Diabetes and Driving Mishaps

Frequency and correlations from a multinational survey

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OBJECTIVE — The intensive treatment of diabetes to achieve strict glycemic control is a common clinical goal, but it is associated with an increased incidence of hypoglycemia. Becoming hypoglycemic while driving is a hazardous condition and may lead to a greater incidence of driving mishaps. This study investigated whether diabetes is associated with increased risk of driving mishaps and correlates of such a relationship.

RESEARCH DESIGN AND METHODS — During routine visits to diabetes specialty clinics in seven U.S. and four European cities, consecutive adults with type 1 diabetes, type 2 diabetes, and nondiabetic spouse control subjects (n = 341, 332, and 363, respectively) completed an anonymous questionnaire concerning diabetes and driving.

RESULTS — Type 1 diabetic drivers reported significantly more crashes, moving violations, episodes of hypoglycemic stupor, required assistance, and mild hypoglycemia while driving as compared with type 2 diabetic drivers or spouse control subjects ($P < 0.01$–0.001). Type 2 diabetic drivers had driving mishap rates similar to nondiabetic spouses, and the use of insulin or oral agents for treatment had no effect on the occurrence of driving mishaps. Crashes among type 1 diabetic drivers were associated with more frequent episodes of hypoglycemic stupor while driving, less frequent blood glucose monitoring before driving, and the use of insulin injection therapy as compared with pump therapy. One-half of the type 1 diabetic drivers and three-quarters of the type 2 diabetic drivers had never discussed hypoglycemia and driving with their physicians.

CONCLUSIONS — Type 1 diabetic drivers are at increased risk for driving mishaps, but type 2 diabetic drivers, even on insulin, appear not to be at a higher risk than nondiabetic individuals. Clinical and treatment factors appear to increase risk, e.g., more frequent hypoglycemia while driving, method of insulin delivery, and infrequent self-testing before driving. Physicians are encouraged to talk to their type 1 diabetic patients about hypoglycemia and driving.

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Abbreviations: BGAT, blood glucose awareness training; DCCT, Diabetes Control and Complications Trial.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

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See accompanying editorial, p. 2464.

Most western countries impose some restrictions on the commercial driving licenses of drivers who have diabetes. The side effects from the treatment of diabetes (principally hypoglycemia) and the potential risk imposed by developing complications (mainly to vision) render diabetes a prospective disability with respect to medical fitness to drive. Impaired awareness of hypoglycemia and recurrent severe hypoglycemia may place drivers at higher risk for driving mishaps. Research studies have demonstrated neuropsychological and driving simulation impairments at modest levels of hypoglycemia (3.6 mmol/l) (1–3). However, the ecological validity, or relevance, of such laboratory findings to routine daily functioning is unclear (4). Several studies have investigated the impact of diabetes on driving (5–7). The conclusion from two reviews was that drivers with diabetes receiving insulin therapy have a slight but statistically significant increased risk of moving vehicle violations (8,9). Both reviews, however, emphasized that intensive insulin therapy is associated with more frequent hypoglycemia. Previous studies usually did not differentiate among type 1 or type 2 diabetes, type or intensity of treatment, age or sex of the diabetic driver, or any regional driving risk factors. In addition, these studies were conducted before publication of the Diabetes Control and Complications Trial (10) and the U.K. Prospective Diabetes Study (11), the results of which encourage intensive therapy and have influenced subsequent diabetes management practices. Consequently, it was considered important to have a post–Diabetes Control and Complications Trial (DCCT) investigation of driving mishaps and diabetes, controlling for variables previously ignored.

We conducted a cross-sectional, multicenter survey of drivers with and without diabetes. Factors studied included location of driving, age, sex, driving exposure, type and duration of diabetes, and mode and intensity of diabetes treatment. Drivers were recruited from seven sites in the U.S. and from four sites in

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Europe. The primary goals of this study were to *1*) assess the relative impact of diabetes and its treatment on driving mishaps, *2*) assess how often the more unrefined measures of automobile crashes and moving vehicle violations occur relative to hypoglycemic stupor while driving and the need for assistance with hypoglycemia while driving, and *3*) identify factors predictive of driving mishaps.

RESEARCH DESIGN AND METHODS

Subjects

Thirteen sites were invited to participate in data collection involving 25 patients with type 1 diabetes, 25 with type 2 diabetes, and 25 nondiabetic spouse control subjects per site. Two clinics refused participation because they did not have the data collection resources. Seven participating clinics were in the U.S. (Boston, Charlottesville, Chicago, Indianapolis, Louisville, St. Louis, and Syracuse) and four in Europe (Amsterdam, the Netherlands; Basel, Switzerland; Edinburgh, Scotland; and Mergentheim, Germany). Diabetic subjects were consecutive patients who attended diabetes specialty outpatient clinics at each site. When spouses accompanied the patients, they were invited to participate. No invited individuals declined to participate. Totals of 341, 332, and 363 individuals with type 1 diabetes, type 2 diabetes, and spouses, respectively, completed the questionnaire. Four, 10, and 37 subjects from each of these groups were eliminated from data analysis because they did not possess a current driver's license. An additional 24 type 1 diabetic and 38 type 2 diabetic drivers were excluded because they had initiated insulin or oral agent treatment within the previous 2 years. This was necessary because we assessed driving mishaps over the previous 2 years. As illustrated in Table 1 (descriptive characteristics), the mean ± SD age of subjects with type 1 diabetes (42.4 ± 12.9 years), type 2 diabetes (56.7 ± 11.1 years), and spouses (50.6 ± 13.7 years) was determined ($F = 93.0$, $P < 0.001$). The percentage of female subjects in the type 1 diabetic, type 2 diabetic, and spouse groups was 49%, 39%, and 43%, respectively ($\chi^2 = 6.2$, NS). The mean driving distances for the groups were 11,310 ± 8,579, 12,463 ± 12,680, and 10,878 ± 10,722 miles per year. A significant difference was observed between U.S. and European mileage ($F = 29.4$, $P < 0.001$), but no significant difference was found between the three groups ($F = 1.1$, NS). Duration of diagnosed diabetes was 19.7 ± 11.6 and 11.3 ± 8.4 years for the type 1 and type 2 diabetic subjects, respectively ($F = 99.1$, $P < 0.001$). Thirty-six percent of the participants with type 1 diabetes were using insulin pump therapy, whereas 4% of participants with type 2 diabetes were also using pump therapy.

Procedure

Patients and spouses were given a one-page, institutional review board–approved questionnaire, which they completed in the clinic or returned by mail. Completion of the questionnaires was entirely voluntary, and anonymity was maintained. The questions that made up the dependent variables are as follow:

1. How many automobile accidents did you have in the last 2 years?
2. How many times were you cited for a moving vehicle violation by a police officer in the last 2 years?
3. How many times in the last 2 years has someone had to help you drive because of hypoglycemia?
4. How many times in the last 2 years have you driven in a hypoglycemic stupor?
5. How many times in the past 6 months have you driven while you were experiencing hypoglycemic symptoms (mild hypoglycemia, not a stupor)?
6. How many miles/kilometers do you routinely drive a year?
7. Has your doctor ever discussed with you hypoglycemia and driving (yes/no)?
8. Is there a blood glucose level at which you would not drive (yes/no)? If yes, what level?
9. How often do you test your blood glucose before you start driving (always/frequently/seldom/never)?

Data analysis

Because miles driven and sex did not differ between groups and did not correlate with number of crashes and because previous studies have shown no difference in crash rates between men and women in this age group (12), these variables were not covaried in the analyses. Having a similar number of each group recruited from each site provided the control for location. Given that some drivers with diabetes and multiple motor vehicle crashes and/or episodes of hypoglycemic stupors had substantially reduced their driving (e.g.,100 miles in the past year), we could not use the traditional crashes/100,000 miles driven because of excessive variance. We took a more conservative approach, investigating the percentage of individuals with driving mishaps in each group. χ^2 tests were used to compare differences in frequency distributions across the three groups, and Mann-Whitney nonparametric tests (Z) were used for group contrasts. To compare average crashes per driver in Europe and the U.S., discriminant analysis was used to identify drivers with type 1 diabetes who did versus did not report crashes in the previous 2 years.

RESULTS

Frequency of events

From the type 1 diabetic, type 2 diabetic, and spouse groups, 19%, 12%, and 8% of the drivers, respectively, reported having at least one auto crash in the past 2 years ($\chi^2 = 17.0$, $P < 0.001$). In separate contrasts, more drivers with type 1 diabetes reported crashes than spouse control subjects ($Z = 4.0$, $P < 0.001$) and drivers with type 2 diabetes ($Z = 2.4$, $P < 0.01$). No differences were found between drivers with type 2 diabetes who were ($n = 159$) or were not ($n = 109$) using insulin (11% vs. 15%) or between drivers with type 2 diabetes and spouse control subjects. The mean number of crashes among those who reported such incidents over the previous 2 years was 1.2, 1.1, and 1.1 per driver for type 1 diabetic, type 2 diabetic, and spouse subgroups, respectively (NS). Although proportionately more European drivers reported more crashes than U.S. drivers ($F = 3.0$, $P < 0.005$), drivers with type 1 diabetes from Europe were not at increased risk of having a crash as compared with the U.S. sample ($t = 1.0$, NS) (Table 1).

From the type 1 diabetic, type 2 diabetic, and spouse groups, 15%, 8%, and 10% of the drivers, respectively, reported receiving a moving vehicle violation in the past 2 years ($\chi^2 = 6.8$, $P < 0.05$). In separate contrasts, more drivers with type 1 diabetes reported moving vehicle violations than drivers with type 2 diabetes ($Z = 2.5$, $P < 0.01$) but not more than spouses ($Z = 1.6$, $P = 0.10$). There were

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Table 1—*Demographic characteristics and driving mishaps for U.S. and European drivers with diabetes and nondiabetic spouses*

	U.S.	Europe	Total	Probability for group effect*	Probability for location effect*
Descriptive characteristics					
n					
Type 1 diabetic subjects	172	141	313		
Type 2 diabetic subjects	177	97	274		
Nondiabetic spouse control subjects	188	138	326		
Mean age (years)					
Type 1 diabetic subjects	42.4	42.4	42.4	<0.001	NS
Type 2 diabetic subjects	55.8	58.1	56.7		
Nondiabetic spouse control subjects	52.6	48.0	50.6		
Diabetes duration (years)					
Type 1 diabetic subjects	21.6	17.5	19.7	<0.001	<0.01
Type 2 diabetic subjects	11.4	11.2	11.3		
Nondiabetic spouse control subjects	—	—	—		
Female sex (%)					
Type 1 diabetic subjects	55	41	49	0.05	<0.001
Type 2 diabetic subjects	47	24	39		
Nondiabetic spouse control subjects	46	41	43		
Drivers talked to their physicians about driving (%)					
Type 1 diabetic subjects	52	52	52	<0.001	NS
Type 2 diabetic subjects	24	34	27		
Nondiabetic spouse control subjects	—	—	—		
Miles/year					
Type 1 diabetic subjects	12,485	9,969	11,310	NS	<0.001
Type 2 diabetic subjects	13,283	10,999	12,463		
Nondiabetic spouse control subjects	13,674	7,102	10,878		
Frequency of events					
Drivers with crashes (%)					
Type 1 diabetic subjects	16	23	19	<0.001	<0.005
Type 2 diabetic subjects	8	19	12		
Nondiabetic spouse control subjects	6	11	8		
Drivers with violations (%)					
Type 1 diabetic subjects	19	10	15	0.03	0.05
Type 2 diabetic subjects	7	9	8		
Nondiabetic spouse control subjects	13	7	10		
Drivers with hypoglycemic stupor (%)					
Type 1 diabetic subjects	31	4	18	<0.001	<0.001
Type 2 diabetic subjects	8	0	5		
Nondiabetic spouse control subjects	—	—	—		
Drivers who needed assistance (%)					
Type 1 diabetic subjects	24	7	17	<0.001	<0.001
Type 2 diabetic subjects	7	0	5		
Nondiabetic spouse control subjects	—	—	—		
Drivers with hypoglycemia while driving in past 6 months (%)					
Type 1 diabetic subjects	28	16	22	<0.001	<0.001
Type 2 diabetic subjects	6	0	4		
Nondiabetic spouse control subjects	—	—	—		

*Continuous variables (age, diabetes duration, miles) were compared using ANOVA. All other comparisons used nonparametric tests.

no differences between drivers with type 2 diabetes who were or were not using insulin (10% vs. 9%) or between drivers with type 2 diabetes or spouses. European drivers had fewer moving vehicle violations than U.S. drivers ($F = 4.54$, $P < 0.05$), but drivers with type 1 diabetes from the U.S. were not at increased risk of receiving a violation compared with the European sample ($F = 2.05$, NS).

More drivers with type 1 diabetes reported episodes of hypoglycemia stupor while driving than those with type 2 diabetes over the previous 2 years (18% vs. 5%, $\chi^2 = 22.9$, $P < 0.001$). There was no

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Table 2—*Comparison of type 1 diabetic drivers with and without a recent history of driving mishaps*

	Diabetes duration	Male (%)	On pump (%)	Patients injecting >two shots a day (%)	Talk to physician about driving (%)	Blood glucose threshold	SMBG before driving (%)	Access to carbohydrate
Crashes	20.4	45	24	64	48	67.1	24	77
No crashes	19.6	52	38	68	54	70.1	40*	85
Violations	17.8	51	36	67	57	65.2	22	75
No violations	20.0	51	35	67	52	70.4*	40*	85
Stupor	23.0	50	44	64	57	65.8	30	87
No stupor	20.2	50	31	68	55	72.3*	40	86
Assistance	22.0	50	45	65	53	69.8	40	83
No assistance	20.5	48	33	67	51	70.5	37	84

*$P < 0.05$ (two-tailed test).

difference between drivers with type 2 diabetes who were or were not using insulin (7% vs. 5%). Drivers who experienced hypoglycemic stupor reported a mean of 3.3 and 2.7 stupor events per driver in the type 1 and type 2 diabetic subgroups, respectively (NS). Drivers with type 1 diabetes from Europe had a lower risk of experiencing hypoglycemic stupor while driving than the U.S. sample ($F = 52.6$, $P < 0.001$).

More drivers with type 1 diabetes reported requiring assistance while driving because of the development of hypoglycemia than those with type 2 diabetes (17% and 5%, $\chi^2 = 20.9$, $P < 0.001$). No difference was observed between drivers with type 2 diabetes who either were or were not using insulin (5% vs. 4%). Drivers with type 1 diabetes from Europe were less likely to receive assistance for hypoglycemia while driving than the U.S. sample ($F = 25.4$, $P < 0.001$).

More drivers with type 1 diabetes reported episodes of mild symptomatic hypoglycemia while driving in the past 6 months than subjects with type 2 diabetes (22% vs. 4%, $\chi^2 = 27.9$, $P < 0.001$). No difference was observed between drivers with type 2 diabetes who either were or were not using insulin (5% vs. 3%). Drivers with type 1 diabetes from Europe were at similar risk of having symptomatic hypoglycemia while driving compared with the U.S. sample ($F = 1.75$, NS).

Factors associated with driving mishaps

When comparing those type 1 diabetic drivers (Table 2) who did or did not have a crash, a moving vehicle violation, hypoglycemic stupor, or required assistance for hypoglycemia, there was no difference in terms of duration of diabetes, sex, insulin delivery system, or intensity of insulin therapy (≤2 insulin injections/day vs. >2/day). However, drivers who had crashes, moving vehicle violations, and hypoglycemic stupor while driving differed from those without such events in two ways. Drivers with a recent history of a driving mishap reported allowing their blood glucose to decline to a lower level before deciding not to drive and were also less likely to measure their blood glucose before driving ($P < 0.05$).

Discriminant analysis correctly classified only 70% of those drivers with type 1 diabetes who did or did not report crashes ($\chi^2 = 17.8$, $P < 0.001$) and 71% of those who did or did not experience hypoglycemic stupor while driving ($\chi^2 = 11.4$, $P = 0.003$). Three variables contributed significantly to higher probability for crashes: experiencing more episodes of hypoglycemic stupor while driving ($P < 0.001$), performing blood glucose monitoring less frequently before driving ($P < 0.001$), and taking insulin by subcutaneous injection rather than using an insulin pump ($P < 0.001$). Two variables contributed significantly to a higher probability for hypoglycemic stupor: accepting lower blood glucose as the threshold for deciding not to drive ($P = 0.003$) and more frequent episodes of mild symptomatic hypoglycemia while driving ($P = 0.003$).

Post hoc analyses

Because of the differences in mean age and because drivers below age 25 and above age 60 years have progressively higher risk of crashes and violations, we compared the three groups across the categories <25, 25–60, and >60 years of age. The groups differed significantly in these age categories ($\chi^2 = 94.5$, $P < 0.001$) with 11%, 0%, and 3% of the type 1 diabetic, type 2 diabetic, and spouse groups being <25 years of age and 11%, 40%, and 27% being >60 years of age, respectively. However, this difference in age distribution did not account for differences between groups in terms of driving mishaps. When considering the variables, crashes, stupor, requiring assistance, and violations, there were no significant subject group × age category interactions.

CONCLUSIONS

— These international, cross-sectional, multicenter retrospective survey data collected 7 years after the DCCT demonstrate that driving mishaps are more common among drivers with type 1 diabetes. This was consistent across driving mishap variables: crashes, violations, stupor, receiving assistance, and symptomatic hypoglycemia while driving. This phenomenon is not unique to the U.S. or European countries. European type 1 diabetic drivers (Table 1) indicated fewer episodes of hypoglycemic stupor while driving. This may be because some European countries' license reviews occur every 3 years for drivers with diabetes, and licenses are revoked if there is a history of hypoglycemia unawareness or recurrent severe hypoglycemia. Thus, this may have removed some higher-risk Eu-

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ropean drivers with diabetes from our sample.

Patients with type 2 diabetes, which is not associated with frequent hypoglycemia (13), had no increased incidence of driving mishaps compared with spouse control subjects, whether using insulin treatment or taking only oral medications. Even when contrasting extreme groups, those not on insulin and those taking two or more insulin injections/day ($n = 109$ vs. 123, respectively), there was still no difference in crash rates (13% vs. 9%). These findings may have implications for lifting current driving restrictions for interstate commercial license for drivers with type 2 diabetes who require insulin treatment.

Given the difference in driving mishaps, it is understandable that drivers with type 1 diabetes were twice as likely to have spoken with their physicians about hypoglycemia and driving compared with drivers with type 2 diabetes (52% vs. 27%, respectively, $P < 0.01$). However, the observation that nearly one-half of the drivers with type 1 diabetes surveyed had never spoken with their physicians about hypoglycemia and driving represents a significant oversight. Such an oversight is even more problematic when considering that the messages given to these patients by their physicians about hypoglycemia and driving are very inconsistent (14). Given the current data, a set of guidelines for patients with type 1 diabetes might include: *1*) measure blood glucose before driving and at intervals during long drives, *2*) do not begin driving when blood glucose is <5 mmol/l, and *3*) if hypoglycemia is suspected while driving, immediately discontinue driving, consume fast-acting carbohydrates, and do not resume driving until blood glucose level and cognitive motor functioning return to normal levels. The rationale for not driving when blood glucose is below 5 mmol/l is that we have demonstrated that driving is impaired in the 3.6-mmol/l range. Using a threshold of 5 mmol/l provides a larger blood glucose range before the driver's blood glucose levels decrease to a point where driving is significantly impaired.

These data are considered reliable for several reasons. These anonymously collected data did not come from a single location. Unlike pre-DCCT studies, this study considered type of diabetes, treatment regimen, location, exposure, and sex. In addition, these data are consistent with other larger, nondiabetes-related studies, which show no difference in crashes between men and women in this age-group (12).

Because hypoglycemia was not experimentally manipulated in this study, the causal role of hypoglycemia and subsequent neuroglycopenia at the time of the event cannot be concluded. Increased crash rates may have been associated with the long-term complications of diabetes, such as retinopathy or neuropathy. This premise, however, is unlikely for several reasons. First, previous research has shown that drivers with visual impairments are likely to stop driving (15). Additionally, such complications have not been associated with increased risk of driving mishaps (16). Further implication of hypoglycemia as the causal mechanism for this increased crash rate comes from the discriminant analysis, demonstrating that crashes were associated with the occurrence of hypoglycemic stupor while driving and that occurrence of hypoglycemic stupor was associated with mild symptomatic hypoglycemia while driving. The significance of these variables or the classification of high/low risk from the discriminant analysis will depend on further cross-validation studies.

Indirect support for the association of hypoglycemia as a risk for driving mishaps comes from two independent studies demonstrating that participation in blood glucose awareness training (BGAT) has been shown to reduce crashes and moving vehicle violations by two-thirds at long-term follow-up (17,18). BGAT is a behavioral intervention designed to aid patients in anticipating, preventing, detecting, and treating hypoglycemia. In addition, BGAT improved patients' judgment as to when not to drive with low blood glucose.

Even though drivers with type 1 diabetes reported twice as many crashes as the nondiabetic spouse group, this is one-half of the reported increased driving risk associated with other medical conditions, such as attention deficit/hyperactivity disorder (19), sleep apnea (20), or alcohol abuse (21). Notably, these latter higher-risk groups do not have legislative driving restrictions. Thus, the findings of the present survey cannot be used to restrict driving of individuals with type 1 diabetes but should serve to indicate the potential need for preventative steps to be taken to reduce the risk of possible crashes for drivers with type 1 diabetes.

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