Hypoglycemia and the Decision to Drive a Motor Vehicle by Persons With Diabetes

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Although retrospective studies have failed to demonstrate consistently a higher incidence of automobile crashes among individuals with type 1 diabetes than in the general population, it has been shown, using a driving simulator, that driving performance deteriorates significantly when the blood glucose (BG) level is reduced to between 3.6 mmol/L (65 mg/dL) and 2.6 mmol/L (47 mg/dL).\(^1\)\(^2\) At these levels of mild to moderate hypoglycemia, steering was disrupted, resulting in swerving, spinning, and increased time across midline and off the road. Global driving performance was impaired in 35% of the subjects with type 1 diabetes. Unfortunately, 50% of these subjects who were blind to their BG level within this range stated that they would drive under similar conditions. These findings have been replicated in our laboratory.\(^2\)\(^3\)

Since these data were obtained using a driving simulator, it is unclear the extent to which subjects’ decisions to drive might be extrapolated to real-life situations where they might be able to assess their ability more accurately or where distractions and competing demands might influence their decisions. We have developed handheld computer (HHC) technology that collects data regarding BG level symptoms, cognitive functioning, BG estimation accuracy, self-management behaviors, and decision making from subjects with type 1 diabetes while they are engaging in their daily routines.\(^4\)\(^5\)

These data were collected 3 to 6 times each day over a period of 3 to 4 weeks. The specific question, “Based on your

Context Laboratory studies have shown impairments in driving performance among subjects with type 1 diabetes mellitus when their blood glucose (BG) level is between 2.6 and 3.6 mmol/L (47-65 mg/dL). However, to our knowledge, no data exist examining subjects’ decisions to drive at various BG levels during their daily routine.

Objective To examine type 1 diabetic subjects’ decisions to drive during their daily routine based on perception of BG levels compared with actual measured BG levels.

Design and Setting Two separate groups of patients were recruited 2 years apart from 4 academic medical centers.

Participants All subjects were adults with type 1 diabetes who were drivers and who performed at least 2 BG tests per day. Group 1 (initial) subjects (n = 65) had a mean (SD) age of 38.6 (8.9) years with a mean (SD) diabetes duration of 20.5 (10.6) years, were taking 38.8 (16.8) U/d of insulin, and had a mean (SD) glycosylated hemoglobin (HbA1c) level of 10.0% (1.9%). Group 2 (replication) subjects (n = 93) were 35.8 (8) years old with a mean diabetes duration of 17.0 (10.6) years, were taking 40.0 (15.5) U/d of insulin, and had a mean (SD) HbA1 level of 8.5% (1.6%). Each subject used a handheld computer to record data on symptoms, cognitive function, insulin dosage, food, activity, estimated and actual BG levels, and whether he/she would drive. Data were entered 3 to 6 times per day for a total of 50 to 70 collections per subject during a 3- to 4-week period.

Main Outcome Measures Decisions to drive when subjects estimated their BG level to be less than 2.2 mmol/L (40 mg/dL), 2.2 to 2.8 mmol/L (40-50 mg/dL), 2.8 to 3.3 mmol/L (50-60 mg/dL), 3.3 to 3.9 mmol/L (60-70 mg/dL), 3.9 to 10 mmol/L (70-180 mg/dL), and more than 10 mmol/L (>180 mg/dL), and driving decisions when actual BG levels were in these ranges.

Results Subjects stated they would drive 43% to 44% of the time when they estimated their BG level to be 3.3 to 3.9 mmol/L (60-70 mg/dL), and 38% to 47% of the time when their actual BG level was less than 2.2 mmol/L (40 mg/dL). Logistic regression analysis demonstrated that number of autonomic symptoms, degree of impairment on cognitive function tests, and BG level estimate predicted 76% to 80% of decisions to drive (P<.01 for all). Approximately 50% of subjects in each group decided to drive at least 50% of the time when their BG level was less than 3.9 mmol/L (70 mg/dL).

Conclusions Our data suggest that persons with type 1 diabetes may not judge correctly when their BG level is too low to permit safe driving and may consider driving with a low BG level even when they are aware of the low level. Health care professionals should counsel their patients about the risk of driving with hypoglycemia and the importance of measuring BG level before driving.

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See also Patient Page.
estimate of your current BG, would you drive now?" was asked each time the subjects used the HHC, prior to actual BG measurement. We hypothesized that subjects with type 1 diabetes would decide not to drive when they estimated their BG level to be low (<3.9 mmol/L [70 mg/dL]) and that most of them would decide not to drive when their actual BG level was low. We further hypothesized that the decision whether or not to drive would be based on symptoms of their low BG level. To strengthen the validity of the findings, a replication study was performed 2 years later with a separate cohort of subjects with type 1 diabetes.

**METHODS**

**Subjects**

The initial study group (group 1, n = 65) consisted of adults with type 1 diabetes who were recruited from the University of Virginia, Vanderbilt University, and the Joslin Diabetes Clinic to participate in a larger study of Blood Glucose Awareness Training. The replication study group (group 2, n = 93) was recruited 2 years later from the University of Virginia, Vanderbilt University, and the University of Maryland to participate in a larger study of the causes and consequences of severe hypoglycemia. Each study was approved by the institutional review boards of the respective institutions and informed consent was obtained from all subjects. All subjects had to be familiar with self blood glucose monitoring and performing at least 2 BG determinations daily to participate. Subjects were excluded if they had a history of psychiatric illness, substance abuse, or severe microvascular or macrovascular complications of diabetes. All subjects were paid $100 for their participation.

The demographic characteristics of each group are shown in Table 1. Group 1 subjects were slightly older, had a longer average duration of diabetes, and had higher average glycosylated hemoglobin levels (HbA1) than subjects in group 2. (HbA1 levels were determined by a boronate affinity column chromatography method with nondiabetic levels <6.9%). Mean insulin doses were similar in both groups. All subjects were drivers.

**Procedure**

All subjects were instructed in the use of an HHC (Psion 250, Psion, United Kingdom). This HHC prompted subjects to do the following: (1) rate on a scale of 0 to 6 the extent to which they were experiencing 4 autonomic symptoms (jitteriness, pounding heart, trembling, and sweatiness) and 4 neuroglycopenic symptoms (difficulty concentrating, visual disturbances, light-headedness, and lack of coordination); (2) perform 2 cognitive function tests (serial subtractions and reaction time); (3) rate their perception of their degree of impairment in performing each cognitive test on a scale of 0 to 6; (4) enter whether or not their most recent insulin, food, and exercise was more, less, or usual in amount; (5) estimate their current BG level and enter the value; (6) answer the question, "Based on your estimate of your current BG, would you drive now?"; and (7) obtain a blood sample, measure their actual BG level, and enter the value. Measured BG values entered within 45 seconds after the prompt to "measure your BG" invalidated the trial since that was the minimal amount of time needed to lance a fingertip, obtain a blood sample, and have the BG meter determine the BG level with the BG monitor (One Touch II blood glucose monitor, Lifescan, Milpitas, Calif) for all subjects used. Subjects were asked to use the HHC during a 3- to 4-week period every time they performed routine self blood glucose monitoring and anytime they felt their BG level might be low (<3.9 mmol/L [70 mg/dL]). Subjects in group 1 were asked to perform 50 trials, while subjects in group 2 were asked to perform 70 trials.

**Data Analysis**

Data from each subject's HHC were downloaded to a computer for analysis. For this study, symptom ratings, cognitive performance scores, perceived degree of impairment, estimated BG level, driving decision, and actual BG level for each trial were examined. For each group, all data (with the exception of driving decisions) from trials with estimated BG levels in each of the ranges (<2.2 mmol/L [<40 mg/dL], 2.2-2.8 mmol/L [40-50 mg/dL], 2.8-3.3 mmol/L [50-60 mg/dL], 3.3-3.9 mmol/L [60-70 mg/dL], 3.9-10 mmol/L [70-180 mg/dL], and >10 mmol/L [>180 mg/dL]) were averaged. The frequency of subjects stating that they would drive when their estimated BG level was within these ranges was calculated. Similar analyses were conducted when actual BG levels were in the same ranges. In addition, the mean low actual BG level was computed for each group, as was the mean frequency of low BG measurements per subject, the percentage of detection of a low BG level (estimating BG level <3.9 mmol/L [70 mg/dL] when actual BG level was <3.9 mmol/L [70 mg/dL]), and the percentage of time subjects decided to drive when their actual BG level was less than 3.9 mmol/L (70 mg/dL). To determine whether or not the results were skewed due to a relatively small number of subjects experiencing a high number of BG readings less than 3.9 mmol/L (70 mg/dL) or a small number of subjects deciding to drive very frequently when their BG level was low, the subjects in each study were ordered in terms of their percent deci-

<table>
<thead>
<tr>
<th>Table 1. Demographic Data*</th>
<th>Group 1: Initial Study (n = 65)</th>
<th>Group 2: Replication Study (n = 93)</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>Age, y</td>
<td>38.6 (8.9)</td>
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<tr>
<td>Duration of diabetes, y</td>
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<tr>
<td>HbA1, %</td>
<td>10.0 (1.9)</td>
<td>8.5 (1.6)</td>
<td>&lt;.001</td>
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</tbody>
</table>

*HbA1 indicates glycosylated hemoglobin. All data are mean (SD).
sion to drive when BG level was low. Percent decisions to drive when BG level was low were calculated for each of the 4 quartiles in each subject group. In addition, the average number of actual low BG readings for subjects in these quartiles was computed.

Correlations between demographic data (including age, duration of diabetes, insulin dosage, and HbA1c level), percentage of detection of a low BG level, driving history (miles and hours per week, number of accidents, and number of traffic violations), and the decision to drive were determined for both groups. Finally, logistic regression analysis was used to determine which of the variables collected during the HHC trials significantly contributed to the decision to drive.

**RESULTS**

The frequencies of how often subjects stated they would drive when they estimated their BG level to be in different ranges are shown in the Figure. Subjects stated they would drive 40% to 45% of the time when they estimated their BG level to be between 3.3 and 3.9 mmol/L (60-70 mg/dL) (group 1 = 43%, group 2 = 44%), and a substantial percentage of the time subjects stated they would drive when they estimated their BG level to be less than 2.2 mmol/L (40 mg/dL) (group 1 = 38%, group 2 = 18%). The Figure also shows the frequencies at which subjects stated they would drive prior to determining that their actual BG level was in each range. Approximately 60% of the time subjects stated they would drive when their actual BG level was between 3.3 and 3.9 mmol/L (60-70 mg/dL) (group 1 = 60%, group 2 = 64%). Subjects stated they would drive 38% (group 1) and 47% (group 2) of the time their actual BG level was less than 2.2 mmol/L (40 mg/dL).

The mean (SD) low BG level was similar in group 1 and group 2 (3.2 [0.3] mmol/L [56.9 [6.2] mg/dL] vs 3.1 [0.2] mmol/L [55.8 [4.4] mg/dL], P = .21), but group 1 subjects had a lower percentage of actual low BG measurements (<3.9 mmol/L [70 mg/dL]) during the 3-week trial than group 2 subjects (14% [10%] vs 19% [11%, P = .006) and a lower percentage of detection of a low BG level (35% [32%] vs 47% [27%, P = .01). However, both groups of subjects decided a similar percentage of time that they would drive when their actual BG level was less than 3.9 mmol/L (70 mg/dL) (53% [36%] vs 55% [29%, P = .78) (Table 2).

None of the demographic variables (age, disease duration, insulin dosage, and HbA1c level) correlated with the decision to drive when BG level was less than 3.9 mmol/L (70 mg/dL). However, percentage of detection of a low BG level negatively correlated with the decision to drive for both groups (group 1: r = −0.29, P < .01; group 2: r = −0.68, P < .001). In other words, when actual measured detection of a low BG level was worse, subjects were more likely to decide to drive when their BG level was low. Hours driven per week correlated positively with the decision to drive in group 1 subjects (r = 0.36, P = .002), with a trend toward a statistically significant correlation for group 2 subjects (r = 0.15, P = .07). This suggests that subjects who drive more decide to drive more frequently when their BG level is less than 3.9 mmol/L (70 mg/dL). The actual numbers of motor vehicle collisions (group 1 = 11, group 2 = 11) and/or traffic violations (group 1 = 3, group 2 = 19) over the previous 12 months were not large enough to examine correlations between their frequency and decisions to drive when their BG level was low. However, there were no statistical differences between decisions to drive when BG level was less than 3.9 mmol/L (70 mg/dL) in individuals who had or had not experienced motor vehicle accidents (P = .83) or violations (P = .75).

Logistic regressions predicting the decision to drive were similar for both groups, with estimate of BG level, number of autonomic symptoms, and degree of impairment on cognitive function tests contributing significantly to the decision to drive or not to drive when BG level was less than 3.9 mmol/L (70 mg/dL). Table 3 presents the odds ratios of these 3 variables together with 95% confidence intervals and significance levels. These 3 variables predicted 76% of the decisions to drive in group 1 subjects and 80% of the decisions to drive in group 2 subjects.

Table 4 presents the percent decisions to drive when BG level was less than 3.9 mmol/L for subjects grouped in quartiles in terms of this variable. In the first quartile, which represents the high-
est risk, the subjects decided to drive 85% or more of the time when their BG level was low; the next 25% decided to drive 57% to 85% of the time when their BG level was low; the next 25% decided to drive 28% to 57% of the time when their BG level was low; and in the highest, presumably safest quartile, the subjects decided to drive less than 28% of the time when their BG level was low. Similar results are shown for subjects in group 2.

In addition, Table 4 shows the mean number of actual low BG level determinations per subject in each quartile. One-way analysis of variance showed that these means were not different across the quartiles. Approximately half of the subjects in each group decided to drive when their BG level was low 50% or more of the time. The distribution of their decisions was not skewed by differences in the occurrence of a low BG level.

**COMMENT**

Nearly 45% of the time when subjects with type 1 diabetes estimated their BG level to be in a range previously shown to be associated with deterioration in driving performance, they decided to drive. This finding was observed for both the initial and replication groups of subjects despite differences in age, disease duration, level of glucose control (HbA1c), frequency of low BG level, and ability to detect a low BG level. Thus, the findings are significant for 2 large and different groups of adults with type 1 diabetes studied in their natural environment several years apart. While the findings may not be applicable to all individuals with type 1 diabetes, the heterogeneity of our study groups suggests the potential magnitude of the problem identified. In addition, the findings corroborate our previous studies of hospitalized subjects using a driving simulator where 50% of subjects decided to drive when actual BG levels were in a similar range.

The observation that 18% to 38% of the time subjects decided that they would drive even though they estimated their BG level to be dangerously low (<2.2 mmol/L [40 mg/dL]) is alarming. Decisions to drive were based on the number of autonomic symptoms detected, perceived degree of cognitive impairment, and detection of a low BG level. Unfortunately, accurate detection of a low BG level did not guarantee that an individual would decide not to drive at that moment. When the data were analyzed with subjects grouped as to their perceived ability to recognize symptoms of hypoglycemia, those with reduced symptom awareness decided to drive when they estimated their BG level to be low less frequently than did those who reported symptom awareness. Thus, those subjects with better low BG level symptom detection were less cautious about their ability to drive when they detected their low BG level than those with reduced symptom awareness.

In addition, despite a great deal of individual difference in deciding to drive when BG level was low (25% decided to drive more than 80% of the time their BG level was low while 25% decided to drive less than 33% of the time their BG level was low), our data do not suggest that a small proportion of our sample was responsible for our statistical findings. Indeed, 50% of subjects in both samples decided to drive at least 50% of the time their BG level was low.

The decision to drive an automobile is complex and although we explored a number of relevant variables contributing to that decision, there are likely to be other factors in this decision that we did not evaluate. The decision to drive has been described as an example of complex, self-regulatory decision making, best described by a system of transitional probabilities. An internal condition (low BG level) leads to symptom perception, appraisal of ability to drive, and finally a decision. Symptom perception, appraisal, and decision making can be affected by a number of cognitive, affective, social, and environmental factors such as the need to drive, previous experience driving with a low BG level, or inability to treat due to lack of available glucose.

These data should not be construed to mean that individuals with type 1 diabetes should not be permitted to drive or that their privilege to drive should be restricted. Indeed, the frequency of motor vehicle crashes is not known to be higher among drivers with type 1 diabetes. However, these data do suggest that persons with type 1 diabetes need to be cautious before driving a motor vehicle. Given the relatively low level of low BG level detection among these subjects, the suggestion that individuals measure their BG level and raise potentially low BG levels prior to driving does not seem unreasonable. In addition, drivers with diabetes should always carry rapid-acting glucose with them and plan their journeys to ensure that they will not be late for a meal.

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Improving detection of a low BG level could be beneficial for some individuals. Blood Glucose Awareness Training, an 8-week biobehavioral intervention designed to assist persons with type 1 diabetes to more accurately estimate their BG level, has been shown to improve detection of low BG level, even in individuals with reduced awareness of hypoglycemia. Such improvement has been sustained for at least 1 year.

The decision whether or not to drive at any particular moment rests with the driver. However, data such as these should alert health care professionals to the need to discuss safe driving practices with their patients. Initial discussions should include queries regarding the rules that individual patients use in determining their fitness to drive. Patient education should emphasize the importance of including a BG level determination as part of their decision making. Those individuals who would choose to drive when their BG level is in a range previously shown to be unsafe (<3.6 mmol/L [65 mg/dL]) should be strongly encouraged to modify their driving rules. Interestingly, physicians have not been alerted previously to the importance of counseling their patients with type 1 diabetes regarding their driving decisions. The individual with type 1 diabetes needs to be aware of the danger of relying on perceived driving skill, previous driving experience, and ability to detect a low BG level to remain safe behind the wheel.

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REFERENCES