Driving Safety in Adolescents and Young Adults With Type 1 Diabetes

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Adolescent and young adult (AYA) drivers are at high risk for automobile accidents and fatalities (1–3). Unintentional accidents were the leading cause of death in 2017 of individuals aged 15–19 years in the United States (4). Factors that increase driving safety risk associated with AYA drivers include lack of driving experience, developmental factors such as poor executive function, and propensity for risk-taking behaviors (5,6). Furthermore, cognitive abilities such as self-control and emotional regulation are continuing to develop through late adolescence and into young adulthood, making AYA drivers particularly vulnerable to practicing unsafe driving behaviors (7). Brain development—in particular the prefrontal cortex, which relates to impulse control—is known to continue well into young adulthood, not reaching adult dimensions until the mid-20s (8,9).

AYAs with type 1 diabetes face a unique set of challenges relating to driving safety. Blood glucose fluctuations leading to hypoglycemia can temporarily impair cognitive function (10–12) and lead to unsafe driving conditions (13). Given the safety risks posed by hypoglycemia, the American Diabetes Association (ADA) has made specific recommendations to promote safe driving for individuals with diabetes (14). The ADA recommends that drivers with type 1 diabetes measure their blood glucose level before driving and at regular intervals if they are driving for longer than 1 hour. Individuals with type 1 diabetes should be counseled to always carry appropriate rapid-acting glucose and complex micronutrient snacks. If symptoms of hypoglycemia occur, individuals should immediately stop driving, check their blood glucose, and treat low blood glucose levels. Additionally, driving should only be resumed after achievement of euglycemia and once cognitive functioning has been recovered (i.e., ideally 30–60 minutes after euglycemia is achieved

because of concern about delayed cognitive function recovery) (14). Parents of adolescents with type 1 diabetes report that their teens are unlikely to adhere to safe driving practices consistently (15). A recent study of Canadian adolescents with type 1 diabetes suggests that many do not adhere to driving safety recommendations around glucose monitoring in the context of diabetes management (16).

AYAs are also at high risk for engaging in behaviors that increase driving risk and contribute to distracted driving and fatalities, including texting while driving and substance use (17,18). Similar to the cognitive impairment seen with hypoglycemia, alcohol or marijuana use also can result in severe sensory and motor impairment, including reduced awareness of external stimulation (19,20). Driving after alcohol or marijuana use increases the risk of motor vehicle accidents (MVAs), and prevalence of driving after use of these substances has been reported to be high among AYAs (21). Studies have indicated that, in the United States, 12–28% of AYAs report driving under the influence of alcohol, and 3–11% report driving under the influence of marijuana (18,22,23). Additionally, use of cell phones and texting are major causes of distracted driving and MVAs (24). According to the Centers for Disease Control and Prevention, 45% of U.S. high school students report texting while driving (25). Texting while driving has been shown to increase both reaction time while driving and the likelihood of having an MVA (26). To our knowledge, research has yet to examine substance use and texting while driving in AYAs with type 1 diabetes.

The aim of this study was to examine self-reported diabetes-specific driving practices, hypoglycemia management practices around driving, and substance use and texting while driving in AYAs with type 1 diabetes.

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Research Design and Methods

Participants and Procedures

The study population included AYAs (aged 15–22 years) seen as a part of an AYA Diabetes Transition Program, which included a pediatric diabetes clinic in a stand-alone pediatric hospital partnered with an adult diabetes care center, between September 2017 and July 2019. This clinic was located in Washington State. Patients with a clinical diagnosis of type 1 diabetes who reported driving were eligible to complete the survey examining driving safety behaviors. Surveys were completed electronically on a tablet using the Tonic for Health application (tonicforhealth.com), a Health Insurance Portability and Accountability Act–compliant platform, at each patient's first AYA clinic visit as part of the clinic intake process. All patients who completed the clinical intake process for the AYA clinic during the study period were asked whether they drive, and, if so, they were given the driving safety behavior survey to complete. All aspects of the study followed a protocol approved by the Seattle Children's Research Institute's institutional review board.

Measures/Analysis

A pediatric multidisciplinary diabetes team experienced in clinical research developed the driving safety behavior survey items based on published ADA driving recommendations (14) and a literature review. No previous validated survey instruments were available to guide questionnaire development. An initial bank of survey items was developed and reviewed by a team of pediatric endocrinologists, pediatric psychologists, clinical researchers, and adolescent medicine physicians. The final questionnaire explored diabetes management behaviors related to driving safety, as well as general unsafe driving practices (Supplementary Appendix 1). Clinical data were obtained via clinic intake forms and chart review. These included A1C at the time of the first AYA visit, insulin delivery method, continuous glucose monitoring (CGM) system use, and demographic data.

Descriptive statistics were used to describe driving behaviors. χ^2 Tests or t tests were used to examine differences between driving practices by age, time since diagnosis, sex, and CGM use. For the purposes of this analysis, responses were dichotomized to rarely/never and always/often, where applicable. χ^2 Tests for independence (Yates continuity correction) were performed to examine relationships among technology use (i.e., insulin pump and CGM) and driving behaviors. All analyses were conducted using SPSS, v. 19, statistical software.

TABLE 1 Participant Characteristics ($n = 101$)

Age, years	19.3 $\pm$ 1.4 (15.5–22.0)
Time since diagnosis, years	9.4 $\pm$ 4.5 (0.1–19.9)
A1C, %	8.4 $\pm$ 1.7 (5.4–14)
PAID-T score (diabetes distress)	30.1 $\pm$ 13.1 (14–78)
PHQ-9 score (depression)	4.2 $\pm$ 4.7 (0–22)
Female sex	45
Race/ethnicity	
Non-Hispanic white	76
Non-Hispanic black	4
Hispanic	11
Other	4
Not stated	5
Insurance	
Private	85
Medicaid/Medicare	14
Self-pay	1
Insulin pump use*	64
CGM use	53

Data are mean $\pm$ SD (range) or percentages. *Versus a multiple daily injection regimen. PAID-T, Problem Areas in Diabetes–Teen questionnaire; PHQ-9, nine-item Patient Health Questionnaire depression module.

Results

One hundred thirty-seven patients completed the intake process in the AYA clinic during the study period. Of those, 105 participants reported driving and completed the driving safety behavior survey as part of their clinical intake. Four patients declined participation; thus, the study sample was 101 participants, for whom descriptive data are presented in Table 1. Forty-five percent of participants were female, with an average age of 19.3 years (SD 1.4). Fifty-three percent of participants used CGM, and 64% used an insulin pump. The average duration of type 1 diabetes was 9.4 years (SD 4.5), and the average A1C was 8.4% (SD 1.7).

Diabetes-specific driving behaviors are presented in Table 2. Forty-two percent of participants reported checking their blood glucose level rarely or never within 30 minutes before driving. If they had a glucose level <70 mg/dL before driving, 53.5% reported waiting until a recheck glucose level (after treatment) was ≥ 70 mg/dL before driving. When looking at all participants, 50.5% reported pulling over their vehicle, treating hypoglycemia, and waiting until their glucose was ≥ 70 mg/dL when they experienced hypoglycemia while driving or were alerted that they were becoming hypoglycemic via CGM. Sixty-four percent reported always having a source of rapid-acting glucose available when driving.

TABLE 2 Driving Safety Behaviors

Behavior	Rarely/Never	Often	Always
Do you check blood glucose within 30 minutes before driving?	41.6	42.6	15.8
Do you have a source of rapid-acting glucose available when driving?	8.9	26.7	64.4
	<5 Times	5–10 Times	≥11 Times
How often have you had hypoglycemia (blood glucose <70 mg/dL) at any time in the past month?	29.7	45.5	24.8
	Never	1–5 Times	≥6 Times
How often have you had hypoglycemia (blood glucose <70 mg/dL or symptomatic) while driving in the past month?	53.5	43.6	3.0
			Yes
Have you had severe hypoglycemia (seizure or need for assistance) in the past year?			7.9
Do you have hypoglycemia unawareness?			4.0
Have you ever had a car accident?			36.6
Have you ever had a car accident while glucose was low?			0
Do you wear a medical alert?			38.6
If hypoglycemia occurs when you are about to drive, do you treat and wait until you are normoglycemic to drive?			53.5
If hypoglycemia occurs while driving, do you pull over, treat, and wait until you are normoglycemic to drive?			50.5

Data are %.

Nearly half of participants (46.6%) reported having a low blood glucose while driving in the past month. Of those who reported having hypoglycemia while driving, 42.6% reported treating and waiting for euglycemia when this occurred. Approximately 8% of participants reported an episode of severe hypoglycemia (seizure or need for assistance) in the past year. No participants reported having an MVA while hypoglycemic.

Participants who experienced hypoglycemia while driving had significantly longer durations of diabetes (11.2 ± 3.9 years) than those who reported not experiencing hypoglycemia while driving (8.0 ± 4.6 years) [$t(99) = -3.82$, $P < 0.01$]. Participants who continued driving while experiencing hypoglycemia also had a longer mean duration of diabetes (10.33 ± 4.62 years) compared with those who waited to confirm euglycemia before driving (8.58 ± 4.25 years) [$t(99) = 1.98$, $P < 0.05$]. There was a significant difference in age for those who reported checking their glucose before driving (19.1 ± 1.4 years) and those who do not (19.7 ± 1.2 years) [$t(99) = 2.32$, $P < 0.05$]. There was also a significant difference in age for those who chose not to recheck glucose after treatment and confirm euglycemia when experiencing hypoglycemia before driving (19.7 ± 1.3

years) compared with those who waited for euglycemia (19.1 ± 1.4 years) [$t(99) = 2.35$, $P < 0.05$]. There were no significant differences in driving behaviors across sex. A trend for the association between pump status and checking blood glucose 30 minutes before driving was observed [$\chi^2(1, n = 101) = 3.65$, $P = 0.06$, $\phi = 0.21$ (small effect)]. There were no other significant associations with technology and driving behaviors.

General driving-related risk behaviors were examined. Nine percent reported driving within a few hours of consuming alcohol, 5.9% reported driving while feeling the effects of alcohol or other drugs, 10.9% reported driving within a few hours of using marijuana, and 39.6% reported texting while driving (7.9% daily, 14.9% few times a week, and 16.8% few times a month).

Discussion

In this study, approximately half of AYAs with type 1 diabetes reported experiencing hypoglycemia while driving within the past month. More than one-third of AYAs with type 1 diabetes reported not always having a source of rapid-acting glucose available to treat hypoglycemia while

driving, and >40% shared that they do not check their glucose level before driving. Furthermore, only about half of participants reported confirming normoglycemia before initiating or reinitiating driving after hypoglycemia. These results suggest that many AYAs with type 1 diabetes need to be better counseled about avoiding, detecting, and treating hypoglycemia while driving.

The importance of taking measures to prevent hypoglycemia while driving and mitigating associated risks has been well described (27–29). For example, in one prospective study of adult drivers with type 1 diabetes, 52% of participants reported at least one hypoglycemia-related driving mishap in a 12-month period (28). Our finding that a significant percentage of AYAs with type 1 diabetes experience hypoglycemia while driving demonstrates the need for clinical teams to routinely query AYAs about recent experiences concerning hypoglycemia while driving. Frequent in-clinic assessment of driving risk, including asking about driving and hypoglycemia history, as well as behaviors influencing driving risk (diabetes- and nondiabetes-related), is likely prudent to direct education and resources to those at highest risk for driving mishaps.

Similar to studies of U.S. adults with type 1 diabetes, many AYAs with type 1 diabetes in our study reported unsafe diabetes management practices in the context of driving (16,30). In addition, although our study included both adolescents and young adults in the United States, it is worth noting that our results regarding rates of blood glucose level checks before driving and episodes of hypoglycemia while driving were almost identical to those found with Canadian adolescent licensed drivers (16).

Our study highlights the lack of adherence to safe diabetes driving practices in the United States and suggests that there is a need for incorporating improved education to increase safe driving practices among AYAs with type 1 diabetes. Methods that have been used to encourage behavior change in adolescents, such as motivational interviewing or family-based interventions, may be considered when designing an intervention to improve driving safety in this population (31,32).

Rates of marijuana use before driving (10.5%) and texting while driving (~40%) among AYAs with type 1 diabetes in this study were similar to those in the general AYA population (3–11% endorse marijuana use and driving and 45% endorse texting while driving) (18,21,22,25). However, the rate of driving after alcohol use was lower than has been reported in other studies of AYAs without type 1 diabetes. It is estimated that nearly one-fourth of AYAs in the general population drive after consuming alcohol, whereas only

about 10% of AYAs with type 1 diabetes in our study reported doing so (23). This finding suggests there is likely some effective education and awareness around the impact of alcohol on blood glucose, specifically that alcohol contributes to acute and delayed-onset hypoglycemia and can also exacerbate the effects of hypoglycemia (33,34).

The detrimental cognitive impact of hypoglycemia and alcohol on driving can be cumulative, and thus, alcohol consumption before driving is incredibly risky for individuals with type 1 diabetes (34). Although our study suggests that there is some understanding of the consequences of alcohol consumption in the AYA population, there are still some AYAs with type 1 diabetes who do drive after consuming alcohol. Given that many AYAs with type 1 diabetes often fail to engage in behaviors that would prevent or adequately treat hypoglycemia before and during driving (e.g., not monitoring glucose, not bringing rapid-acting carbohydrates, and not pulling over if hypoglycemia occurs), the compounded impact of alcohol use and hypoglycemia on cognition and driving ability places these adolescents at particularly high risk for driving mishaps.

Legislation focused on banning texting while driving has decreased the impact of this behavior on MVAs (35). Just before initiation of this study, the state of Washington passed a law that made it illegal to talk or send text messages on a wireless device while driving. Washington State also has graduated driver licensing laws for teenage drivers, a practice that is associated with reduction of alcohol use and risky driving behaviors in youth (36). Despite these measures, nearly 40% of the participants in this study reported texting while driving, and a higher number of AYAs might be engaging in risky driving behaviors in states where such legislation and licensing requirements are not in place.

Few associations were observed among demographic and clinical factors and specific driving behaviors, suggesting that unsafe driving practices may be universal in this population. We did find that AYAs with a longer duration of type 1 diabetes were more likely to experience hypoglycemia when driving and less likely to stop driving when experiencing hypoglycemia. This finding suggests that AYAs who have had a longer duration of diabetes may be at increased risk for unsafe driving practices and could be a focus of clinical and educational interventions to improve safety around driving.

Of note, technology use did not significantly affect driving practices; however, this finding may simply reflect the need for a larger sample size to explore the benefits of technology

use on prevention and detection of hypoglycemia in the context of driving. Furthermore, CGM and insulin pump technology continued to evolve throughout the study period and will continue to do so, which may affect how these tools are used to improve driving safety. CGM use in particular has been shown to reduce hypoglycemia risk and thus could be particularly effective in enhancing driving safety (37,38). However, children and adolescents have been found to have a high level of attrition in CGM use over time, and sustained use is more difficult in this population (38).

This study has limitations. Given that self-reported data were used, the study may suffer from response and social desirability bias. Participants may have underreported unsafe driving practices because the surveys were completed in the clinical setting, and participants were aware that the clinical team would have access to their responses. However, the need to promote improved driving safety practices in AYAs with type 1 diabetes would remain, even without such biases. Furthermore, the survey instrument developed to assess driving behaviors among AYAs with type 1 diabetes has not yet been validated as a research or clinical tool. Finally, data collected as a part of this study were from a convenience sample in the context of an AYA diabetes transition clinic visit. Therefore, these data may not be representative of driving behaviors of the general population of AYAs with type 1 diabetes.

Conclusion

Results from this study demonstrate that hypoglycemia while driving is common and that AYAs with type 1 diabetes are not optimally implementing safe driving practices, particularly around prevention, detection, and treatment of hypoglycemia. Furthermore, like the general AYA population, many AYAs with type 1 diabetes report unsafe behaviors around substance use before driving and texting while driving. Given that instilling good driving practices in young drivers can translate into improved adherence in adulthood, further education and other behavioral interventions to promote safe driving practices among AYAs with type 1 diabetes should be pursued.

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DUALITY OF INTEREST

No potential conflicts of interest relevant to this article were reported.

AUTHOR CONTRIBUTIONS

A.J.R. conceptualized and designed the study, coordinated and supervised data collection, and drafted the initial manuscript. A.M. and F.S.M. contributed to the data acquisition and analysis plan and interpretation. C.T., C.P., I.B.H., K.R., and J.P.Y.-F. conceptualized and designed the study. All authors reviewed, revised, and approved the final manuscript. A.J.R. 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.

PRIOR PRESENTATION

Preliminary abstract data from this study were presented in poster format at the American Diabetes Association's 79th Scientific Sessions, 7–11 June 2019, San Francisco, CA.

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