BRIEF REPORT

Pediatric Endocrinology Trainees' Education and Knowledge About Insulin Pumps and Continuous Glucose Monitors

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Abstract

Background: Recent data demonstrating a lack of improvement in average hemoglobin A1c levels despite the increased use of insulin pumps and continuous glucose monitors (CGMs) suggest that patients are not using these technologies optimally. Suboptimal provider understanding of these devices may be a contributing factor.

Methods: We sought to assess fellows' knowledge, attitudes, and practices regarding insulin pumps and CGMs using a mixed-methods survey. We polled 42 pediatric endocrinology fellows and 69 attending physicians in pediatric endocrinology using items on a five-point Likert scale.

Results: Perceived fellow knowledge of insulin pumps and CGMs was only 3.6 ± 1.0 and 3.6 ± 0.9 , respectively. Despite consensus about the need for pediatric endocrinologists to understand these technologies, only 14.7% of fellows reported the presence of a formal curriculum about these technologies at their institutions. Potential gaps identified in fellows' knowledge include general use and troubleshooting, advanced insulin pump features, infusion sets and dermatological complications, systematic approach to data, interpretation and application of CGM data, and keeping pace with technological advances.

Conclusions: Our data suggest suboptimal fellow knowledge and understanding of insulin pumps and CGMs in pediatric type 1 diabetes management, which is likely attributable to inadequate education in fellowship training programs. The development of formal educational curricula targeting areas of weakness identified in this survey may improve clinician knowledge of these technologies and ultimately impact patient education and care.

Keywords: Graduate medical education, Continuous glucose monitor, Insulin pump, Pediatric, Diabetes technology, Type 1 diabetes.

Introduction

TYPE 1 DIABETES (T1D) is one of the most common conditions managed by pediatric endocrinologists.¹ Care of patients with T1D focuses on attaining glycemic control as close to normal as possible while minimizing hypoglycemia to prevent long-term complications.² For the past decade, the use of insulin pumps and continuous glucose monitors (CGMs) has increased dramatically.^{3–5} From 2014 to 2017 insulin pump use among patients <26 years of age in the T1DX exchange (T1DX) remained stable around 62%.^{6,7} In contrast, CGM use doubled over this same time period from 11% in 2014–2015 to 22% in 2016–2017.^{6,7} Research assessing the impact of these technologies has resulted in mixed conclusions. Some studies have found no benefit to the use of

these technologies and have also identified increased rates of diabetic ketoacidosis (DKA) in pump users.^{8–11} However, other studies have shown improvements in glycemic control and health-related quality of life while simultaneously reducing the incidence of severe hypoglycemia and DKA.^{5,12–16}

Despite increasing use of these technologies in clinical practice, the average A1c among patients <26 years of age in the T1DX is not improving. In 2010–2012 the average A1c in this population was 8.5%.^{6,7} In 2016–2017 the average was 8.9%. The lack of improvement in glycemic control despite these technological advances suggests patients are not able to take full advantage of their capabilities during real-world use. Suboptimal clinical patient education may be one contributing modifiable factor. To complicate matters further, as of December 2018 there are four different manufacturers of

insulin pumps and CGMs that are FDA approved and widely used for T1D in the United States. With no standardization of language or settings across devices and little hands-on experience with these technologies, learning to effectively counsel patients and to use these diabetes-related devices presents a challenge for pediatric endocrinologists.¹⁷ To the best of our knowledge there are no existing data describing pediatric endocrinology fellows' education or knowledge about the use of insulin pumps or CGMs in pediatric T1D management. We, therefore, sought to assess perceptions of pediatric trainees' education and knowledge of these technologies.

Throughout this article, the term fellow refers to an American or Canadian trainee who has already completed specialty training in pediatrics and is now focused on subspecialty training in pediatric endocrinology.

Methods

Study data were collected and managed using the REDCap research electronic data capture tools hosted at Boston Children's Hospital.¹⁸ A link to the REDCap survey was embedded in an e-mail distributed to 1270 members of the Pediatric Endocrine Society (PES) in the United States and Canada. Face validity of the survey was assessed by having several fellows and attending physicians review the survey and provide itemized feedback in an interview format. Attending physicians were asked to rate their perceptions of fellows' skills and knowledge on completion of training. Fellows were asked about perceptions of their own current personal skills and knowledge. Attending physicians not supervising fellows were excluded from analysis.

The survey included 34 Likert scale-based questions, 8 free-response questions, and 7 demographic questions. A five-point Likert scale (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree) assessed perceptions of knowledge of these devices, clinical management of patients using these devices, and fellows' education about these devices. Eighteen questions about insulin pumps assessed knowledge of benefits and limitations of use, basal rates, carbohydrate ratios, correction factors, initial insulin pump doses, infusion sets, temporary basal rates, extended boluses, management with physical activity, practical aspects of use, and features of different systems. Sixteen questions about CGMs assessed knowledge of benefits and limitations of use, interpreting arrows indicating rates of glycemic change, calibration, troubleshooting discrepant blood glucose and CGM data, alert settings for hypo- and hyperglycemia, interpretation of tracings and use for insulin adjustments, practical aspects of use, and features of different systems. Free-response questions explored how respondents learned about insulin pumps and CGMs and areas for improvement in fellows' knowledge of these devices.

Responses were anonymous. There was no financial compensation for participation. A copy of the survey is available on request. This study was deemed exempt by the institutional review board at Boston Children's Hospital.

Quantitative data were analyzed using IBM SPSS Statistics for Windows version 24.0 (IBM, Armonk, NY). The Likert scale data are reported as means and standard deviations. Independent *t*-tests were used to compare responses from attending physicians and trainees. Paired *t*-tests were used to compare perceptions of specific aspects of fellows'

knowledge and education. ANOVA was used to compare fellows' self-perceptions of knowledge by year of training. Statistical significance was defined as *P*-values <0.05.

Thematic analysis of qualitative responses was performed by three members of the research team (B.E.M., G.W., and K.C.G.). Each of these team members independently reviewed all free-text comments to generate initial codes, which were organized using Microsoft Excel[®]. Initial codes were discussed by the group to generate a list of second-cycle codes. Each team member then applied the revised coding framework to all free-text comments. The team met to reach consensus on the final coding and dominant themes.

Results

Survey response rate

The survey was distributed to 1270 members of PES. The response rate was 8.7% (*n* = 111), including 17.6% of fellows and 4.3% of attending physicians. Twenty-five attending physicians were excluded from participation because they did not supervise fellows caring for patients with T1D. A total of 86 surveys were analyzed: 44 from attending physicians and 42 from fellows. Responses were fielded from June 14, 2018 through July 16, 2018 across two distributions of the survey. Fellows who responded after the start of the new academic year in July had all completed at least 1 year of pediatric endocrinology training and were instructed to identify their year of training for the 2017–2018 academic year. See Table 1 for additional demographic information.

No question revealed significant differences between attending physicians' perceptions of trainees' knowledge and skills on completion of training and fellows' perceptions of their own knowledge and skills at their current level of training. Therefore, data from the two groups were combined for analyses.

Quantitative data

Perceptions of fellows' overall knowledge of insulin pumps and CGMs were only 3.6 ± 1.0 and 3.6 ± 0.9 , respectively, on a five-point Likert scale. Only 2 of the 20 concepts assessed showed a difference in trainees' self-perceptions according to year of training: knowledge of unique features of different insulin pumps [$F_{(2, 31)} = 3.45$, $P < 0.04$] and the ability to adjust insulin doses using CGM tracings [$F_{(2, 31)} = 3.42$, $P < 0.05$]. Collectively, second- and third-year fellows (3.4 ± 0.9) rated themselves more highly than first-year fellows (2.5 ± 1.0) on knowledge of different insulin pump features [$t(32) = 2.64$, $P < 0.01$]. Second- and third-year fellows (4.2 ± 0.6) also rated themselves more highly than first-year fellows (3.5 ± 0.9) on their ability to adjust insulin doses using CGM tracings [$t(32) = 2.47$, $P < 0.002$].

Fellows who reported the presence of a formal educational curriculum at their institution were perceived to have greater knowledge of insulin pumps [$t(71) = 2.48$, $P < 0.008$] and CGMs [$t(71) = 1.85$, $P < 0.01$]. Fellows who had the opportunity to wear CGMs for educational purposes perceived themselves to have greater CGM knowledge [$t(41) = 2.03$, $P < 0.011$] although this was not seen in fellows who wore insulin pumps for educational purposes. There were no statistically significant differences in insulin pump or CGM knowledge based on training program size or the number of fellow patients using pumps or CGMs.

TABLE 1. DEMOGRAPHIC INFORMATION FOR THE 42 FELLOWS AND 44 ATTENDING PHYSICIANS INCLUDED IN THIS SURVEY

<i>Fellows</i>			<i>Attending physicians</i>		
Years of experience	First year	50%	0–5	12.8%	
	Second year	23.6%	5–10	30.8%	
	Third year	26.5%	10–20	23.1%	
			>20	33.3%	
<i>Number of fellows at institution</i>					
0–3		32.4%		53.8%	
4–6		41.1%		25.6%	
7–9		17.6%		17.9%	
10 or more		8.8%		2.6%	
<i>Formal fellows’ pump and CGM curriculum at institution</i>					
Yes		14.7%		25.6%	
<i>Personal number of patients using pump or CGM</i>					
0–20		44.2%		2.6%	
21–50		20.1%		5.1%	
51–100		23.5%		30.8%	
>100		11.8%		61.5%	
<i>Pump or CGM experience outside of work</i>					
No personal experience		44.1%		10.3%	
Personal or family member use for T1D	Pump	0%	Pump	5.1%	
	CGM	2.9%	CGM	5.1%	
Worn for education	Pump	29.4%	Pump	60.0%	
	CGM	44.1%	CGM	71.8%	

CGM, continuous glucose monitor; T1D, type 1 diabetes.

Likert scale scores for perceptions of trainees' knowledge of insulin pumps and CGMs were divided into quartiles. On the five-point Likert scale the smallest absolute difference between the lowest scoring concept in the top quartile and the highest scoring concept in the bottom quartile was 0.99 [$t(73)=9.61$, $P<0.001$]. Fellows' knowledge of the following concepts were in the top quartile: counseling about insulin pump and CGM benefits and limitations, assessing basal rates, assessing correction factors, and assessing carbohydrate ratios. Fellows' knowledge of the following concepts were in the bottom quartile: extended boluses, infusion sets, counseling patients about practical aspects of insulin pump and CGM use, and counseling about unique features of different insulin pumps and CGMs.

There was near universal consensus about the importance of pediatric endocrinologists' understanding of insulin pumps and CGMs, with 96.3% and 98.6% of respondents, respectively, either agreeing or strongly agreeing. However, only 51.2% and 47.3% of respondents agreed or strongly agreed about the adequacy of trainees' education about insulin pumps and CGMs. Only 25.6% of attending physicians and 14.7% of fellows reported the presence of a formal educational curriculum at their institution. Most of these curricula were described as limited introductory lectures or fellow attendance at patient education classes. Finally, 89.7% and 84.5% of respondents agree or strongly agree that a formal curriculum about insulin pumps and CGMs, respectively, would enhance fellow education and improve patient care.

TABLE 2. REPRESENTATIVE QUOTES FOR THE THREE DOMINANT THEMES THROUGH WHICH FELLOWS LEARNED ABOUT INSULIN PUMPS AND CONTINUOUS GLUCOSE MONITORS

<i>Fellows' experiences learning about insulin pumps</i>	<i>Fellows' experiences learning about CGMs</i>
1. "had patients show me"; "treating patients and helping them troubleshoot"	1. "direct patient care"; "CGM class for patients"; "taking parent calls overnight"
2. "most of what I know about pumps is from diabetes camp"	2. "through our CDEs"
3. "briefly during orientation with our diabetes educators"	3. "personal trial of a Dexcom® for 1 week"

Qualitative data

Sixty-six of the 86 respondents (76.7%) entered free responses. Ninety percent of fellows reported learning about insulin pumps through at least one of three dominant themes (Table 2): (1) direct patient care, (2) diabetes camp, and (3) informal education from diabetes educators. Eighty-one percent of trainees reported learning about CGMs through at least one of three dominant themes: (1) direct patient care, (2) informal education from diabetes educators, and (3) wearing the device for educational purposes. Among attending physicians the second most common theme for learning about pumps and CGMs, capturing 52.8% and 41.4% of respondents, respectively, was from device manufacturers/representatives.

The team reached consensus on four final themes for areas for improvement in fellows' knowledge about insulin pumps: advanced insulin pump features, infusion sets and the management of adhesion and dermatological complications, staying current with unique features of different systems and technological advances, and general use and troubleshooting. The team reached consensus on four final themes for areas for improvement in fellows' knowledge of CGMs: general use and troubleshooting, interpretation of data and application for insulin dose adjustments, staying current with unique features of different systems and technological advances, and systematic approaches to data interpretation.

Discussion

To the best of our knowledge, this nationwide survey of pediatric endocrinology trainees and attending physicians is the first to assess perceptions of fellows' knowledge and education about insulin pumps and CGMs. Our results highlight discrepancies between the universally perceived importance of pediatric endocrinologists' understanding of insulin pumps and CGMs and the lack of formal fellowship education about their role in pediatric T1D management.

Trainees were perceived to have better knowledge about subjects that can be generalized from prior knowledge of multiple daily injection (MDI) therapy, including assessing basal rates, correction factors, and carbohydrate ratios. Conversely, fellows were perceived to have less knowledge about concepts specific to insulin pump and CGM therapy, including practical aspects of use, infusion sets, extended boluses, CGM calibration and troubleshooting, and unique features of different systems. When paired with the qualitative data indicating that fellows largely learn about these technologies through patient care, this suggests that fellows may extrapolate their knowledge of MDI and finger-stick blood glucose monitoring (BGM) and apply those principles to insulin pump and CGM therapy. Although information about MDI and finger-stick BGM can serve as a foundation for understanding these technologies, higher level understanding of the unique features of these devices is essential for providers to properly educate patients about their use. The lack of optimal provider education and knowledge may help to explain why the improved glycemic control in clinical trials has not been seen with real-world patient use.^{6,7}

Although there is consensus about the importance of pediatric endocrinologists' understanding of insulin pumps and CGMs, current educational practices are lacking. Less than 15% of fellows and 26% of attending physicians report for-

mal educational opportunities for trainees. Our data indicate that education about the use of these devices in T1D is dependent on clinical experience, diabetes educators, diabetes camps, practicums from industry representatives, and opportunities to wear CGMs for educational purposes. Although experiential learning is a central tenant of adult learning theory, variable patient care experiences among trainees foster inconsistencies in education.¹⁹ This lack of standardization across different settings may explain deficiencies in fellows' knowledge of these devices.

There are several limitations to this study. Participation was limited to physicians with PES membership. Non-response bias is a concern, although the response rate, particularly among fellows, is comparable with other studies utilizing electronic physician surveys.^{20–22} The lack of significant differences between the opinions of attending physicians and trainees supports the generalizability of these data and mitigates some of these concerns. The use of agree/disagree Likert scale choice options and a survey response bias toward physicians who are interested in diabetes technology suggest that the data represent a "best-case" scenario of perceptions of fellows' technology knowledge.²³ Finally, discrepancies between perceptions of fellows' knowledge and current educational practices may be explained by the Dunning-Kruger effect, a psychological phenomenon in which individuals tend to overestimate their own abilities because they lack awareness of their own ignorance.²⁴

In conclusion, our data highlight major gaps between current educational practices, fellows' knowledge, and the perceived importance of pediatric endocrinologists' understanding of insulin pumps and CGMs in pediatric T1D management. The development of formal educational curricula focused on the T1D technology topics identified in our survey may help to improve both trainee education and patient care.

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Author Disclosure Statement

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References

1. Mayer-Davis E, Lawrence J, Dabelea D, et al.: Incidence trends of type 1 and type 2 diabetes among youths, 2002–2012. *N Engl J Med* 2017;376:1419–1429.
2. American Diabetes Association (ADA): Standard of medical care in diabetes—2017. *Diabetes Care* 2017;40 (sup 1): s4–s128.
3. Shalitin S, Peter Chase H: Diabetes technology and treatments in the paediatric age group. *Int J Clin Pract* 2011;65:76–82.
4. Vigersky RA: The benefits, limitations, and cost-effectiveness of advanced technologies in the management of patients with diabetes mellitus. *J Diabetes Sci Technol* 2015;9:320–330.

5. Wong JC, Foster NC, Maahs DM, et al.: Real-time continuous glucose monitoring among participants in the T1D exchange clinic registry. *Diabetes Care* 2014;37:2702–2709.
6. Foster NC, Miller KM, Tamborlane WV, et al.: Continuous glucose monitoring in patients with type 1 diabetes using insulin injections. *Diabetes Care* 2016;39:e81–e82.
7. Foster N, Miller K, DiMeglio L, et al.: Marked increases in CGM use has not prevented increases in HbA1c levels in participants in the T1D Exchange (T1DX) clinic network. In: American Diabetes Association. Orlando, FL, 2018. https://plan.core-apps.com/tristar_ada18/abstract/807d2f9885450670bb994661e3686e95.
8. Evans-Cheung TC, Campbell F, Yong J, et al.: HbA1c values and hospital admissions in children and adolescents receiving continuous subcutaneous insulin infusion therapy. *Diabet Med* 2019;36:88–95.
9. Maahs DM, Hermann JM, Holman N, et al.: Rates of diabetic ketoacidosis: international comparison with 49,859 pediatric patients with type 1 diabetes from England, Wales, the U.S., Austria, and Germany. *Diabetes Care* 2015;38:1876–1882.
10. Wheeler BJ, Donaghue KC, Heels K, Ambler GR: Family perceptions of insulin pump adverse events in children and adolescents. *Diabetes Technol Ther* 2014;16:204–207.
11. Petrie JR, Peters AL, Bergenstal RM, et al.: Improving the clinical value and utility of CGM systems: issues and recommendations. *Diabetes Care* 2017;40:1614–1621.
12. Prahallad P, Tanenbaum M, Hood K, Maahs DM: Diabetes technology: improving care, improving patient-reported outcomes and preventing complications in young people with Type 1 diabetes. *Diabet Med* 2018;35:419–429.
13. Karges B, Schwandt A, Heidtmann B, et al.: Association of insulin pump therapy vs insulin injection therapy with severe hypoglycemia, ketoacidosis, and glycemic control among children, adolescents, and young adults with type 1 diabetes. *JAMA* 2017;318:1358–1366.
14. Zabeen B, Craig ME, Virk SA, et al.: Insulin pump therapy is associated with lower rates of retinopathy and peripheral nerve abnormality. *PLoS One* 2016;11:1–10.
15. Chase HP, Beck RW, Xing D, et al.: Continuous glucose monitoring in youth with type 1 diabetes: 12-month follow-up of the Juvenile Diabetes Research Foundation continuous glucose monitoring randomized trial. *Diabetes Technol Ther* 2010;12:507–515.
16. Naranjo D, Tanenbaum ML, Iturralde E, Hood KK: Diabetes technology: uptake, outcomes, barriers, and the intersection with distress. *J Diabetes Sci Technol* 2016;10:852–858.
17. Rodbard D: Continuous glucose monitoring: a review of successes, challenges, and opportunities. *Diabetes Technol Ther* 2016;18 Suppl 2:S2–3–S2–13.
18. Harris PA, Taylor R, Thielke R, et al.: Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377–381.
19. Yardley S, Teunissen PW, Dornan T: Experiential learning: AMEE Guide No. 63. *Med Teach* 2012;34:e102–15.
20. Garvey KC, Telo GH, Needleman JS, et al.: Health care transition in young adults with type 1 diabetes: perspectives of adult endocrinologists in the U.S. *Diabetes Care* 2016;39:190–197.
21. Agarwal S, Garvey KC, Raymond JK, Schutta MH: Perspectives on care for young adults with type 1 diabetes transitioning from pediatric to adult health systems: a national survey of pediatric endocrinologists. *Pediatr Diabetes* 2017;18:524–531.
22. de Beaufort C, Jarosz-Chobot P, Frank M, et al.: Transition from pediatric to adult diabetes care: smooth or slippery? *Pediatr Diabetes* 2010;11:24–27.
23. Hinz A, Michalski D: The acquiescence effect in responding to a questionnaire. *Psychosoc Med* 2007;4:1860–5214.
24. Dunning D, Johnson K, Ehrlinger J, et al.: Why people fail to recognize their own incompetence. *Am Psychol Soc* 2003;12:83–87.

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