Introduction

Rehabilitation of stroke survivors often requires medical staff to decide whether the patient is competent to drive. This decision must be made carefully to avoid the possibility of driving accidents caused by stroke-related impairments. Cognitive dysfunctions are often more serious factors than motor deficits for stroke patients who wish to drive because driving an automobile requires a high level of cognitive skills [1−4]. On-road driving is the gold standard for assessing fitness to drive for people with disabilities [5]. However, on-road driving assessment may be expensive and require much time for patients [3]. Furthermore, traffic laws in some countries restrict stroke patients from driving on public roads for evaluation of their skills. In cases where on-road testing is not feasible, neuropsychological testing, the Useful Field of View (UFOV) test, and driving simulators are frequently used alternatives. Because the cost of the driving simulators prevents many hospitals from using this device, neuropsychological testing is most frequently used for driving assessment.

Many researchers have reported a relationship between neuropsychological testing and driving skill, and meta-analyses and systematic reviews have revealed such a correlation [3, 6]. Understandably, clinicians desire valid and reliable tools to accurately and easily assess the driving risk associated with cognitive dysfunction [2, 7].

In this article, we report that driving risk in a stroke patient could not be detected with neuropsychological testing, but was detected with the Useful Field of View (UFOV) test and a driving simulator and confirmed with on-road testing. Although it may be more effective to use on-road testing or a driving simulator to assess whether a stroke patient is competent to drive, our results suggest that UFOV may be more a more accessible and cost-effective method for detecting driving risk due to mild cognitive dysfunction.

Keywords: driving skill, cognitive dysfunction, useful field of view (UFOV)

Case introduction

A 52-year-old man experienced sudden onset of loss of consciousness and developed a cerebral infarction after atrial fibrillation. He was diagnosed with cardiogenic cerebral infarction of the right middle cerebral artery region, with damage from the putamen to corona radiata confirmed by magnetic resonance imaging.

He received conservative treatment in an acute hos-
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Hospital and was discharged from a rehabilitation hospital 3 months after onset. Simple Test for Evaluating Hand Function scores (right upper extremity 90, left upper extremity 83) revealed no motor or sensory deficits. The patient’s functional independent measure score was 125 when he was discharged from the rehabilitation hospital. He experienced no problems or complications during hospitalization. He received a medical driving-skill evaluation at our hospital as an outpatient.

Protocol for driving skill evaluation at our hospital

The driving assessment protocol used at our hospital is summarized in Fig. 1. Initially, we interview a patient to determine driving history, car model, and the patients’ plans to drive in the future. In addition, the patient attends a lecture of approximately 1 h regarding traffic law and legal procedures before returning to driving, which raises awareness of issues facing drivers after brain injury. Subsequently, the patient is evaluated with off-road testing, including neuropsychological testing, visual acuity testing, and performance in a driving simulator. The patient’s abilities to adjust the seatbelt and side mirror and to operate the steering wheel and brake and acceleration pedals are evaluated in a parked car. The on-road driving assessment (Fig. 1) is used only in cases of considerable doubt, as the ability of the medical staff to evaluate a patient’s driving skills with on-road testing in Japan is limited institutionally and financially. We refer to previously reported cut-off points (Table 1) for each neuropsychological testing [2, 8]. In addition, competency to drive is not determined with only a single abnormal result, but instead is comprehensively assessed using many results from multiple tests.

Interview

The patient demonstrated strong motivation to drive, as he had a son still in high school and a wife to support. He hoped to be able to drive a car again to maintain his employment at an apartment management company, which required him to transport staff by car. His job required him to drive 5–6 h per working day. He

<table>
<thead>
<tr>
<th>Type of testing</th>
<th>acceptable</th>
<th>doubtful</th>
<th>unacceptable</th>
</tr>
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<tbody>
<tr>
<td>Mini-Mental State Examination</td>
<td>28 or more</td>
<td>27-23</td>
<td>22 or less</td>
</tr>
<tr>
<td>Rivermead Behavioral Memory Test screening</td>
<td>7 or more</td>
<td>−</td>
<td>5 or less</td>
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<tr>
<td>Rivermead Behavioral Memory Test standard profile</td>
<td>16 or more</td>
<td>−</td>
<td>14 or less</td>
</tr>
<tr>
<td>Rey-Osterrieth Complex Figure Test (copy)</td>
<td>34 or more</td>
<td>30–34</td>
<td>29 or less</td>
</tr>
<tr>
<td>“A” Random letter Test</td>
<td>0</td>
<td>1 or more</td>
<td></td>
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<tr>
<td>Trail Making Test-A</td>
<td>42 sec or less</td>
<td>43–54 sec</td>
<td>55 sec or more</td>
</tr>
<tr>
<td>Trail Making Test-B</td>
<td>148 sec or less</td>
<td>149–180 sec</td>
<td>181 sec or more</td>
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<tr>
<td>Behavioural Inattention Test conventional test of score</td>
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<td>−</td>
<td>130 or less</td>
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<tr>
<td>Behavioural test</td>
<td>68 or more</td>
<td>−</td>
<td>67 or less</td>
</tr>
<tr>
<td>Kohs block design test</td>
<td>IQ 90 or more</td>
<td>IQ81–89</td>
<td>IQ 80 or more</td>
</tr>
<tr>
<td>Japanese road signs (original assessment in our hospital)</td>
<td>10 or more</td>
<td>8–7</td>
<td>6 or less</td>
</tr>
</tbody>
</table>
was eager to return to his work as soon as possible, as he feared being fired due to the current difficult economic condition. He had committed some mild traffic violations. Although he had never caused a traffic accident resulting in injury, he had caused an accident resulting in property damage. According to his wife, he exhibited no particular changes in comparison to his behavior, personality, and abilities prior to the stroke.

**Off-road testing results**

The patient had no hemianopia. The following are the results of several off-road tests completed by the patient: Mini Mental State Examination score was 28; Rivermead Behavioral Memory Test screening score was 12 and standard profile score was 18; Rey-Osterreith Complex Figure Test (only copy) score was 35; “A” Random letter test error value was 0; Trail Making Test (TMT) A was completed in 46 s; TMT-B was completed in 48 s; Behavioral Inattention Test (BIT) conventional test score was 146 and behavioral test score was 77; and Kohs Block Design Test IQ was 85.4. In addition, the patient correctly identified 19 out of 20 Japanese road signs in an original assessment used by our hospital, and his vision in both eyes was 0.8 while wearing his glasses. Although these results were not perfect, our medical team could not confirm driving risk.

When tested in a parked car, the patient did not exhibit any notable problems while opening and closing the car door, adjusting the seatbelt and mirrors, inserting the key, or adjusting the speed when operating the steering wheel or stepping on the brake or acceleration pedal. In this test as well, our medical team could not confirm driving risk.

**UFOV testing result**

The Visual Field with Inhibitory Tasks (VFIT) software was used to assess the UFOV or functional visual field (FVF) using dual tasks (Fig. 2) [9]. During the assessment, the useful field of view is measured as the seated patient watches a computer monitor placed on the desk in front of him or her. The VFIT comprises three pretests (simple task, go/no go task, and peripheral task) and a dual task of combined pretests. We adopt tasks excluding the peripheral task. At first, subjects must gaze at the center of the monitor during all tasks.

Four target marks (4 types) on the monitor are indicated for 2500 msec–3000 msec, and subjects must push a button immediately according to various tasks. The simple task is that the subject must always push the button when the target marks appeared on the monitor. If the subject pushes the button before the target marks appear, the result will be a “false alarm (FA)” (same as other tasks). If the subject cannot push the button correctly, the result is an error. The go/no go task requires the subject to push the button only when all target marks are different from each other. If the subject pushes the button when some target marks are the same, the result will be FA (same as dual task). In the dual task, a single target mark (a surrounding mark) appears around four target marks, and the subject must push the button only when all target marks in the center of the monitor are different. After that, the subject must push a predetermined button corresponding to the surrounding mark types. There are four versions (I, II, III, and IV) of the dual task depending on the distance between the target marks and the surrounding mark.

The percentage of correct answers for each stage (peripheral task: indicates the width of the useful field of view) and the number of FAs are recorded. Although no defined clear cut-off scores have been established for VFIT, VFIT developers indicated that the average score for people of the same age as the patient was approximately 90%, and the cut-off score was estimated to be approximately 80% [9].

The patient’s performance on the VFIT was as follows: the percentage of correct answers was 100% in the simple task, 100% in the go/no-go task, and, in the dual task, 84% in stage I, 93% in stage II, 84% in stage III, and 75% in stage IV. The number of FAs was 6% in the go/no-go task, and, in the dual task, 9% in stage I, 6% in stage II, 6% in stage III, and 0% in stage IV. He made mistakes on both left and right sides (slightly more often on the left side) during VFIT (Fig 3).
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Driving simulator

We adapted the UC-win/ROAD software version 3.4 (FORUM8 Co., Ltd) as a driving simulator (Fig. 4). The software provides a steering function that is similar to a TV driving game and is not similar enough to a car to assess steering. Therefore, other driving skills, such as the ability to stay in the center of the lane and to remain stationed at a red traffic signal, are assessed using this simulator.

During assessment with this driving simulator, the patient could not keep to the center of the lane, tending to drive on the left side of the road, and crossed over a guard rail and a sidewalk. Several times an occupational therapist directed him to drive in the center of the lane, after which he initially drove in the center but eventually tended to drive on the left side. No other problems were observed.

On-road testing

The results of the driving simulation and VFIT raised doubts on the patient's competency to drive and an on-road assessment was deemed necessary. We adopted ordinary driving skill evaluation items (e.g., the outer circumference of the course road, slope, and crank) for which healthy driving students are tested. In the 1-h on-road assessment, a driving instructor sat in the front passenger seat, and an occupational therapist sat in the back seat. The patient exhibited no difficulties when instructed to start the car on a hill, stop on a line, and turn a corner. However, when he carefully attempted to stop the car on the left side of the road, he scratched the left tire on the curb. Although the occupational therapist and instructor warned him repeatedly, he scratched the left tire in six out of nine attempts to park on the left side of the road.

From the results of this series of driving assessments, we concluded that the patient was not yet ready to drive due to suspected attention deficits. As the patient showed improvement since the stroke and the impairment was mild, the clinician informed the patient and his wife that there was a possibility that he might be competent to drive in the future. In addition, the physician provided the patient with a medical certificate stating that, with the exception of driving, he was able to return to work. The patient returned to work as a clerical staff without driving responsibilities, and he completed regular ambulatory care at our hospital.

Discussion

In this study, the assessment of a stroke outpatient using neuropsychological tests and off-road assessment in accordance with our protocol did not reveal driving risk. Because visuospatial Meyers, Völbrecht, & Kaster-Bundgaard [10] and attentional Parasuraman & Nestor [11] functions are critical to driving skill, BIT and TMT were performed and did not reveal driving risk. However, on-road assessment revealed that the patient experienced difficulty in stopping the car on the left side of the street, and it was concluded that the risk of driving was sufficiently high to indicate he was not ready to drive yet. The patient's driving risk could not be detected by neuropsychological testing, and this was
likely due to the presence of very mild cognitive disorder. A previous study showed that it was easy to detect driving risk for patients with moderate or heavy cognitive disorders, but that it was more difficult to assess the driving risk for patients with mild cognitive disorders [3]. In a study that found a correlation between visuospatial attention and driving skill, cognitive dysfunction could not be detected with neuropsychological testing [10, 11]. Another study indicated that there is no correlation between neuropsychological testing and driving skill [12], and our results support this conclusion. Although it is possible that our study is a rare case in which driving risk could not be assessed with neuropsychological testing, it should not be dismissed as the risk of accident was considerable.

VFIT and driving simulator assessment also revealed the driving risk of the patient. Previous studies indicated that the UFOV test can be used to assess various cognitive functions (e.g., attentional, visuospatial), that it was superior for detecting the driving risk of elderly drivers, and that the results correlate well with on-road assessment as well as TMT and Rey-Osterrieth Complex Figure Test results [2, 13]. The fact that we could detect a mild cognitive disorder using VFIT and driving simulator suggests that these assessments may be useful for assessing driving risk that cannot be detected with neuropsychological testing. Although driving simulators may be prohibitively expensive, cognitive disorders contributing to driving risk can be assessed in a hospital using only VFIT and a personal computer, because the developer of VFIT offers the test for free with some requirements.

Ultimately, on-road testing is still the most useful assessment of driving risk in cognitive disorder patients after brain injury. However, many therapists cannot use on-road testing due to economic and institutional restrictions. Marshall et al. [2], in describing institutional differences in countries with respect to on-road testing, noted that on-road assessment is used primarily in Canada because most physicians must declare the driving competency of patients and, correspondingly, not used as often in the USA because American physicians are not required to report driving competency, usually. At present, only a few hospitals in Japan use on-road testing. Although Japanese physicians do not have the authority to decide whether a patient can drive or not, driving license authorities often seek medical advice for granting driving privileges, because on-road testing is rarely performed by this organization. Physicians required to assess the driving competency of patients are faced with the disadvantages of neuropsychological testing and a lack of cooperation from driving schools. To address these issues in Japan, we suggest that driving license authorities should employ individuals, such as occupational therapists, who have the knowledge of neuropsychology and driving skill assessment. Until such policy is implemented, driving risk can be assessed in hospitals using the UFOV test or driving simulators.

Conclusion

We used neuropsychological, off-road, and on-road testing to determine the driving skill of a stroke patient. Although driving risk could not be determined by neuropsychological testing, it could be determined by the UFOV test and a driving simulator. Although it may be most effective to use a combination of neuropsychological, off-road, and on-road testing to determine the driving competency, our results suggest that the UFOV test may be a useful alternative when on-road testing and driving simulation is unavailable.

References

Driving risk in a stroke patient with mild cognitive deficit could not be predicted is more than pedal pushing. Applied Neuropsychology. 1999; 6: 154–64.

