Abstract:
Objective We conducted a study to obtain information that could be used to provide Parkinson’s disease (PD) patients with appropriate advice on safe driving.
Methods Consecutive PD patients who visited our office were studied. Among these patients, those who had experienced driving after being diagnosed with PD were interviewed by neurologists and a trained nurse to investigate their previous car accidents, motor function, cognitive function, sleepiness, levodopa equivalent dose (LED), and emotional dysregulation. The rates of major car accidents before and after the onset of PD were compared.
Results Fifteen patients had experienced a major car accident resulting in human injury or serious property damage since the onset of PD. When the rates of major car accidents before and after the onset of PD were compared, the ratio was 4.3 [95% confidence interval (CI) 1.9-9.7]. The incidence of accidents after the onset of PD was correlated with age, disease duration, LED, the cognitive function Mini-Mental Scale Examination (MMSE), Japanese translation of the Montreal Cognitive Assessment (MoCA-J), but not the motor symptom score [Unified Pankinson’s disease rating scale (UPDRS) part III at the time of the study]. The Questionnaire for Impulsive-Compulsive Disorders in Parkinson’s Disease (QUIP) score was also higher in patients with major car accidents.
Conclusion The severity of symptoms (Hoehn-Yahr classification), cognitive function, and disease duration were expected to be risk factors for car accidents. However, the motor symptom score (UPDRS part III) was not associated with the incidence of major car accidents. In addition to a low cognitive function and the severity of symptoms, the QUIP score might be an independent factor that can be referenced when advising PD patients to refrain from driving.
Key words: Parkinson’s disease, driving, safety, car accident, advice to refrain from driving

Introduction
Previous studies have shown that driving a car requires cognitive and psychological abilities with motor skills, and that driving capability decreases according to the progression of Parkinson’s disease (PD), even in patients with mild-to-moderate PD (1-3). Nonetheless, many PD patients still need to drive to get to work or hospital. Previous studies have evaluated the driving skills of PD patients by on-road
Materials and Methods

We screened consecutive PD patients who were diagnosed according to the UK Brain Bank criteria and who visited Ehime University Hospital from August 1, 2014 to October 31, 2015. Those who were currently driving or who had stopped driving after the onset of PD were enrolled as the study population. Interviews were conducted by neurologists and a specially appointed nurse. The following items were evaluated: age, gender, Hoehn-Yahr (H&Y) severity classification, Unified Parkinson’s Disease Rating Scale (UPDRS) score, Japanese translation of the Montreal Cognitive Assessment (MoCA-J) score, Mini-Mental Scale Examination (MMSE) score, Questionnaire for Impulsive-Compulsive Disorders in Parkinson’s Disease (QUIP) score (8), Epworth sleep scale (ESS) score, and drug history at the time of the study. The MoCA-J and MMSE scores both evaluate the cognitive function on a 30-point scale; the MoCA-J score better reflects the frontal lobe function than the MMSE score. The following items concerning the driving status were also evaluated: driving history (period of time in years after the onset of PD and the interview date or the onset of PD and the date on which the patient stopped driving), history of driving accidents, injuries caused by accidents (to self or others), and sleepiness or sudden loss of consciousness at the time of an accident. We analyzed those data related to car accidents. Furthermore the rate of major car accidents before and after the onset of PD was studied. The SAS JMP software program (v10) was used to perform the statistical analyses. Two-tailed p values of <0.05 were considered to indicate statistical significance.

Table 1. Demographic and Clinical Characteristics of the Study Population.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total (n=140)</th>
<th>No car accident Group A (n=109)</th>
<th>Minor car accident Group B (n=16)</th>
<th>Major car accident Group C (n=15)</th>
<th>ANOVA (All group)</th>
<th>t-test (Group A vs. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number, male</td>
<td>74 (66)</td>
<td>55 (54)</td>
<td>8 (8)</td>
<td>11 (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td>66.8±8.7 (42-87)</td>
<td>67.0±8.5 (42-87)</td>
<td>66.3±8.3 (57-87)</td>
<td>65.9±10.5 (45-83)</td>
<td>0.866</td>
<td>0.633</td>
</tr>
<tr>
<td>Disease duration, years</td>
<td>6.8±4.5 (0.7-23.5)</td>
<td>6.3±4.3 (0.7-23.5)</td>
<td>5.9±2.9 (1.4-13.2)</td>
<td>10.2±5.6 (3.1-23.3)</td>
<td>0.006*</td>
<td>0.008*</td>
</tr>
<tr>
<td>Driving duration, years</td>
<td>40.8±10.4 (13-67)</td>
<td>41.0±10.5 (18-67)</td>
<td>39.3±6.3 (25-53)</td>
<td>40.6±12.6 (13-62)</td>
<td>0.713</td>
<td>0.413</td>
</tr>
<tr>
<td>L-dopa, mg/day</td>
<td>359.8±155.9 (0-1,050)</td>
<td>346.2±140.9 (0-850)</td>
<td>351.7±109.0 (200-850)</td>
<td>463.3±236.3 (250-1,050)</td>
<td>0.023*</td>
<td>0.006*</td>
</tr>
<tr>
<td>Total LED, mg/day</td>
<td>551.0±308.6 (0-1,860)</td>
<td>511.0±255.9 (0-1,410)</td>
<td>520.7±247.1 (300-1,115)</td>
<td>871.5±479.7 (250-1,860)</td>
<td>&lt;0.001*</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>H&amp;Y classification</td>
<td>2.6±0.77 (1-5)</td>
<td>2.5±0.8 (1-5)</td>
<td>2.6±0.7 (1-3.5)</td>
<td>3.2±0.7 (2.5-4)</td>
<td>0.011*</td>
<td>0.003*</td>
</tr>
</tbody>
</table>

* p<0.05 for ANOVA and <0.025 for t-test

† Patients who never had car accidents before PD onset. Of the 82 patients still driving, 28 (34.1%) drove ≥5 days/week, 26 (32.7%):1-4 days/week, and 28 (34.1%) 1 day/week.

‡ Patients who had accidents resulting in minor property damage after PD onset. Two patients had 2 accidents, 1 had 4 accidents, and 13 had 1 accident. Of the 12 patients still driving who ≥5 days/week, 1 (8%):1-4 days/week, and 2 (17%): 1 day/week.

§ Patients who had accidents resulting in injury to the patient, passengers or others involved in the accident, or resulting in serious property damage.

Type of accident: rear end accident, all or others, and sleepiness or sudden loss of consciousness at the time of an accident.

Sixteen patients (11%) had experienced a major accident before the onset of PD and 15 patients (11%) had experienced a major accident after the onset of PD. Twenty-six patients (19%) had experienced a minor accident before the onset of PD and 16 patients (11%) had experienced a minor accident after the onset of PD. The mean duration of driving history was 34.9 years before the onset of PD and 5.8 years after the onset of PD. The rate of major accidents after the onset of PD was higher than that before the onset of PD (0.0177 versus 0.0031 accidents/year/person, respectively). When comparing the rate of major car accidents before and after the onset of PD, the ratio was 4.3 [95% confidence interval (CI) 1.9-9.7]. Four of the 15 patients who had experienced a major car accident after the onset of PD stated, “I didn’t realize what was happening until I had already crashed”, indicating that the accident was possibly caused by sudden-onset sleep.

Accidents that had occurred after the onset of PD were categorized into three groups: no accident (group A, n=109), minor accident (group B, n=16), and major accident (group C, n=15) groups. The differences between groups were assessed using the analysis of variance (ANOVA) (Table 1). When the three groups were compared, there was no difference in age or driving history. Additionally, there were no differences in any of the items between groups A and B. In comparison to Group A, Group C had a higher levodopa dose, total levodopa equivalent dose (LED) (9), H&Y classification, UPDRS part II score, UPDRS part IV score, QUIP score, and MMSE score. (Table 1). Furthermore, among the UPDRS part III scores, there were significant differences in the bradykinesia and postural instability values of the groups, while the overall UPDRS did not differ to a statistically significant extent. When we analyzed the differences among the three groups using the Kruskal-Wallis test, the bradykinesia and postural instability values were found to be significantly different (p=0.0119 and p=0.0204, respectively); the Wilcoxon test also revealed significant differences between Groups A and C (p=0.0034 and p=0.0068,
having had a major car accident (Table 2).

PD symptoms but that it was independently correlated with the cognitive function or the severity of the car accident. The analysis revealed that the QUIP score was not correlated with the cognitive function, as measured by the MMSE, declines to increase when cognitive function, as measured by the MMSE score, 100% patients with a score of <2 captured 100% of the patients who failed but only 16.7% of the patients who passed, while a cutoff score of >27 captured 100% of the patients who passed but only 4.9% of the patients who failed. In our study, 100% of the patients with a MoCA-J score of >28 had never had an accident and 100% of the patients with a MoCA-J score ≤10 had experienced a major accident. Even though our investigation was a retrospective interview study, the results were close to those obtained from on-road testing.

The ESS scores of the no accident and major accident groups did not differ to a statistically significant extent. Previous research has also shown that ESS scores and daytime sleepiness were not correlated with driving skill (4, 12, 16). The reasons for this may be that the driving tests were conducted in the morning when patients were in their best “on” state (12). In our study, 4 of the 15 patients in the major accident group had experienced sudden-onset sleep, which led to an accident in three patients. This indicates that the ESS score does not always predict the incidence of PD-related driving accidents.

Dopamine agonists are associated with a risk of sudden-onset sleep; thus, PD patients taking non-ergot alkaloids are warned not to drive. In this cohort, 70% of the PD patients receiving non-ergot alkaloids continued driving against drug label warnings. However, there were no differences between the patients taking non-ergot alkaloids and those taking ergot alkaloids (17). These findings suggest that if medication counseling is provided, then the incidence of car accidents may not increase.

The driving skill of PD patients has been evaluated in various studies (2-7, 11, 12, 16, 18-21). In a study of 104 patients in that previous study. The association between a declining cognitive function and driving performance has also been studied. Esser et al. (15) assessed the actual on-road driving performance of patients with neurological disorders and found that the total MoCA score differed significantly between patients who passed and failed a driving test, and that the factor was independent of their neurological disorders. An assessment of the sensitivity and specificity yielded two cutoff MoCA scores: a cutoff score of <2 captured 100% of the patients who failed but only 16.7% of the patients who passed, while a cutoff score of >27 captured 100% of the patients who passed but only 4.9% of the patients who failed. In our study, 100% of the patients with a MoCA-J score of >28 had never had an accident and 100% of the patients with a MoCA-J score ≤10 had experienced a major accident. Even though our investigation was a retrospective interview study, the results were close to those obtained from on-road testing.

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### Discussion

The risk of accidents when driving has been reported to increase when cognitive function, as measured by the MMSE, declines to ≤24 points (10). In PD patients, the deteriorating cognitive function is also associated with a higher rate of driving accidents (11). In addition, PD patients are slower to make decisions and have reduced spatial cognition, which should further reduce their driving skills in novel situations and on busy roads (12). Studies on driving ability and treatment have also been reported (13). In 2014, Hu et al. (14) evaluated the cognitive function of 486 PD patients and 141 controls using the MMSE and MoCA. They found that although the MMSE scores of PD patients did not change over the long-term course, there was a clear decrease in their MoCA scores. The PD patients in our study had very similar MMSE and MoCA-J scores to the

### Table 2. Estimated Coefficients of a Logistic Multivariate Model of Clinical Characteristics for Having a Major Car Accident.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Estimate</th>
<th>Standard error</th>
<th>χ²</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.53377701</td>
<td>4.2292999</td>
<td>0.13</td>
<td>0.7169</td>
</tr>
<tr>
<td>Age</td>
<td>0.01231868</td>
<td>0.0389516</td>
<td>0.10</td>
<td>0.7518</td>
</tr>
<tr>
<td>Disease duration</td>
<td>0.00241433</td>
<td>0.0168305</td>
<td>0.02</td>
<td>0.8859</td>
</tr>
<tr>
<td>Total LED</td>
<td>-0.0025063</td>
<td>0.0019178</td>
<td>1.71</td>
<td>0.1913</td>
</tr>
<tr>
<td>H&amp;Y classification</td>
<td>-0.7092462</td>
<td>0.5559468</td>
<td>1.63</td>
<td>0.2020</td>
</tr>
<tr>
<td>MMSE</td>
<td>0.11863273</td>
<td>0.0890112</td>
<td>1.78</td>
<td>0.1826</td>
</tr>
<tr>
<td>QUIP</td>
<td>-0.5778229</td>
<td>0.2628645</td>
<td>4.83</td>
<td>0.0279*</td>
</tr>
</tbody>
</table>

*Statistically significant (p<0.05).

PD patients who had a current driver’s license and were driving, researchers conducted on-road testing using a checklist and evaluated disease characteristics, motor symptoms, cognitive function, and epidemiological aspects off-road (20). In that study, 65% of the PD patients passed the on-road test, while 35% failed. In comparison to the patients who passed, the patients who failed were older, had a longer driving history, and walked less over a 1-year period. The drugs used and ESS score were not associated with accidents within a 5-year period (20). Only one crash was reported in that study. In our study, 15 of 140 patients (11%) had experienced a major car accident after the onset of PD. The reason for this difference is not clear, but it may be related to the traffic conditions or the methods used to obtain information from patients. Furthermore, in 2015, the National Police Agency of Japan reported that the rates of driving accidents among normal drivers aged in their 60s and 70s were 0.0052 and 0.0063 accidents/year/person, respectively (22). The rates among PD patients before and after the onset of PD were 0.0031 and 0.0177, respectively. The rate among PD patients before the onset of PD was not higher than that for normal drivers. However, the rate after the onset of PD was higher than that of the normal drivers.

The results of our study are compatible with previous studies on driving among PD patients. However, the present study was associated with some limitations. It should be noted that our study was retrospective in nature. The patients experienced car accidents prior to their clinical examination. Furthermore, although a trained nurse attempted to obtain precise information on the car accidents from the patients and their families, we did not obtain information from the police.

The incidence of car accidents among PD patients was correlated with age, disease duration, cognitive function, and various symptom scores, including the H&Y classification and UPDRS scores part II, part IV. The UPDRS part III score was not associated with the incidence of major car accidents. It has been reported that neurologists overestimate the ability of PD patients to drive (3). The MMSE was associated with the incidence of major car accidents in this study. Patients with dementia, now undergo memory tests at the renewal of their licenses in order to prevent car accidents. It has been reported that neurologists overestimate the ability of PD patients to drive (3). The MMSE was associated with the incidence of major car accidents in this study. Patients with dementia, now undergo memory tests at

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