Nonadherence to Insulin Therapy Detected by Bluetooth-Enabled Pen Cap Is Associated With Poor Glycemic Control

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OBJECTIVE

To objectively evaluate adherence to timing and dosing of insulin by using Bluetooth pen caps and examine factors related to adherence.

RESEARCH DESIGN AND METHODS

Bluetooth-enabled insulin pen caps were used in younger (ages 18–35 years) and older (ages ≥65 years) adults on two or more insulin injections per day.

RESULTS

We evaluated 75 participants with diabetes, 42 younger (29 ± 4 years) and 33 older (73 ± 7 years). Nonadherence was found in 24% of bolus (Apidra) doses and 36% of basal (Lantus) doses. We divided participants into tertiles on the basis of overall adherence, with the most adherent tertile having 85% dose adherence compared with 49% in the least adherent tertile ($P < 0.001$). Participants in the most adherent tertile had better glycemic control than those in the least adherent tertile (7.7 ± 1.1% [61 ± 12 mmol/mol] vs. 8.6 ± 1.5% [70 ± 16.4 mmol/mol], $P < 0.03$).

CONCLUSIONS

Nonadherence to insulin dosing and timing can be objectively assessed by Bluetooth pen caps and is associated with poor glycemic control.

Using a novel technology, this study objectively assessed the adherence to timing and dosing of insulin injections in different age-groups and its impact on glycemic control and hypoglycemia. In addition, we assessed factors related to nonadherence in two different age-groups vulnerable to nonadherence.

RESEARCH DESIGN AND METHODS

After receiving approval from the institutional review board, two populations—young adults (ages 18–35 years) with type 1 diabetes and older adults (ages ≥65 years) with type 1 or type 2 diabetes—who are on two or more insulin injections per day were evaluated. Data on hemoglobin A_{1c}, duration of hypoglycemia (through a Dexcom continuous glucose monitor [CGM]), cognitive function (measured by the Montreal Cognitive Assessment [MoCA]) (1), diabetes-related distress (measured by Problem Areas in Diabetes [PAID]) (2), functionality, hypoglycemia fear (measured by the Hypoglycemia Fear Survey-II [HFS-II]) (3), and hypoglycemia unawareness (measured by the survey by Clarke et al.) (4) were collected.

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Study participants were provided with basal (Lantus) and bolus (Apidra) SoloSTAR insulin pens and Common Sensing Gocap Bluetooth-enabled pen caps that fit on the end of these pens for 1 month. This Bluetooth pen cap registers the position of the insulin pen plunger and automatically sends confirmation of a dose and time of delivery to a smartphone app that sends data to a web portal. Study participants were blinded to the data on the app. We measured nonadherence by comparing the prescription that was provided to the participant by his or her physician with what the participant actually administered. For basal dose nonadherence, we calculated the number of times the dose was missed or taken outside the 1-h window from the prescribed set time. For bolus dose nonadherence, time windows were created for breakfast (6 A.M.–11 A.M.), lunch (11 A.M.–4 P.M.), dinner (4 P.M.–10 P.M.), and overnight (10 P.M.–6 A.M.). The doses were determined to be correct (a dose given in time window), missing (zero doses given in time window), or extra (anything beyond one dose given in time window) during each of these intervals. Missing and extra doses were considered nonadherent. Although this way of assessing nonadherence may favor participants who are more regular in their daily injections, it was preferable to calculating the average number of daily injections per patient because the latter did not reflect the daily variability in nonadherence, which is the purpose of the study. We divided study participants into tertiles on the basis of adherence to their total insulin doses. A blinded CGM (Dexcom G4 software 505) was worn for the first 14 days of the study by those participants not using a personal CGM to assess duration of hypoglycemia.

Continuous data are presented as mean ± SD when normally distributed and as median (range) when not normally distributed. Frequency data are presented as *n* (%). Between-group differences in participant characteristics are compared with the *t* test for continuous variables (comparison of means) and Fisher exact test for categorical variables (comparison of proportions).

RESULTS

A total of 75 participants were recruited into the study: 42 in the younger cohort (mean hemoglobin A_{1c} 8.1% [65 mmol/mol]) and 33 in the older cohort (mean hemoglobin A_{1c} 8.5% [69 mmol/mol]). Sixty-eight of 75 (41 younger and 27 older) participants completed the study. Compared with the younger population in our study, older participants were more likely to have type 2 diabetes (48% vs. 0%), mild cognitive dysfunction (64% vs. 23%), a higher number of comorbidities (6 vs. 1), more daily medications (10 vs. 4), a higher risk of recent falls (26% vs. 2%), and a higher risk of vision (19% vs. 5%) and hearing (19% vs. 2%) impairments. However, a higher percentage of participants in the younger cohort had one or more episodes of hypoglycemia compared with the older cohort (95% vs. 70%, $P < 0.006$).

Over a 1-month period, deviation from insulin prescription was identified at least once in all (100%) the participants. Lack of adherence was found in 24% (range 1–81%) of bolus doses (25% in the younger and 22% in the older cohort), and 36% (range 0–80%) of basal doses (42% in the younger and 27% in the older cohort). The older participants with lower MoCA scores (lower cognitive function) had lower adherence with bolus doses ($P < 0.018$). When we evaluated participants on the basis of tertiles of adherence, the most adherent tertile had 85% dose adherence compared with 49% in the least adherent tertile ($P < 0.001$). The patients in the most adherent tertile had better glycemic control than those in the least adherent tertile (7.7 ± 1.1% [61 ± 12 mmol/mol] vs. 8.6 ± 1.5% [70 ± 16.4 mmol/mol], $P < 0.03$) (Fig. 1). The most adherent tertile missed 11% of the bolus doses, whereas 50% of bolus doses were missed in the least adherent tertile ($P < 0.001$). On the other hand, in the most adherent tertile, 38% of injected doses were extra doses compared with 21% in the least adherent tertile ($P = 0.02$). There were more participants using a personal CGM in the most adherent tertile (9 of 23 vs. 3 of 23, $P = 0.045$). Diabetes-related distress score, presence of depression, living status, number of daily medications, number of comorbid conditions, duration of hypoglycemia, fear of hypoglycemia, and hypoglycemic unawareness did not differ between the most adherent and the least adherent tertiles.

CONCLUSIONS

We used a novel technology to objectively assess adherence to insulin dose and timing in participants using multiple daily injections and found that in both the younger and the older populations, nonadherence was seen in approximately one-third of the doses. Importantly, we showed that nonadherence was associated with poor glycemic control. Our results showed a prevalence of nonadherence that was similar to those shown in studies where nonadherence was self-reported by patients (5). However, the Bluetooth pen cap technology provides information regarding the exact timing and dose deviation and specific patterns of nonadherence. This information regarding nonadherence patterns at certain times of the day, or certain days of the week, can be useful for patients when making behavioral changes and for clinicians when making informed treatment changes.

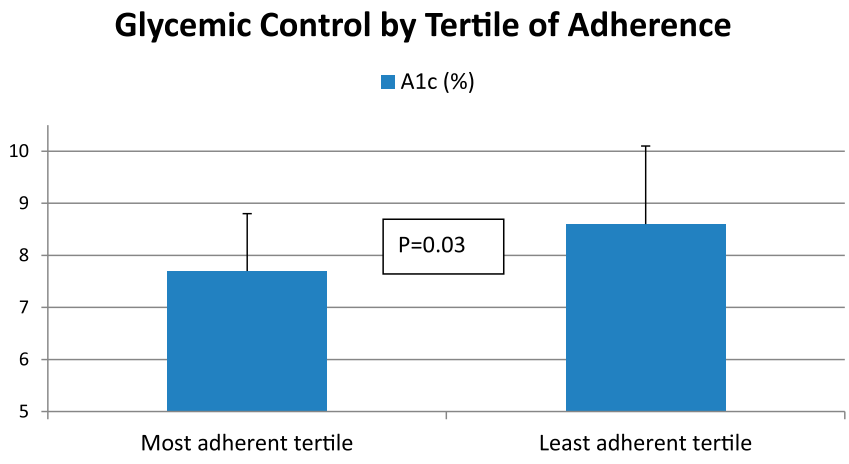

Figure 1—Glycemic control by tertiles of adherence.

When we evaluated participants by tertiles of adherence, the participants in the least adherent tertile had a higher number of missed doses, whereas those in the most adherent tertile had a higher number of extra doses. This pattern was most pronounced in the younger cohort, which is likely due to a higher number of correction doses taken by this cohort. This pattern may also partly explain the higher number of younger participants with hypoglycemia compared with the older cohort, although the total duration of hypoglycemia measured by CGM was not different between the groups.

Bluetooth pen technology is likely to be used by patients themselves or their caregivers and can provide a log of insulin doses taken as well as dose reminders. Future intervention studies are needed to evaluate these features. Currently, clinicians depend on home monitoring logs and self-reported insulin administration to change insulin doses without information regarding true dose adherence. This technology may close the gap that currently exists between patient-reported adherence and actual adherence.

The limitations of our study include a small sample size and a lack of information regarding meal and snack times and reasons for nonadherence, which may lead to doses being erroneously counted as missed or extra. We avoided collecting these data out of the concern that it may influence adherence itself. Future larger intervention studies are needed to assess reasons for nonadherence and whether this technology can translate into improved adherence and glycemic control.

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