Treatment Intensification With Insulin Pumps and Other Technologies in Patients With Type 2 Diabetes: Results of a Physician Survey in the United States

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An online survey was conducted to assess the perspectives and use of diabetes technologies by a sample of U.S. primary care physicians (PCPs) and endocrinologists to optimize intensive insulin therapy in patients with type 2 diabetes. Overall, endocrinologists reported using diabetes technologies more frequently than PCPs for patients with type 2 diabetes requiring basal-bolus insulin therapy. PCPs and endocrinologists who were highly focused on diabetes management with insulin therapy reported using insulin delivery devices (insulin pumps and wearable tube-free patches) when patients are not achieving their A1C target while taking basal plus three or more prandial injections of insulin daily.

It is widely recognized that glycemic control is suboptimal in many patients with type 2 diabetes (1,2). Many factors may contribute to inadequate glycemic control, including poor patient adherence (2). Adherence becomes more challenging when the treatment is perceived as difficult and burdensome, as is the case with basal-bolus insulin therapy (2). In a global survey of patients with diabetes who inject insulin, over half of the respondents reported intentionally skipping insulin injections (3). More than 80% of patients and physicians in one survey reported that they wished insulin injections would fit patients' daily lives (4), and up to 71% of patients on multiple daily injection (MDI) regimens do not regularly inject insulin outside of their home (5). Adherence to medication therapy remains low because of the complexity of the treatment regimens (e.g., multiple daily dosing, quality-of-life disruption, discomfort, and inconvenient medication delivery devices) (6–8).

Advances in medical devices and technologies may help decrease treatment complexity, improve patient convenience, optimize therapy, and potentially improve adherence to medications. For example, advances in insulin pump technology, along with the development of rapid-acting insulin analogs, have allowed continuous subcutaneous insulin infusion (CSII) technology to closely mimic physiological insulin secretion, helping patients reach recommended treatment goals while improving adherence (9).

Ideal candidates for CSII include not only patients with type 1 diabetes, but also those with intensively managed insulin-dependent type 2 diabetes (10). The safety and efficacy of insulin pump therapy in patients with type 2 diabetes were demonstrated in the Opt2mise program, in which patients who failed to achieve adequate glycemic control on MDI therapy achieved significant, sustained improvements in glycemic outcomes when switched to pump therapy (11,12).

Advances in continuous glucose monitoring (CGM) systems can help patients better understand the impact medications and lifestyle choices have on their glycemic control. CGM historically has been used almost exclusively by patients with type 1 diabetes; however, CGM also benefits patients with type 2 diabetes. In a study evaluating the use of CGM in patients with type 2 diabetes on an MDI regimen, patients randomized to the CGM arm had a higher degree of patient satisfaction, a reduction in A1C levels, and an increased time in the target glucose range compared to usual care (13).

Determining when technological interventions (e.g., insulin delivery devices [traditional insulin pump or wearable tube-free patch], CGM systems, and smartphone applications [apps]) are appropriate

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options to optimize intensive insulin therapy in patients with type 2 diabetes can be a challenge for both primary care physicians (PCPs) and endocrinologists. Therefore, we conducted an online survey to assess and better understand current practice trends related to the use of diabetes technologies for the management of type 2 diabetes among PCPs and endocrinologists in the United States.

Materials and Methods

Study participants were engaged by the survey and research company Toluna (www.toluna-group.com) using their Curizon health care panel database (www.curizon.com) and were selected based on their registration profile information. Details describing how the database was formed are a proprietary secret of Toluna; consequently, this information could not be shared with the study investigators. Participants were contacted via an email message that linked directly to the online screener and subsequent survey.

An initial online screening was conducted to determine study eligibility. Inclusion criteria included PCPs (family practice, general practice, primary care, and internal medicine) and endocrinologists who had been in practice for 5–35 years, who worked in a private or group practice in a community-based clinic or a community hospital, and who spent ≥75% of their time treating patients as opposed to doing research, management, teaching, or other professional commitments. Eligible PCPs must have personally treated ≥20 patients with type 2 diabetes per month, with ≥25% of these patients prescribed insulin therapy at the time of the survey. Eligible endocrinologists must have personally treated ≥80 patients with type 2 diabetes, with ≥50% of these patients prescribed insulin therapy at the time of the survey. Both PCPs and endocrinologists must have been treating patients with insulin on basal-bolus therapy.

The subsequent survey consisted of seven questions related to respondents' current practices, comfort level, and perspectives on the use of diabetes-related technologies. These questions were developed in collaboration with practicing physicians who treat patients with type 2 diabetes to ensure their relevance in clinical practice.

When asked about traditional insulin pumps and wearable tube-free patches, visual aids (two unbranded sample images of a traditional durable insulin pump and two unbranded sample images of U.S.-marketed, wearable, tube-free patches) were provided to respondents to assist in differentiating pump types. Traditional durable insulin pump devices and wearable patch devices were described broadly in the questionnaire, and product-specific questions were not asked.

The questions did not specify the differences between a stand-alone pump and an integrated insulin pump system. The same approach was taken with questions regarding CGM systems; questions were broadly described and not product-specific. The questions did not describe flash CGM systems and focused on the added value of data generated by CGM systems in general, to aid treatment decisions. Survey respondents were compensated for completing the survey.

Survey results were analyzed using descriptive statistics. Some questions were force-ranked in 1–9 or 1–6 scales. For the questions with a 1–9 scale, the top three ranks received higher weights, the sum of all weights equaled 1.0, and the score range was 0.02–0.24, with 4.04 being the minimum possible and 48.48 the maximum possible weight rank score. Weights were assigned as follows: for rank 1, a 0.05 increment; for rank 2, a 0.04 increment; for rank 3, a 0.03 increment; and for ranks 4–9, weights were equally distributed in 0.02 increments.

For the questions with a 1–6 scale, only the top rank was given more weight, the sum of all weights equaled 1.0, and the score range was 0.04–0.30, with 8.08 being the minimum possible and 60.6 the maximum possible weight rank score. A 0.06 increment was assigned for rank 1, and for ranks 2–6, weights were equally distributed in 0.05 increments.

Results

The online screening and survey were conducted between 18 November and 4 December 2017. A national sample of physicians from the United States was recruited by Toluna. A total of 449 practicing physicians completed the initial online screening; 247 did not meet the inclusion criteria, leaving 202 eligible physicians to complete the online survey. Of the 202 participants who completed the online survey, about half were PCPs (n = 102) and the other half were endocrinologists (n = 100).

Identifying Technologies and Patients

PCPs and endocrinologists reported similar use of traditional pumps and lifestyle apps for their patients with type 2 diabetes receiving basal-bolus insulin therapy (Figure 1). Overall, more endocrinologists than PCPs reported using CGM (87 vs. 28.4%) and wearable tube-free patch pumps (56 vs. 22.6%)

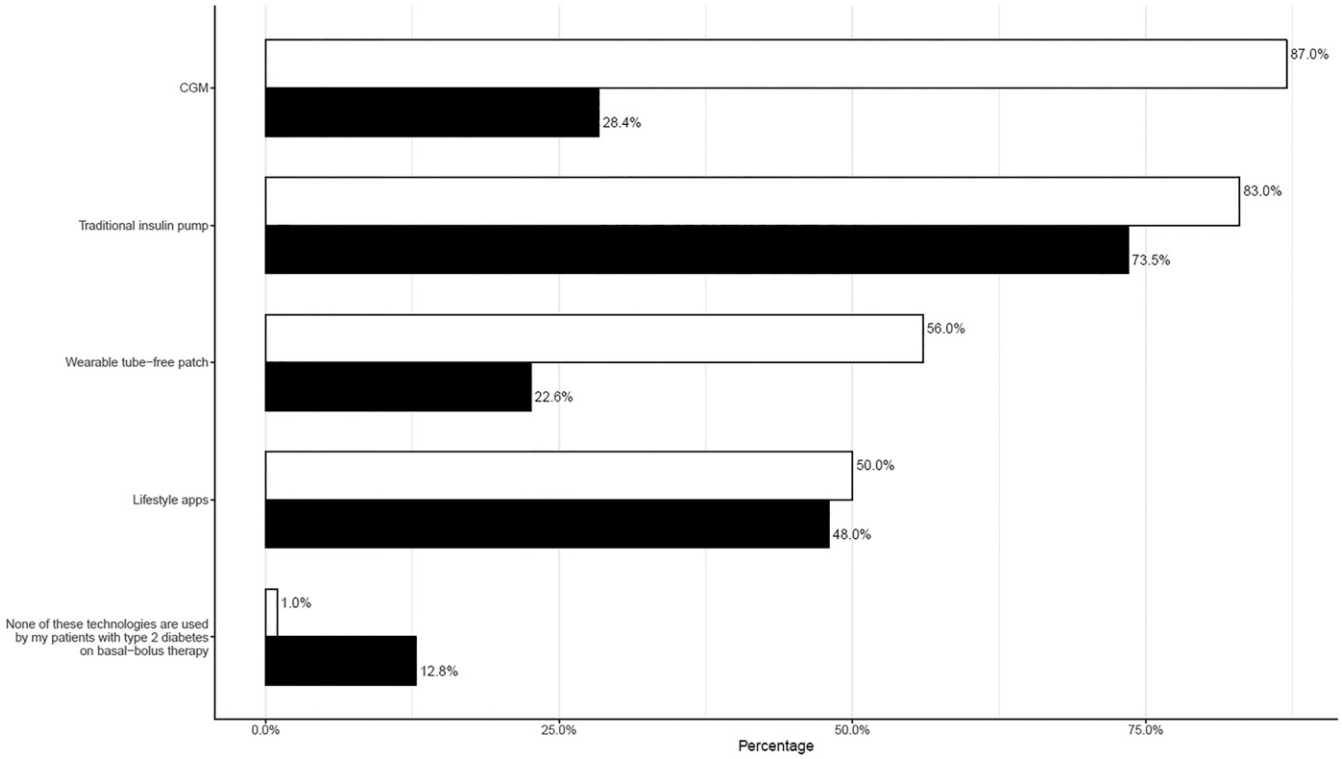

FIGURE 1 Results on the use of advanced technologies by patients with type 2 diabetes on basal-bolus insulin therapy, as perceived by 202 physicians responding to a 2017 online survey. White bars = endocrinologists (n = 100); black bars = PCPs (n = 102).

for their patients with type 2 diabetes using a basal-bolus insulin regimen. One noticeable difference between endocrinologists and PCPs was the overall use of any advanced technologies for patients with type 2 diabetes on basal-bolus insulin therapy. Only 1% of endocrinologists reported not using any of the advanced technologies compared to ~13% of PCPs.

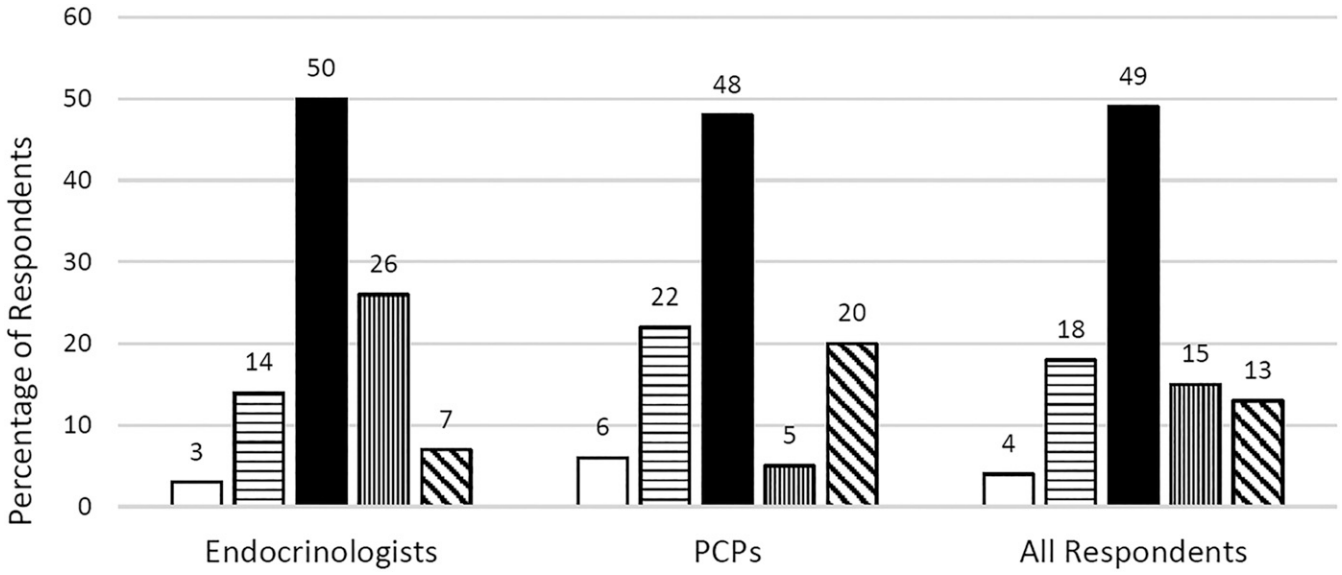

FIGURE 2 Trigger for when to use a traditional insulin pump or wearable tube-free patch, as perceived by 202 physicians responding to a 2017 online survey. White bars = basal plus one prandial injection of insulin per day and still not at patient's A1C target; horizontally striped bars = basal plus two prandial injections of insulin per day and still not at patient's A1C target; black bars = basal and three prandial injections of insulin per day and still not at patient's A1C target; vertical striped bars = basal-bolus insulin regimen regardless of A1C level; downward diagonal striped bars = do not use traditional insulin pump or wearable tube-free patch but rather continue to modify insulin dosing regimen to improve glycemic control.

Almost half of the respondents reported considering using insulin delivery devices when patients had not achieved their A1C goal despite the use of a basal insulin and three or more prandial injections of insulin per day (Figure 2). Differences in pump use between endocrinologists and PCPs were noted for patients with type 2 diabetes receiving less than three bolus insulin injections or not at their A1C target regardless of their basal-bolus insulin regimen. About one-fourth of the endocrinologists considered using an insulin pump or patch for patients on a basal-bolus regimen regardless of A1C level, as opposed to <5% of PCPs. More PCPs (19.6%) reported not using a traditional insulin pump or wearable tube-free patch and continuing to modify the insulin-dosing regimen to improve glycemic control compared to endocrinologists (7.0%).

The three most important patient attributes that both endocrinologists and PCPs reported considering when identifying appropriate candidates for a wearable tube-free patch included patients who are motivated to achieve tighter blood glucose control, those with appropriate health literacy and cognitive ability, and those who request an insulin delivery device. Moreover, a similar proportion of endocrinologists and PCPs responded that patients not controlled on current therapy and early adopters of technologies were deemed appropriate candidates for a wearable tube-free patch. In contrast, 20% of endocrinologists and 10.8% of PCPs reported that patients with a history of very poor adherence were suitable candidates for a wearable tube-free patch.

Respondents were asked how well certain patient factors predict success with a given intervention using a 5-point rating scale (from 1 = not at all predictive to 5 = very predictive). Positive predictive factors to interventional success included a patient's motivation to achieve tighter blood glucose control (60%), appropriate health literacy and cognitive ability (49%), and a history of very good adherence (48%).

Clinical Practice Trends Regarding Diabetes Technology

When asked about their comfort level with using traditional insulin pump therapy on a rating scale of 1–5 (from 1 = very uncomfortable to 5 = very comfortable), 75% of the endocrinologists reported being very comfortable compared to <25% of the PCPs. The proportion of respondents who selected very uncomfortable was <5% for both endocrinologists and PCPs.

The same 5-point rating scale (from 1 = very uncomfortable to 5 = very comfortable) was used to assess respondents' comfort level with initiating, monitoring, and adjusting a wearable tube-free patch. Unlike the previous findings regarding comfort using a durable insulin pump, a higher percentage of PCPs reported being comfortable or very comfortable initiating a wearable tube-free patch (73.9 vs. 52%) and monitoring and adjusting insulin using a wearable tube-free patch pump (82.6 vs. 56%). Less than 2% of endocrinologists reported being uncomfortable or very uncomfortable with initiating, monitoring, and adjusting a wearable tube-free patch. In contrast, 10.5% of PCPs reported being uncomfortable or very uncomfortable initiating and 8.7% reported being uncomfortable or very uncomfortable monitoring and titrating a wearable tube-free patch.

Perceived Benefits of and Barriers to Using Diabetes Technology

Respondents were asked about features that deter them from using technologies in their clinical practice to help successfully manage patients. When considering answers from all respondents, cost/insurance coverage, device complexity, and patient acceptance were ranked as the three leading features that deter physicians from using technologies (Table 1). Complexity of device was a common response for both PCPs and endocrinologists; however, endocrinologists ranked cost/insurance coverage and patient acceptance as top deterrents, whereas PCPs placed a higher ranking on the requirement of extra office time and difficulty in training/monitoring patients.

When asked about specific features of an insulin delivery device that are most important with regard to recommending one medical device over another for patients with type 2 diabetes, respondents consistently selected ease of use, flexible dosing, and large insulin reservoir as the three most important features (Table 2).

Respondents were asked what technologies, in conjunction with an insulin delivery device, would have the greatest utility/impact in helping patients with type 2 diabetes achieve glycemic targets. Although the order of ranking differed between endocrinologists and PCPs, both perceived the following features as providing the greatest utility: an insulin delivery device requiring fewer injections, graphical representation of glucose data correlated to insulin dosing data, and an objective capture of insulin dose and delivery time (Table 3).

TABLE 1 Barriers to Using Diabetes Technologies in Type 2 Diabetes, as Perceived by 202 Physicians in a 2017 Online Survey

Respondents	Feature	Weighted-Rank Score*
Endocrinologists (n = 100)	Other: cost/insurance coverage	20.06
	Patient acceptance	16.60
	Complexity of device	14.38
	Patient anxiety	12.47
	Difficulty in training/monitoring patients	12.03
	Extra resources requirement	11.41
	Extra office time requirement	11.07
	Perceived low efficacy	10.41
	Protected health information data security	6.38
PCPs (n = 102)	Complexity of device	16.12
	Extra office time requirement	14.27
	Difficulty in training/monitoring patients	14.24
	Patient acceptance	13.79
	Extra resources requirement	13.19
	Patient anxiety	10.70
	Other: cost/insurance coverage	10.33
	Perceived low efficacy	8.93
	Protected health information data security	6.52

*Possible weighted rank score range: 4.04–48.48.

Survey results indicate that, for PCPs, the biggest deterrents to using technologies include complexity of the device, extra office time requirements, and difficulty in training/monitoring patients.

Discussion and Conclusions

Medical devices, and technologies in general, may be tools that can assist patients with type 2 diabetes to achieve individual glycemic targets, but determining when best to implement a device in the treatment continuum can be challenging for both PCPs and endocrinologists. The results of this survey provide a better understanding on the use of technologies in the type 2 diabetes population among PCPs and endocrinologists, as well as perceptions of and barriers to using diabetes technologies.

The reported use of CGM systems in patients with type 2 diabetes was more common among endocrinologists compared to PCPs (87 vs. 28.4%). This difference in the use of CGM may be due to CGM being more commonly used in patients with type 1 diabetes who are more likely to be treated by an endocrinologist than by a PCP. Therefore, endocrinologists may be more familiar and comfortable with the use of CGM systems compared to PCPs.

Many trials have shown the clinical benefit of CGM use in patients with type 1 diabetes receiving insulin with an insulin pump (14–17). A recent study by Beck et al. (13) reported that the use of CGM was associated with improved glycemic outcomes in patients with type 2 diabetes treated with MDI. As more evidence on the clinical benefit of CGM in patients with type 2 diabetes is established and these technologies become more accessible to all patients, CGM may become more commonly used in patients with type 2 diabetes by both endocrinologists and PCPs.

Approximately one-fourth of PCPs, compared to a little more than half of endocrinologists surveyed, stated that patients use wearable tube-free patch pumps, suggesting this technology is not as commonly used as traditional insulin pumps, despite study results

TABLE 2 Important Insulin Delivery Device Features for Using Diabetes Technologies in Type 2 Diabetes, as Perceived by 202 Physicians in a 2017 Online Survey

Respondents	Feature	Weighted-Rank Score*
Endocrinologists (n = 100)	Ease of use (simplified device with easy-to-use functions)	18.11
	Flexible dosing	14.81
	Large insulin reservoir (multiple day wear)	12.22
	Wireless controller	11.13
	Wearable tube-free patch	10.55
	Insulin dose capture report	9.05
	Data report through provider portal for real-time data collection	9.00
	Connectivity to other branded devices	8.73
	Patient lifestyle apps	6.40
PCPs (n = 102)	Ease of use (simplified device with easy-to-use functions)	19.30
	Flexible dosing	12.77
	Large insulin reservoir (multiple day wear)	12.53
	Wearable tube-free patch	11.74
	Wireless controller	11.69
	Insulin dose capture report	9.36
	Data report through provider portal for real-time data collection	8.80
	Patient lifestyle apps	8.45
	Connectivity to other branded devices	5.35

*Possible weighted rank score range: 4.04–48.48.

demonstrating that wearable insulin pumps can provide improved glycemic results compared to MDI therapy (18–20). These findings may be due to the general lack of awareness of these devices as a treatment alternative for patients with type 2 diabetes on MDI. Additionally, wearable tube-free patch pumps were not approved for Medicare patients until 5 January 2018, and many Medicaid plans do not cover these devices (21).

One of the main goals of this survey was to determine how physicians define patients with type 2 diabetes as having failed insulin therapy and when physicians consider treatment intensification with an insulin pump. As expected, patients taking a basal injection plus three prandial injections of insulin who have not achieved their A1C target are more likely to be treated with a traditional pump or wearable tube-free patch compared to those who are taking a basal injection plus one prandial injection and not achieving their recommended A1C target. Endocrinologists were more likely than PCPs to consider the use of a traditional pump or wearable tube-free patch in patients taking a basal-bolus regimen regardless of A1C.

In a global survey of physicians' and patients' perception of insulin therapy, both groups reportedly wished insulin treatment would be flexible to fit patients' lives and that good glycemic control with insulin did not require daily injections (4). When recommending an insulin delivery device to patients who are unable to achieve their glycemic goals with an MDI regimen, specific features offered by a system may address the unmet needs and disease burden. In this survey, ease of use (simplified device with easy-to-use functions), flexible dosing, and a large insulin reservoir (multiple day wear) were the most important features considered when selecting one insulin delivery device over another by both PCPs and endocrinologists. Both groups reported that the technologies that would have the greatest utility and impact in helping patients with type 2 diabetes achieve glycemic

TABLE 3 Technological Features, in Conjunction With Insulin Delivery Devices, That Would Have the Greatest Utility/Impact on Achieving Glycemic Targets, as Perceived by 202 Physicians in a 2017 Online Survey

Respondents	Feature	Weighted-Rank Score*
Endocrinologists (n = 100)	Graphical representation of glucose data correlated to insulin dosing data	21.92
	Objective capture of insulin dose and delivery time	18.71
	Insulin delivery device requiring fewer injections	18.71
	Real-time glucose data transmission to clinician portal	14.06
	Patient lifestyle apps	13.38
	Real-time insulin data transmission to clinician portal	13.22
PCP respondents (n = 102)	Insulin delivery device requiring fewer injections	22.09
	Objective capture of insulin dose and delivery time	17.62
	Graphical representation of glucose data correlated to insulin dosing data	17.10
	Patient lifestyle apps	14.98
	Real-time insulin data transmission to clinician portal	14.68
	Real-time glucose data transmission to clinician portal	13.54

*Possible weighted rank score range: 4.04–48.48.

targets include an insulin delivery device requiring fewer injections, graphical representation of glucose data correlated to insulin dosing data, and the ability to objectively capture insulin dose and delivery time data. Ideally, next-generation insulin delivery devices will incorporate all these features into one system.

Both physician groups indicated that the key factors for identifying appropriate candidates for a wearable tube-free patch include the providers' perception of patients' motivation to achieve tighter blood glucose control, patients' appropriate health literacy and cognitive ability, and patients' interest in using a device. The first two of these characteristics, along with a history of very good adherence, were seen as the most crucial factors in predicting patients' success with a given intervention.

Endocrinologists reported that cost/insurance coverage was the top deterrent preventing the use of diabetes technologies to help manage patients' disease, which is consistent with published literature identifying cost as a commonly reported barrier (4). PCPs ranked device complexity as the top deterrent that prevents them from using diabetes technologies to treat patients. This finding may be because PCPs are not as familiar with insulin delivery devices, and their practices may lack the resources (e.g., personnel, experience, and time) needed to educate and train patients. Future studies should examine potential drivers (i.e., insurance coverage and device awareness) and deterrents that affect utilization of wearable tube-free patches or traditional pumps in patients with type 2 diabetes.

Limitations of this survey study include potential sample selection bias. Inclusion criteria for participation in this survey may have preferentially selected prescribers with more experience or a special interest in treating type 2 diabetes compared to the general population of PCPs and endocrinologists, thus limiting the external validity of these findings. This scenario may be due to the rigorous inclusion screening criteria, resulting in the selection of physicians who may specialize in diabetes care. Therefore, results of technology use among survey responders may not be an accurate representation of clinical practice among general practice PCPs and endocrinologists in the United States. Additionally, access to sample demographics (e.g., practice site locations) was limited because this was an online survey conducted by a third party.

Based on survey results, when considering candidates for a technology-based intervention, patients who should benefit the most are those who are highly motivated to achieve tighter blood glucose control, have an interest in trying a new technology, and possess an

appropriate level of health literacy and cognitive ability to use technological devices. Moreover, next-generation insulin delivery devices should be designed to reduce the number of injections, feature larger insulin reservoirs, provide graphical representations of glucose data correlated to insulin dosing data, capture insulin dose/delivery time data objectively, and provide greater dosing flexibility.

The primary barriers to using diabetes technologies identified by both PCPs and endocrinologists are device complexity and patient acceptance. Although technologies are becoming more intuitive, further education and training around the utility of diabetes technologies are needed. The use of clinical support staff (i.e., for training/monitoring patients) may alleviate the potential burden (e.g., extra office time required) associated with the initiation of a new medical device. Increased education and awareness of both health care providers and patients on the potential benefits afforded by diabetes technologies would also help ease the strongest disincentives indicated by endocrinologists (i.e., patient acceptance and complexity of device). Increasing use of diabetes technologies may improve treatment adherence and persistence and ease disease burden. Professional health care organizations should consider developing clear, unified guidelines on how to prioritize and optimize the use of technologies in managing patients with type 2 diabetes.

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AUTHOR CONTRIBUTIONS

G.G. and E.M.M. contributed to discussion and reviewed/edited the manuscript. D.S., A.E., T.O., and R.S. researched and analyzed data, contributed to discussion, and reviewed/edited the manuscript. G.G. 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.

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