacy issues, particularly as a child ages.

It should be noted that while many suggested features are not integrated into systems currently approved by regulatory authorities, some features can be found in investigational or Do-It-Yourself (DIY) open access systems. For example, OpenAPS and Loop offer more remote monitoring features for parents and caregivers [19]. The iLet (Bionic Pancreas) system and others utilize a dual-hormone system [20]. Others have attempted single announcements for meals and system feedback [21]. Though these systems are promising, their investigational status or open-access/independently-created models may be a barrier to those who do not have the technologies, means, or capability to access these systems.

There are some limitations to the current study. First, parent perceptions were primarily from mothers, likely the primary diabetes caregivers for their children, who received care at large, research- and technology-focused diabetes clinics. Additionally, most of the participants were female, diabetes technology users, and identified as non-Hispanic white, which likely influenced a variety of responses, suggesting a need to survey more males and non-technology users in the future. Furthermore, many of the technologies mentioned by participants (smart phones, FitBits, voice activated devices) suggest a higher SES and may not be easily available or well-utilized by all.

Participants' suggestions for innovative features centered on making management easier and more convenient in daily life, while effectively, safely, and discreetly managing glucose levels. Artificial pancreas design efforts should consider these recommendations from children, teens, young adults, and parents to maximize future system uptake and ongoing use in youth with type 1 diabetes.

ACKNOWLEDGMENTS

Funding.

This research was supported by National Institutes of Health grants DP3DK113511, DP3DK104057, T32DK007260, P30DK036836, and K12DK094721; the Katherine Adler Astrove Youth Education Fund; the Maria Griffin Drury Pediatric Fund; the Eleanor Chesterman Beatson Fund; and The Michael and Rosemary Ryan Pediatric Diabetes Research Fund. The content is solely the responsibility of the authors and does not necessarily represent the official views of these organizations.

Author Disclosures.

L.M.L. provides consulting services for Boehringer Ingelheim Pharmaceuticals, ConvaTec, Dexcom, Inc., Insulet Corporation, Insulogic, Janssen Pharmaceuticals, Novo Nordisk, Roche Diagnostics, Sanofi U.S., Laxmi, Medtronic, and Lifescan. S.A.W. has received consulting fees from Eli Lilly, Sanofi, Medtronic, and Zealand Pharmaceuticals and honoraria for serving as a speaker for Insulet and Tandem. E.D. has received personal fees from Eli Lilly and Company and Dexcom; has received research support from Dexcom, Insulet, and Roche. E.D. is currently an employee and shareholder of Eli Lilly and Company. The work presented in this paper was performed as part of E.D.'s academic appointment and is independent of his employment with Eli Lilly and Company. P.V.C, L.K.V., and D.A.B report no conflicts of interest relevant to this article.

REFERENCES

1. Miller KM, Beck RW, Foster NC, Maahs DM. HbA1c Levels in Type 1 Diabetes from Early Childhood to Older Adults: A Deeper Dive into the influence of technology and socio-economic status on HbA1c in the T1D Exchange Clinic Registry Findings. Diabetes Technol Ther 2020.
2. Foster NC, Beck RW, Miller KM, Clements MA, Rickels MR, DiMeglio LA, et al. State of Type 1 Diabetes Management and Outcomes from the T1D Exchange in 2016–2018. Diabetes Technol Ther 2019; 21:66–72. [PubMed: 30657336]
3. Beck RW, Bergenstal RM, Laffel LM, Pickup JC. Advances in technology for management of type 1 diabetes. Lancet 2019.
4. Naranjo D, Suttiratana SC, Iturralde E, Barnard KD, Weissberg-Benchell J, Laffel L, et al. What End Users and Stakeholders Want From Automated Insulin Delivery Systems. Diabetes Care 2017; 40:1453–1461. [PubMed: 28842523]
5. Barnard KD, Pinsker JE, Oliver N, Astle A, Dassau E, Kerr D. Future artificial pancreas technology for type 1 diabetes: what do users want? Diabetes Technol Ther 2015; 17:311–315. [PubMed: 25629627]
6. Garza KP, Jedraszko A, Weil LEG, Naranjo D, Barnard KD, Laffel LMB, et al. Automated Insulin Delivery Systems: Hopes and Expectations of Family Members. Diabetes Technol Ther 2018; 20:222–228. [PubMed: 29565721]
7. Iturralde E, Tanenbaum ML, Hanes SJ, Suttiratana SC, Ambrosino JM, Ly TT, et al. Expectations and Attitudes of Individuals With Type 1 Diabetes After Using a Hybrid Closed Loop System. Diabetes Educ 2017; 43:223–232. [PubMed: 28340542]
8. Quintal A, Messier V, Rabasa-Lhoret R, Racine E. A qualitative study exploring the expectations of people living with type 1 diabetes regarding prospective use of a hybrid closed-loop system. Diabet Med 2020.
9. QSR International Pty Ltd. NVivo qualitative data analysis Software. Version 11.2 edn 2016.
10. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol 2006; 3:77–101.
11. Glaser BG, Holton J. Remodeling Grounded Theory. 2004 2004; 5.
12. Patton MQ. Enhancing the quality and credibility of qualitative analysis. Health Serv Res 1999; 34:1189–1208. [PubMed: 10591279]
13. Messer LH. Why Expectations Will Determine the Future of Artificial Pancreas. Diabetes Technol Ther 2018; 20:S265–S268. [PubMed: 29916739]
14. Commissariat PV, Harrington KR, Whitehouse AL, Miller KM, Hilliard ME, Van Name M, et al. "I'm essentially his pancreas": Parent-Perceptions of Diabetes Burden and Opportunities to Reduce Burden in the Care of Children <8 Years Old with Type 1 Diabetes. Pediatr Diabetes 2019.
15. Lawton J, Blackburn M, Rankin D, Allen JM, Campbell FM, Leelarathna L, et al. Participants' Experiences of, and Views About, Daytime Use of a Day-and-Night Hybrid Closed-Loop System in Real Life Settings: Longitudinal Qualitative Study. Diabetes Technol Ther 2019; 21:119–127. [PubMed: 30720338]
16. Olshansky E, Sacco D, Fitzgerald K, Zickmund S, Hess R, Bryce C, et al. Living with diabetes: normalizing the process of managing diabetes. Diabetes Educ 2008; 34:1004–1012. [PubMed: 19075082]
17. Commissariat PV, Kenowitz JR, Trast J, Heptulla RA, Gonzalez JS. Developing a Personal and Social Identity With Type 1 Diabetes During Adolescence: A Hypothesis Generative Study. Qual Health Res 2016; 26:672–684. [PubMed: 26893304]
18. Anderson LM, Papadakis JL, Vesco AT, Shapiro JB, Feldman MA, Evans MA, et al. Patient-Reported and Parent Proxy-Reported Outcomes in Pediatric Medical Specialty Clinical Settings: A Systematic Review of Implementation. J Pediatr Psychol 2019.

19. Kesavadev J, Srinivasan S, Saboo B, Krishna BM, Krishnan G. The Do-It-Yourself Artificial Pancreas: A Comprehensive Review. Diabetes Ther 2020; 11:1217–1235. [PubMed: 32356245]

20. El-Khatib FH, Balliro C, Hillard MA, Magyar KL, Ekhlaspour L, Sinha M, et al. Home use of a bihormonal bionic pancreas versus insulin pump therapy in adults with type 1 diabetes: a multicentre randomised crossover trial. Lancet 2017; 389:369–380. [PubMed: 28007348]

21. Trevitt S, Simpson S, Wood A. Artificial Pancreas Device Systems for the Closed-Loop Control of Type 1 Diabetes: What Systems Are in Development? J Diabetes Sci Technol 2016; 10:714–723. [PubMed: 26589628]

NOVELTY STATEMENT

- Discrepancies between functionalities of an "artificial pancreas" system and expectations of youth with diabetes likely influence uptake and durability of use. This may contribute to lack of glycemic target attainment in youth with type 1 diabetes, despite increased diabetes technology use.
- This qualitative analysis explored youth and parents' suggestions for novel features of an ideal artificial pancreas system. Suggestions focused on 1) enhancing user interface, 2) increasing automation of glucose management, and 3) integration of commercial features.
- Integration of participant-driven suggestions into future artificial pancreas systems may reduce burden while maximizing system uptake and use in youth with diabetes.

Table 1.

Semi-Structured Interview Questions

These questions are about your thoughts and feelings about using an automated insulin delivery system. There are some automated insulin delivery systems that you may have heard of, like a "closed-loop system" or an "artificial pancreas". We are trying to learn more about what patients with diabetes and parents think about these automated insulin delivery systems. I will be asking for your opinions about how a system like this would affect your life, and any particular features or suggestions you have **to create your "ideal" device**. So for the following questions, I want you to imagine an automated insulin delivery system that is made up of 3 parts: an insulin pump, a continuous glucose monitor (CGM), and a third device that acts like the "brains" or the controller that connects the CGM and pump and helps them work together to manage your diabetes.
1 What specific features would make a system like this beneficial in your life?
2 How would you want an automated system to work when you eat?
3 How would you want an automated system to work when you exercise?
4 If you could customize the alerts in some way (like the sound it makes or when it goes off), how would you do it?
5 What is the bare minimum you'd like a system like this to do in order for it to be beneficial to you?
6 Think about a perfect automated system. How would this ideal system look?
7 What special features would it have?
8 Would you like having the option of not having to bolus for a meal/snack if it meant limiting carb intake to 50 grams for that meal/snack? Why or why not?

Table 1includes the introduction to the interview to provide clarity for the reader. Questions listed are from a specific sub-section of the interview on "Ideal Device Features," analyzed for the purposes of this manuscript.

Table 2.

Participant Characteristics

Youth	Children (n=11)	Adolescents (n=10)	Young Adults (n=18)	Full Sample (N=39)
Age (years)	11.2±0.8	15.7±1.6	21.4±2.4	17.0±4.7
Sex (% female)	72	70	72	72
Race/etdnicity (% non-Hispanic white)	100	60	83	82
T1D duration (years)	5.3±2.2	9.7±3.8	11.7±5.2	9.4±4.9
HbA1c (%) (mmol/mol)	8.2±0.8 66±9	8.5±1.1 69±12	8.6±1.2 70±13	8.4±1.1 68±11
Pump users (%)	100	70	72	79
CGM users (%)	100	70	78	82
Parents				**Full Sample (N=44)**
Mothers (%)				91
Race/ethnicity (% non-Hispanic white)				86
Age of parent's child with T1D (years)				10.6±4.5

Table 2 presents demographic and biomedical characteristics of youth and parent participants in the full sample, and stratified by agegroups. Children are between the ages of 8–12, Adolescents between ages 13–17, and Young Adults between ages of 18–25. All data are presented as mean and standard deviation (M±SD) or percent (%).

Table 3.

Specific Innovative Features Suggested Per Theme

Theme	Participant-suggested features included in theme
Enhancing the Appeal User Interface	• Customizable appearance (Y) • Subtle appearance (Y, P) • Voice activation of system (Y, P) • Single-button announcements by user (Y, P) • Selective sharing of data (Y) • Remote monitoring and dosing by parents (P)
Steps Toward Automation	• Inclusion of glucose in system (Y, P) • Automatic ketone testing (Y, P) • Eliminate pre-bolusing (Y, P) • Suggestions and feedback from system (Y, P) • No carbohydrate limits regardless of degree of automation (Y, P) • Validation from the system (Y)
Innovative and Commercial Add-Ons for Greater Convenience	• Personalized food libraries (Y, P) • Barcode scanners (Y, P) • Automatic detection of exercise by heart rate monitor or step counter (Y, P) • Pleasant alert sounds and visuals (Y, P) • Incentives/prizes to engage in management (Y, P) • Location tracking for safety (P) • Location tracking for food/restrooms (Y) • Automatic detection and pre-bolusing for food (Y)

Table 3 summarizes each theme with a list of specific, innovative features suggested by participants. Y = youth reported, P = parent reported