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Real-World Hypoglycemia Avoidance With a Predictive Low Glucose Alert Does Not Depend on Frequent Screen Views

Sarah Puhr, PhD[1], Mark Derdzinski, PhD[1], Andrew Scott Parker, PhD[1], John B. Welsh, MD, PhD[1], and David A. Price, MD[1]

Abstract

Background: Frequent real-time continuous glucose monitoring (rtCGM) data viewing has been associated with reduced mean glucose and frequent scanning of an intermittently scanned continuous glucose monitoring (isCGM) system has been associated with reduced hypoglycemia for patients with diabetes. However, requiring patients to frequently interact with their glucose monitoring devices to detect actual or impending hypoglycemia is burdensome. We hypothesized that a predictive low glucose alert, which forecasts glucose ≤55 mg/dL within 20 minutes and is included in a new rtCGM system, could mitigate hypoglycemia without requiring frequent device interaction.

Methods: We analyzed estimated glucose values (EGVs) from an anonymized convenience sample of 15,000 patients who used Dexcom G6 (Dexcom, Inc, San Diego, CA, USA) and its mobile app for at least 30 days with or without the "Urgent Low Soon" alert (ULS) enabled. Screen view frequency was determined as the frequency with which the trend screen was accessed on the app. Multiple screen views within any 5-minute interval were counted as one. Hypoglycemia exposure for patients in the top and bottom quartiles of screen view frequency (>8.25 and <3.30 per day, respectively) was calculated as the percentage of EGVs below various thresholds.

Results: Over 93% of users enabled the ULS alert; its use was associated with significantly reduced hypoglycemia <55 and <70 mg/dL, independent of screen view frequency.

Conclusion: Use of the G6 ULS alert may disencumber rtCGM users by promoting significant reductions in hypoglycemia without requiring frequent device interactions.

Keywords

alarms, alerts, continuous glucose monitoring, hypoglycemia, predictive alerts, device interaction, screen views

Glucose monitoring is essential to achieving normoglycemia for patients with insulin-treated diabetes. Two types of continuous glucose monitoring (CGM) systems currently exist:[1] real-time (rt) CGM systems automatically transmit historic and current glucose measurements and velocity of glucose change from a wearable body sensor to a nearby receiver or mobile device via Bluetooth, and provide programmable alerts and fixed alarms. The currently available intermittently scanned (is) CGM system provides the same type of glucose data but requires the user to purposely scan the sensor to obtain this information; it does not include audible alerts or alarms for impending or actual hypoglycemia. Accordingly, a person with diabetes needs to recognize the need to scan and be willing to scan (and rescan) to detect hypoglycemia. This places a cognitive burden on isCGM users. If the person is sleeping, if their attention is diverted, or if they have impaired awareness of hypoglycemia (IAH), they may not recognize the need to scan. The I HART CGM study compared time spent low in people type 1 diabetes and IAH treated with rtCGM to those treated with isCGM and found that rtCGM, but not isCGM, reduced hypoglycemia exposure.[2,3]

[1]Dexcom, Inc, San Diego, CA, USA

Corresponding Author:
Sarah Puhr, PhD, Dexcom, Inc, 6340 Sequence Dr, San Diego, CA 92121, USA.
Email: sarah.puhr@dexcom.com

Frequent interaction with CGM systems has been associated with improved glycemia. That is, frequent viewing of an rtCGM system receiver or mobile app trend screen has been associated with decreased A1C[4] and mean glucose;[5] percentage time spent in hypoglycemia, hyperglycemia, and time in range were not measured in these studies. Frequent scanning of an isCGM system by real-world patients was associated with decreased time spent in hypoglycemia and hyperglycemia, and increased time spent in range.[6] The average number of scans per day was 16.3 scans daily (median [IQR]: 14 [10-20]). Time spent less <55 mg/dL was 43.4 and 26.2 minutes daily for low-frequency and high-frequency scanners, respectively.

These device interactions, combined with the need to integrate glucose information with dietary and activity decisions, come at a significant cost. Indeed, a task analysis for type 1 diabetes management was generated by compiling information and standards from multiple authorities; it contained *over 600 items* necessary to successfully manage diabetes.[7] The burden and complexity of diabetes management contribute to diabetes distress (DD), a condition which has been directly linked to poor glycemic control and problematic self-care behaviors.[8-10] Feelings related to diabetes management and glucose monitoring that contribute to DD include concerns about the possible negative judgments of others, being overwhelmed by the amount equipment and materials necessary for management, and disappointment with one's own self-care efforts.[10] While rtCGM therapy has been shown to modestly reduce DD,[11] patients using rtCGM still demonstrate low levels of distress. As diabetes therapy advances, the goal should be to reduce diabetes management burden and distress—not increase them.

We examined whether a predictive low glucose alert could warn rtCGM users of impending hypoglycemia without requiring frequent viewing of a glucose trend screen. We evaluated estimated glucose values (EGVs) from an anonymized convenience sample of 15,000 patients during use of a sixth-generation rtCGM system with or without the predictive, "Urgent Low Soon" (ULS) alert enabled. The system has optional and customizable threshold alerts and a fixed, Urgent Low alarm at 55 mg/dL that cannot be disabled. The ULS alert is enabled by default and triggered when an EGV ≤55 mg/dL is predicted in the next 20 minutes; the activation of a ULS alert overrides low threshold alert activations in the following 30 minutes to limit alarm fatigue. Hypoglycemia exposure among users within the top and bottom quartiles of screen view frequency was analyzed separately.

Methods

We examined device settings and voluntarily uploaded EGVs from patients who used Dexcom G6 (Dexcom, Inc, San Diego, CA) between 5/1/18 and 8/31/18. Patients were included if they had uploaded one or more valid EGV (39-401 mg/dL) daily for at least 30 days to the G6 mobile app on an internet-connected smart device, which passively and continuously uploads data to the Dexcom Cloud. App users had agreed to the privacy policy and consent to use of their anonymized data for research purposes. Of all patients meeting the selection criteria, 15,000 patients were then randomly selected and divided into quartiles based on screen view frequency.

Screen view frequency was determined as the frequency with which the trend screen was accessed on the G6 mobile app; screen views were grouped in five-minute intervals, that is, accessing the trend screen twice in the same five-minute interval counted as one screen view. The top (frequent; >8.25 views/day) and bottom (infrequent; <3.30 views/day) quartiles of screen view frequency were evaluated separately; users within the top and bottom quartiles of screen view frequency who had enabled (default setting) or disabled the ULS alert were compared. To classify patients into ULS enabled/disabled cohorts, we took the last known alert setting for that patient and only considered data after that setting was made (ie, patients should not have changed alert setting during the interval we aggregated their data). Exposure to biochemical and clinical hypoglycemia was calculated as the percentage of EGVs <70 mg/dL and <55 mg/dL, respectively. *P* values were computed using a two-sided Welch's unequal variance *t*-test between population means.

Results

Daily screen view frequency varied between G6 users; the mean (SD) daily screen view frequency among the top and bottom quartiles of screen view frequency within users who disabled the ULS alert was 2.5 (0.5) and 14.1 (6.9) and within users who enabled the ULS alert was 2.5 (0.5) and 13.3 (5.8), respectively (Table 1). The ULS alert remained enabled among >93% of G6 users.

Time spent in biochemical and clinical hypoglycemia was similar among users that had disabled the ULS alert (and relied solely on the Urgent Low Alarm), whether they were frequent or infrequent screen viewers (Table 1). Enabling the ULS alert was associated with significantly less biochemical and clinical hypoglycemia for both infrequent and frequent screen viewers. Infrequent screen viewers with the ULS alert enabled reduced their time spent in hypoglycemia by more than 36% compared to those with the ULS alert disabled—spending 2.6% of time (37.4 minutes daily) and 0.7% of time (10.1 minutes daily) in biochemical and clinical hypoglycemia, respectively, when the ULS was enabled and 4.3% of time (61.9 minutes daily) and 1.1% of time (15.8 minutes daily) in biochemical and clinical hypoglycemia, respectively, when the ULS was disabled. Similarly, frequent screen viewers nearly halved their time spent in hypoglycemia by enabling the ULS alert—spending 2.5% of time (36.0 minutes daily) and 0.6% of time (8.6 minutes daily) in biochemical and clinical hypoglycemia, respectively, when the ULS was enabled and 4.7% of time (67.7 minutes daily) and

Table 1. Hypoglycemia Exposure Among G6 Users Who Disabled the ULS Alert or Maintained the Default Setting and Infrequently or Frequently Accessed the Trend Screen on the Mobile App.

	ULS disabled			ULS enabled		
	Infrequent screen viewers (<3.30 screen views/day)	Frequent screen viewers (>8.25 screen views/day)	*P* value	Infrequent screen viewers (<3.30 screen views/day)	Frequent screen viewers (>8.25 screen views/day)	*P* value
N	246	163	—	3494	3588	—
Mean screen views/day	2.5 (0.5)	14.1 (6.9)	—	2.5 (0.5)	13.3 (5.8)	—
Time <70 mg/dL (%)	4.3 (4.0)	4.7 (4.5)	.3	2.6 (3.1)†	2.5 (2.8)†	.2
Time <55 mg/dL (%)	1.1 (1.5)	1.2 (1.6)	.7	0.7 (1.2)†	0.6 (1.0)†	<.005

Values reported are mean (SD).
†$P < .005$ vs the same group in ULS Disabled.

1.2% of time (17.3 minutes daily) in biochemical and clinical hypoglycemia, respectively, when the ULS was disabled. There was a small but statistically significant difference in time spent <55 mg/dL (on average less than 2 minutes daily) of uncertain clinical significance between infrequent and frequent screen viewers when the ULS was enabled (p<.005).

Conclusion/Discussion

We assessed whether frequent device interaction could be decoupled from hypoglycemia avoidance using a timely and accurate low glucose alert. Time spent in clinical hypoglycemia was significantly less than that reported previously by isCGM users,[6] whether or not G6 users frequently interacted with their display device or enabled the ULS alert. Furthermore, we found that the predictive ULS alert was associated with significant reductions in clinical and biochemical hypoglycemia, independent of screen view frequency. The low rate at which the ULS alert was disabled suggests that it was unobtrusive and perceived as useful, rather than a nuisance.

The observed reduction in hypoglycemia during use of the ULS alert required action on the part of the user, either carbohydrate intake or manual changes to insulin doses. Automated insulin delivery (AID) systems that integrate CGM and insulin pumps are now available. The Dexcom G6 system can be integrated with do-it-yourself and commercially available AID systems such as Loop[12] and Basal-IQ,[13] and automated insulin suspension may contribute to further reductions in hypoglycemic exposure. The metabolic and psychological consequences of AID systems are the subject of active study.[14] Because of their ability to increase or decrease the rate of insulin delivery in response to rising or falling glucose without user input, AID systems have the potential to further decrease the burden of diabetes management.[15,16] However, if frequent calibrations are required or patients are often forced out of automatic insulin delivery mode, the physical and cognitive burdens of AID system use may be greater than those of CGM with MDI treatment or sensor-augmented pump therapy.

The current study was strengthened by a large, real-world patient sample. However, it was limited by the lack of demographic information for the patients and the narrow population of Dexcom users that were evaluated; among patients who transitioned to G6 immediately after the launch were those whose experience with CGM may not be representative of the population at large. Moreover, excluding individuals who accessed their CGM data on a receiver alone may have biased the study population. Other device settings, such as data sharing or threshold alert settings, were not evaluated and may have confounded the observations. Further studies are needed to dissect complex behavioral patterns and device settings from observed glycemic profiles, especially in distinct patient subpopulations, such as in patients with IAH.

Abbreviations

AID, automated insulin delivery; CGM, continuous glucose monitoring; DD, diabetes distress; EGV, estimated glucose value; IAH; impaired awareness of hypoglycemia; isCGM, intermittently scanned continuous glucose monitoring; rtCGM, real-time continuous glucose monitoring; T1D, type 1 diabetes mellitus; ULS, Urgent Low Soon.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The authors are employees of Dexcom, Inc.

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