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A comparison of driving errors in patients with left or right hemispheric lesions after stroke

Myoung-Ok Park, MPH, OT[1)]

[1)] *Department of Occupational Therapy, Division of Health Science, Baekseok University: 76 Munam-ro, Dongnam-gu, Cheonan-si, Chungcheongnam-do, Republic of Korea*

Abstract. [Purpose] The aim of this study was to compare the incidence of driving errors among patients with left or right hemispheric lesions due to stroke. [Subjects and Methods] Thirty stroke patients participated in the study. Driving errors were assessed using a virtual reality driving simulator. [Results] Significant differences were shown in center line crossing frequency, accident rate, brake reaction time, total driving error scores, and overall driving safety between participants with left or right hemispheric lesions. [Conclusion] Driving rehabilitation specialists should consider hemispheric function when teaching driving skills to stroke survivors, because patients with lesions in the left or right hemispheres after stroke show differences in driving skills.

Key words: Stroke, Driving error, Hemispheric lesion

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INTRODUCTION

Physical and cognitive impairments due to cerebrovascular disease cause difficulty driving, resulting in limitation of stroke patients' social participation and vocational resumes[1)]. Driving enables mobility within the community and is thus important to the ability of brain injury patients to sustain an independent lifestyle[2)]. For most clients of rehabilitation specialists who have experienced a stroke, spinal cord injury, or traumatic brain injury, loss of driving ability appears to result from deficits in sensory function, vision, perception, cognition, and language, as well as motor function[3)]. Therefore, driving training and assessment are essential aspects of performing safety driving. Although actual on-road driving training is ideal for regaining driving skills after brain injury, safety issues due to road hazards must be considered. Therefore, virtual reality driving simulations are used as training tools by several driving rehabilitation centers[4)]. The effectiveness of driving simulator training has been tested in previous studies of older adults or patients with traumatic brain injury or spinal cord injury and of a normal adult with anxiety after a car accident[5, 6)]. Driving simulators have also been used in several studies to identify driving errors in elderly individuals and those with cerebral injury[7, 8)]. According to the American Stroke Association, drivers who have suffered a stroke commit more than twice as many driving errors as normal drivers, including errors in making left turns[9)]. The aim of this study is to compare the driving errors made by stroke patients with right or left hemispheric lesions, a distinction that has not been addressed in previous studies.

SUBJECTS AND METHODS

Thirty stroke patients who received rehabilitation training at a day-care center in Seoul were included in the present study. Participants included 23 males (76.7%) and 7 females (23.3%) with a mean age of 47 years (SD = 12.96) and mean driving experience before stroke of 15 years (SD = 8.22). 16 of the patients had right hemispheric lesions (53.3%) and 14 had left hemispheric lesions (46.7%). All participants were informed of the purpose and methods of this study, in accordance with the ethical principles of the Declaration of Helsinki (1975, revised 1983). The subjects provided written consent prior to the experiment, which was approved by the institutional review board of the National Rehabilitation Center. Patients were included if they had received their first stroke diagnosis one year ago and had a driver's license and driving experience before the onset of stroke. Patients were excluded if they were unable to comprehend or follow the instructions for using a driving simulator. A driving simulator (GDS-300, Gridspace) was used to assess driving errors. The driving simulator included a virtual on-road course with road traffic rules. The test course simulated driving in downtown Seoul and on the highway and was designed to resemble actual driving, incorporating various buildings, moving cars, traffic signals, and road signs. While participants used the simulator, driving errors were tracked by the simulator software. Driving errors that were assessed included failure to use the seat belt, maintain speed, or follow the road, and crossing of the center line. The maximum score on this simulator was 100 points. Safe driving was indicated by a

Corresponding author. Myoung-Ok Park (E-mail: parkmo@bu.ac.kr)

Table 1. Comparison of driving errors between stroke patients with left and right hemisphere lesions (n = 30)

	Right hemisphere lesion (n = 16)	Left hemisphere lesion (n = 14)		
	Frequency (%) or mean ± SD	Frequency (%) or mean ± SD	χ^2 (df)	Odds ratio
Failed to use seat belt	9 (56.2%)	9 (64.3%)	0.021 (1)	0.71
Exceeded speed limit	3 (18.8%)	2 (14.3%)	0.107 (1)	1.38
Turn signal errors	34.37 ± 20.55*	12.64 ± 9.53*		
Drop out the course	5 (31.2%)	7 (50.0%)	1.09 (1)	2.20
Crossed center line	10 (62.5%)*	7 (50.0%)*	0.47 (1)*	1.66*
Accidents	4 (25.0%)*	8 (61.5%)*	3.95 (1)*	4.8*
Brake reaction time (sec)	0.99 ± 0.21*	9.00 ± 29.18*		
Total error score	32.12 ± 18.47*	18.64 ± 16.57*		

*Significant difference between right and left hemisphere lesion groups, $p < 0.05$. SD: standard deviation

Table 2. Comparison of driving simulation time and failure rate between patients with left and right hemisphere lesions (n = 30)

	Right hemisphere lesion (n = 16)	Left hemisphere lesion (n = 14)		
	Frequency (%) or mean ± SD	Frequency (%) or mean ± SD	χ^2 (df)	Odds ratio
Total driving time (minutes)	24.26 ± 7.73	19.86 ± 8.02		
Failures	4 (25.0%)*	9 (64.3%)*	4.69 (1)*	5.4*

*Significant difference between right and left hemisphere lesion groups, $p < 0.05$. SD: standard deviation

cut-off score of 80 points; scores below this threshold were marked as failures[10]. Participants completed one practice trial using the exercise mode of the simulator, because some patients appeared to develop symptoms of motion sickness while using the simulator[11]. Participants then completed the test course. Approximately 10 min were required for normal drivers to complete the test course. Statistical analyses were performed using SPSS software (version 20.0). Descriptive statistics were used to summarize the general characteristics of the participants. The Student's t-test and χ^2 test were used to compare driving errors between participants with left or right hemispheric lesions. All statistical significance levels were set at 0.05.

RESULTS

There were no significant differences between participants with left or right hemispheric lesions in the frequencies of failure to use the seat belt, exceeding the speed limit, or drop-out of the course. However, there were significant differences in the frequencies of center line crossing, turn signal errors, and accidents, as well as brake reaction time, and total driving error scores (Table 1). There was no significant difference in the time needed for participants to complete the test course; however, there was a significant difference in the test failure rate (total test score < 80 points) (Table 2).

DISCUSSION

Driving rehabilitation is important for the ability of stroke survivors to maintain an independent lifestyle and to participate in the community[12]. To help drivers who have experienced strokes to regain their mobility within the community, driving rehabilitation specialists assess their driving skills and analyze driving errors. The aim of this study was to compare driving errors between stroke patients with left or right hemispheric lesions. Significant differences were shown in the frequencies of turn signal errors and center line crossing, accident rate, and brake reaction time. Specifically, participants with right hemispheric lesions were approximately 1.7 times more likely to cross the center line and 4.8 times more likely to have an accident compared to participants with left hemispheric lesions. Additionally, there was a significant difference between participants in overall driving safety, as shown by a significantly higher failure rate among patients with right hemispheric lesions compared to those with left hemispheric lesions. These results are similar to those of a previous study conducted by Akinwuntan and colleagues, which argues that the hemisphere affected by the lesion is an important factor influencing driving performance after stroke[13]. Similarly, a study conducted by Quigley and colleagues, which included 50 stroke patients who participated in driving rehabilitation, found that 52% of participants with right hemispheric lesions passed the relicensing test, compared to 74% of participants with left

hemispheric lesions[14]. These results may be due to symptoms caused by right hemisphere lesions such as unilateral spatial inattention. Recognition of and attention to features of the driving environment, such as vehicles, roads, and traffic signs, are critical for safe driving. It is possible that patients with unilateral spatial inattention due to lesions of the right parietal areas experienced difficulties receiving sensory information related to the driving environment.

As with all studies, this study had limitations. The number of participants was small, and all participants had lesions restricted to the left or right hemispheres. Therefore, further studies should recruit greater numbers of subjects and investigate driving errors among patients with multiple lesions or different types of stroke, such as ischemic or hemorrhagic stroke. Despite these limitations, this study has important implications for driving rehabilitation. Significant differences were found in driving errors between stroke patients with left and right hemispheric lesions. Therefore, driving rehabilitation specialists should be trained to consider the specialized functions of each hemisphere when teaching driving skills to stroke survivors.

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