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Driving Simulation Can Improve Insight into Impaired Driving Skills in Cirrhosis

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Abstract

Background—Minimal hepatic encephalopathy (MHE) is associated with poor driving skills and insight. Increasing insight may improve receptiveness for therapy or driving restrictions.

Aim—To evaluate the change in the self-assessment of driving skills (SADS) using a driving simulator.

Methods—Cirrhotic patients and age/education-matched controls underwent MHE testing with inhibitory control (ICT) and the psychometric hepatic encephalopathy score (PHES). SADS, a Likert scale from 0 to 10, was administered just before and after a standardized driving simulation comprising testing and navigation tasks. The percentage SADS change from baseline was compared within/between groups.

Results—A total of 84 patients (60% men, age 55 years) and 12 controls were included. Controls were significantly better than cirrhotics on cognitive/simulator testing. The baseline SADS was similar between the groups. The baseline patient SADS was only correlated with ICT lures ($r = -0.4$, $P = 0.001$). Post-simulation, 60% of patients improved their insight, i.e., reduced SADS (from 8 to 6.5, $P = 0.0001$) compared to 25% of controls ($P = 0.02$). The mean percentage SADS reduction was also higher in cirrhotics (18% vs. 8%, $P = 0.03$). MHE on ICT patients had a significantly higher SADS improvement ($P = 0.004$) compared to the other patients; no difference was seen in those with/without MHE due to the PHES. The percentage SADS reduction in patients was correlated with getting lost ($r = 0.468$, $P < 0.0001$), crashes ($P = 0.002$), and centerline/road-edge excursions ($P = 0.01$). There was a significantly higher percentage SADS reduction in cirrhotics who got lost (25%) compared to those who did not get lost (12%) and controls (8%, $P = 0.014$).

Conclusions—Insight into driving skills in cirrhosis improves after driving simulation and is highest in those with navigation errors and MHE on ICT. Driving simulator-associated insight improvement may be the first step towards the cognitive rehabilitation of driving skills in cirrhosis.

Keywords

Driving skills; Minimal hepatic encephalopathy; Insight; Cognitive rehabilitation; Cirrhosis

Introduction

The spectrum of neuro-cognitive impairment in cirrhosis (SONIC), especially minimal hepatic encephalopathy (MHE), has an adverse impact on the daily lives of affected patients [1]. Studies have shown a high likelihood of driving impairment and poor outcomes in simulated and actual driving in patients with MHE [2, 3]. The legal implications of this issue are being increasingly recognized, and the restriction of driving privileges could be an option for selected patients [4, 5]. However, there is also evidence that patients with cirrhosis and cognitive dysfunction also suffer from poor insight into their driving skills, which could decrease their compliance with any restriction of their driving privileges [6]. Increasing insight may, therefore, improve the acceptance of management strategies. The therapy of SONIC is drug-based; however, since the natural history of this condition is unclear, the duration of possible treatment is likely to be prolonged [7]. Therefore, other approaches to improve insight are needed. There is evidence that cognitive rehabilitation can improve insight into other disease processes with similar cognitive impairments [8, 9]. This, however, is not clear in SONIC or MHE. The improvement of insight is an important first step in improving outcomes in the future. The aim of the study was to evaluate the effect of cognitive testing and driving simulation on personal driving assessment in patients with cirrhosis compared to healthy controls. The a priori hypothesis was that subjects with worse driving simulation outcomes would develop the highest insight into their driving skills.

Methods

Cirrhotic patients without current or prior history of overt hepatic encephalopathy (HE) who were current car drivers were prospectively included after obtaining written informed consent. These were matched by age and driving duration to healthy controls. All controls

were current car drivers and were not on psycho-active medications. We excluded patients on overt HE therapy, prior overt HE, those who had focal neurological deficits, current alcohol or substance abuse, those who were not currently driving, on psycho-active drugs apart from chronic anti-depressant therapy, and those who were unable to give informed consent.

All subjects underwent a standard psychometric test battery comprising the number connection tests A/B (NCT-A/B; tests of psychomotor speed and set shifting), digit symbol test (DST; test of psychomotor speed and attention), and block design test (BDT; a test of visuo-motor coordination and psychomotor speed), along with the inhibitory control test (ICT; a test of response inhibition, working memory, and sustained attention: outcomes are lures and targets) [10, 11]. A high score on the BDT, DST, and ICT targets and a low score on the other test measures indicate good cognitive performance. MHE according to the standard battery was defined as abnormal performance in two or more of the following four tests: NCT-A, NCT-B, DST, or BDT, compared to controls as set out in guidelines and prior studies in this population [7, 11]. ICT lures >6 were used to define MHE diagnosed by ICT based on prior studies from our group [11].

After the cognitive testing, a Likert scale (ranging from 1 to 10), termed the self-assessment of driving skills (SADS), inquiring about the subject's personal assessment of their driving skills was administered.

Subsequently, a driving simulation on the BR1100 Driving Simulator by Beta Research Inc. (Los Gatos, CA; <http://www.beta-research.com>) was performed that comprised of three parts [12]:

- (a) *Training simulation*: the training run was given to familiarize patients with the equipment and ensure their ability to follow the tasks on the simulator screen. This lasted for 15 min.
- (b) *Drive testing task*: the second part consisted of driving through several pre-set scenarios over 25 min. The outcomes noted were the number of speeding violations, crashes, and excursions from the edge of the road and from the centerline. No minimum driving speed was required.
- ©) *Navigation task*: this was a task modified from Marcotte et al. that entailed driving through a virtual city on a route traced on a map [13]. There were clearly marked signs at each turn guiding subjects to make appropriate decisions and leading them to the marked destination. Getting lost in this virtual city was indicated by turns that led patients off the marked path, termed illegal turns. Only the first turn off of the marked path was counted as an illegal turn. Both illegal turns and navigation crashes were considered to be outcomes for this task.

After the completion of the simulation, the SADS was re-administered to record their post-simulation assessment. This simulation does not decide who is a safe or an unsafe driver, but, rather, records the number of outcomes.

Importantly, neither the patients nor the control groups were informed of their results in comparison to the norms until they had completed their post-simulation SADS, in case they inquired about their performance.

This protocol was approved by the Institutional Review Board at the Virginia Commonwealth University Medical Center.

Statistical Analysis

The absolute and percentage change in the SADS before and after the simulation was recorded. This was correlated with cognitive performance on individual tests. The percentage change in the SADS was also correlated with individual outcomes on the driving simulation (testing crashes, testing speeding, testing road-edge excursions, testing centerline excursions, illegal turns, and navigation crashes). A P -value < 0.05 was considered to be significant and all data are presented as mean $\pm$ standard deviation unless mentioned otherwise.

Results

Eighty-four patients (51 men and 33 women, age 55 ± 7 years, education 14 ± 2 years, average driving duration 37 ± 9 years) were included in the study. The majority had hepatitis C cirrhosis ($n = 41$), while the remaining had non-alcoholic fatty liver ($n = 23$), alcoholic ($n = 13$), and other ($n = 5$) causes of cirrhosis. There was no significant difference in age (54.5 ± 5.8 vs. 55.5 ± 8 years, $P = 0.55$) or driving duration experience (36.7 ± 8.7 vs. 37.6 ± 9.1 years, $P = 0.64$) between genders in the cirrhotic population.

There were 12 healthy controls that were age- and education-matched to the patients (7 men and 5 women, age 54 ± 6 years, education 14 ± 4 years, average driving duration 36 ± 7 years).

Cognitive Performance

MHE according to standard psychometric tests was present in 45% of tested patients (no impairment: 33%, impaired on one test: 22%, impaired on two tests: 18%, impaired on three tests: 15%, and impaired on all four tests: 11%). ICT performance was impaired in 55% of patients. The mean performance results on all tests were as follows: NCT-A: 33 ± 12 s, NCT-B: 88 ± 57 s, DST: 65 ± 16 , BDT: 32 ± 15 , ICT lures: 9 ± 7 , and ICT targets: $97 \pm 6\%$. None of the controls met the criteria for impaired performance and, similar to prior studies, their performance was as follows: NCT-A: 23 ± 5 s, NCT-B: 64 ± 7 s, BDT: 50 ± 9 , DST: 85 ± 10 , ICT targets: $98 \pm 2\%$, and ICT lures: 4 ± 1 .

Driving Simulation

In the cirrhotic patients, the mean time to complete the test run was 27 ± 4 min and the mean time to complete the navigation run was 16 ± 4 min. In the testing run, there were a mean of 2.3 ± 1.7 (median 2) crashes, 4.3 ± 3.9 (median 3) speeding errors, 13 ± 10 (median 3) centerline crossings, and 6.3 ± 11.5 (median 8) road-edge crossings. In the navigation run, a mean of 1 ± 1.5 (median 1) illegal turns and 0.5 ± 1 (median 0.5) crashes were seen. Thirty (36%) of the patients got lost during the navigation maze, i.e., had one or more illegal turns. In contrast, controls had a significantly lower rate of crashes (1.3 ± 2 , $P = 0.03$), speeding errors (2.4 ± 3 , $P = 0.01$), centerline crossings (8 ± 7 , $P = 0.02$), and road-edge crossings (4 ± 5 , $P = 0.01$). Similarly, controls had a significantly lower number of navigation outcomes, with a mean of 0.5 ± 1 ($P = 0.01$) illegal turns and 9% of controls had one illegal turn ($P = 0.03$ compared to patients). There was no significant difference in the simulation outcomes between genders in the patient or control groups.

In patients, the performance on ICT, but not the other tests, was significantly correlated with driving simulator findings. ICT lures were significantly positively correlated with all testing (crashes $r = 0.4$, speeding $r = 0.3$, centerline crossings $r = 0.5$, and road-edge crossings $r = 0.4$) and navigation outcomes (illegal turns $r = 0.4$ and crashes $r = 0.3$). ICT targets were only significantly negatively correlated with testing outcomes (crashes $r = -0.5$, speeding $r = -0.4$, centerline crossings $r = -0.7$, and road-edge crossings $r = -0.5$). As expected,

patients with abnormal ICT performance had poor overall driving simulator performance (Table 2).

Baseline SADS

In patients, the mean score before simulator testing was 8.0 ± 1.2 , which was statistically similar to controls (Table 1). Confirming prior observations, the baseline SADS score was not significantly different between cirrhotics with and without MHE diagnosed by standard tests (7.6 ± 1.4 vs. 8.1 ± 1.1 , $P = 0.15$) or ICT (8.0 ± 1.1 vs. 7.6 ± 1.2 , $P = 0.32$). The only cognitive test in which the baseline SADS in patients was correlated with was ICT lures ($r = -0.4$, $P = 0.001$). Interestingly, male cirrhotic patients considered themselves to be significantly better drivers at baseline than women (8.1 vs. 7.5 , $P = 0.035$).

In controls, there was no significant correlation between the baseline SADS and cognitive tests.

Change in SADS

The mean patient SADS post-simulation was 6.5 ± 1.4 (range 1–10). This was significantly reduced compared to the scores prior to the simulation ($P = 0.0001$). There was a reduction of the SADS in 60% of patients; the remaining scores were unchanged. None of the patients increased their score after the procedures. The median reduction in the SADS was 1 (range 0–9) and the mean percentage reduction compared to the baseline SADS was $18 \pm 20\%$. In contrast, the controls' post-simulation SADS did not change significantly compared to their baseline, to 7.0 ± 2 ($P = 0.09$ compared to pre-simulation). The median SADS reduction in controls was 0 (range 0–2) and the mean percentage reduction was 8 ± 10 . There was a reduction of the SADS in only 25% of controls ($P = 0.02$ compared to patients).

There was a significantly higher reduction of the SADS in all cirrhotics (1.45 ± 1.73) compared to controls (0.63 ± 0.92 , $P = 0.03$). Despite statistically similar simulator outcomes, there was a trend towards higher SADS reduction in cirrhotic women compared to men (21.9% vs. 13.8%, $P = 0.08$). Correspondingly, patients with MHE on ICT had a significant percentage reduction in the SADS, but there was no change in the percentage reduction if standard cognitive tests were used to classify MHE ($19.2 \pm 17.7\%$ vs. $14.6 \pm 18.4\%$, $P = 0.27$) (Table 2). This was to be expected, since ICT was correlated with simulator outcomes.

Correlation Between the Percentage SADS Reduction, Driving Simulation, and Cognition

In patients, the percentage reduction in the assessment of driving skills was correlated between several driving simulator outcomes, indicating improvement in insight. The percentage SADS reduction was significantly correlated with getting lost on navigation ($r = 0.468$, $P < 0.0001$) and navigation crashes ($r = 0.4$, $P = 0.002$). In the testing simulation, the percentage reduction was correlated with road-edge excursions ($r = 0.3$, $P = 0.01$) and centerline crossings ($r = 0.3$, $P = 0.03$). However, there was no correlation between the percentage SADS reduction and speeding or crashes in the testing run.

The percentage reduction in the SADS was higher if the patient had gotten lost in the virtual maze compared to those who did not have any illegal turns (25% vs. 12%, $P = 0.021$). The percentage reduction in those patients who did not get lost was similar to that of controls (12% vs. 8%, $P = 0.29$), but this percentage reduction was significantly higher in those who got lost compared to controls (25% vs. 8%, $P = 0.006$, analysis of variance [ANOVA] $P = 0.014$ between all three groups, Table 3).

Since controls had significantly better simulator outcomes compared to cirrhotics, no correlation between control SADS change, cognition, or driving simulation results was observed.

Discussion

Driving impairment is expected in cirrhotic patients with MHE due to cognitive abnormalities, as well as fatigue [3, 12, 14]. The increase in accidents in patients with MHE can often lead to troubling legal dilemmas for the clinicians [15]. Patients with MHE have been shown to have poor insight into their driving skills when compared to the assessment of observers who were familiar with their driving [6]. These issues require sensitive handling with the patients and, therefore, increasing insight into driving impairments can increase the receptiveness of patients and their families for any restriction of driving privileges [5]. The current study demonstrates that the SADS can be improved in cirrhosis and this improvement is directly associated with poor driving simulator performance, especially during navigation.

The SADS at baseline in cirrhotics was similar to controls, which confirms prior data that insight was affected in this population [6]. However, the study results showed that, regardless of the pre-simulation assessment, there was a corresponding reduction in the self-appraisal of driving skills depending on simulation outcomes. This reduction was significantly higher in patients compared to controls, who had performed well on simulation. During the simulation, getting lost, crashes during the navigation run, and tasks associated with planning and judgment were specifically associated with this downgrade in driving skill self-assessment [12]. We found that the change in appraisal in patients who did not get lost was similar to healthy controls, reiterating the role of navigation errors in improving insight into driving skills.

Getting lost in the virtual city is an event that is likely to trigger introspection. Navigation is a complex and advanced phenomenon that is either allocentric (landmarks kept on changing) or egocentric (based on body axes) [16]. Allocentric spatial representations include prominent features in the environment that may serve as navigationally relevant locations for the purpose of spatial orientation and memory storage, while egocentric representations use the sensorimotor representation of whole-body, head and gaze motion, the mental representation of distance, time, and number of routes that have been traveled, and the temporospatial relationship of all information to proceed [16]. In our virtual city driving simulation with the map, both of these were tested simultaneously and were instrumental in revealing to the patients that their navigation skills were worse than they had initially estimated. Getting lost is one of the leading reasons for referral for the diagnosis of mild cognitive impairment in Alzheimer's disease [17]. SONIC also represents a form of non-anamnestic mild cognitive impairment and, correspondingly, the "getting lost state" in the virtual city was an important signal for downgrading their self-appraisal. Our results confirm prior studies in that cognitive testing, specifically with ICT, was associated with driving simulator outcomes [2, 12]. It also demonstrates that ICT lures were directly correlated with how patients thought of themselves as drivers at baseline. This correlation is likely due to the longer duration and relative rapidity of ICT stimuli compared to the relatively smaller individual psychometric tests that can increase insight into poor performance. Since simulator findings were closely linked to ICT, it is, therefore, not surprising that patients with MHE on ICT had a significantly higher reduction in the SADS, but not those with MHE diagnosed through standard tests.

The utility of cognitive rehabilitation using driving simulation has been proven in traumatic brain injury and stroke [18, 19]. However, these conditions have a clear onset and have legal

definitions regarding driving restrictions. These can increase adherence, with subsequent therapies designed to bring patients into the mainstream, specifically regarding driving [19, 20]. In contrast, there are no specific driving restrictions in cirrhosis and cognitive dysfunction, and there are no legal or societal obligations to clear cirrhotic patients for driving capability [5]. Therefore, it is imperative that the self-realization of driving skills be encouraged in these patients through objective parameters such as driving simulation.

We found that cirrhotic women, despite having an equivalent age, driving duration, and simulator outcomes, rated themselves to be worse drivers than men at baseline and trended towards greater percentage SADS reduction. This may be an extension of prior experience indicating that women are more likely to acknowledge psychological difficulty and, subsequently, seek treatment compared to men [21].

It is unclear why there is a difference in insight into driving skills, but anosognosia or denial could be important reasons. Anosognosia, an individual's unawareness of impairment, is often measured as a discrepancy between the patients' self-report compared to that of a caregiver or a health care professional's clinical rating. This has also been demonstrated with respect to driving skill assessment in cirrhotic patients with cognitive impairment [6]. Anosognosia in stroke, Alzheimer's disease, and traumatic brain injury is associated with multi-focal brain region impairment, particularly involving frontal-parietal areas [22–24]. Since the fronto-parietal regions and central executive system are associated with cognition abnormalities in SONIC, this may be one mechanism [25]. Anosognosia is an important feature of overt HE. While none of the included patients had ever reached that stage, it may be possible that this “unawareness” starts before the appearance of overt HE symptoms. On the other hand, denial is described as a psychological defensive mechanism. Denial could be important, since patients with SONIC have a multitude of complaints related to health-related quality of life, and, therefore, might be aware of a functional decline without formally acknowledging it [26, 27]. The present study was not designed to disentangle the relative contribution of organic (anosognosia) and psychological (denial) factors to self-awareness. It is also interesting to note that regular driving does not affect insight, since the baseline SADS was similar between groups, but the relatively short simulation forces subjects to re-evaluate their driving skills. We believe that this is partly due to the relative rapidity of the simulation compared to real-life driving that results in a significantly higher number of outcomes during simulation. Also, the subjects who get lost in the simulator do not have recourse to external help in guiding them back to the desired route, sharpening their insight into their situation. Nevertheless, it is clear that getting lost during the simulation served as a “wake-up call” for the study subjects.

The study is limited by the use of the simulation, which is not actual driving. However, the simulator was used as a cognitive tool in this study, which would enable the subject to translate their actions into consequences without putting either themselves or the examiner in danger. The clinical significance of improvement in the SADS and its translating into real-life outcomes can be debated; however, the encouragement of the re-appraisal of abilities may be the first step in responding to therapies and other interventions for the treatment of SONIC. The enhancement of health-related quality of life and driving skills in SONIC has been reported using lactulose and rifaximin [27–29]. While insight has never been specifically measured before, it is an important issue, since it can help patients get out of the “pre-contemplation” stage and make them receptive to therapeutic options that may be necessary.

We conclude that the self-appraisal of driving skills in patients with SONIC can be improved after driving simulation. This improvement in psychological insight is associated with navigation errors and is higher in those patients with poor performance on ICT. The

simulator can be a tool for providing objective feedback regarding driving skills and likely improve receptiveness to driving restrictions or therapies for the improvement of driving skills if needed. Further research is required into the prospective evaluation of strategies of cognitive rehabilitation in SONIC.

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Table 1
Self-assessment of driving skills in controls and cirrhotic patients

	Cirrhotic patients (<i>n</i> = 84)	Controls (<i>n</i> = 12)	<i>P</i> -value between groups
Baseline SADS	8.0 ± 1.2	7.6 ± 0.7	0.36
Post-simulation SADS	6.5 ± 1.4 [*]	7.0 ± 1.1	0.27
Change in SADS	1.3 ± 1.5	0.6 ± 0.8	0.04
Percentage change in SADS	18 ± 20	8 ± 11	0.04

Insight into driving skills, i.e., reduction in the self-assessment of driving skills (SADS), was significantly larger in cirrhotic patients but not in controls, and this was statistically significant between groups

^{*}
 $P = 0.0001$ compared to baseline assessment

Table 2
Driving simulation and self-assessment of driving skills in controls compared to cirrhotic patients according to inhibitory control performance

	Controls (<i>n</i> = 12)	Normal ICT (<i>n</i> = 46)	MHE due to ICT (<i>n</i> = 38)
Illegal turns	0.3 ± 0.7	0.5 ± 1.2	1.4 ± 1.7*
Road-edge excursions	4 ± 5	2.8 ± 2.5	8.7 ± 15.0*
Centerline crossings	8 ± 7	10.1 ± 5.9	14.8 ± 11.6*
Crashes	1.3 ± 2	1.9 ± 1.2	2.9 ± 2.1*
Speeding errors	2.4 ± 3	3.2 ± 3.1	4.8 ± 4.3*
Baseline SADS	7.6 ± 0.7	7.8 ± 1.1	7.7 ± 1.4
Post-simulation SADS	7.0 ± 1.1	7.1 ± 1.3	5.9 ± 1.9*
Change in SADS	0.6 ± 0.8	0.9 ± 0.9	1.8 ± 1.7*
Percentage change in SADS	8 ± 11	11 ± 12	22 ± 21*

Driving simulator performance was worse in patients with abnormal ICT performance compared to those with normal ICT and controls. Insight into driving skills, i.e., reduction in the self-assessment of driving skills (SADS), was significantly higher in cirrhotic patients with poor ICT performance compared to controls or cirrhotic patients with normal ICT performance. There was no significant difference between controls and those with normal ICT performance on any of the criteria listed above

* $P < 0.05$ compared to controls and cirrhotics with normal ICT performance

Table 3
Self-assessment of driving skills in controls compared to cirrhotic patients who did or did not get lost in the virtual city on simulation

	Controls (<i>n</i> = 12)	Cirrhotics who got lost (<i>n</i> = 33)	Cirrhotics who did not get lost (<i>n</i> = 51)
Baseline SADS	7.6 ± 0.7	7.8 ± 1.2	7.9 ± 1.2
Post-simulation SADS	7.0 ± 1.1	5.8 ± 1.2*	6.9 ± 1.9
Change in SADS	0.6 ± 0.8	2 ± 2*	1.0 ± 1.3
Percentage change in SADS	8 ± 11	25 ± 12*	12 ± 10

Insight into driving skills, i.e., reduction in the self-assessment of driving skills (SADS), was significantly larger in cirrhotic patients who got lost compared to controls or cirrhotic patients who did not get lost on the navigation task of the virtual city

* $P < 0.05$ compared to controls and cirrhotics who did not get lost