PAPER

Parkinson's disease and driving ability

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Objectives: To explore the driving problems associated with Parkinson's disease (PD) and to ascertain whether any clinical features or tests predict driver safety.
Methods: The driving ability of 154 individuals with PD referred to a driving assessment centre was determined by a combination of clinical tests, reaction times on a test rig and an in-car driving test.
Results: The majority of cases (104, 66%) were able to continue driving although 46 individuals required an automatic transmission and 10 others needed car modifications. Ability to drive was predicted by the severity of physical disease, age, presence of other associated medical conditions, particularly dementia, duration of disease, brake reaction, time on a test rig and score on a driving test (all $p<0.001$). The level of drug treatment and the length of driving history were not correlated. Discriminant analysis revealed that the most important features in distinguishing safety to drive were severe physical disease (Hoehn and Yahr stage 3), reaction time, moderate disease associated with another medical condition and high score on car testing.
Conclusions: Most individuals with PD are safe to drive, although many benefit from car modifications or from using an automatic transmission. A combination of clinical tests and in-car driving assessment will establish safety to drive, and a number of clinical correlates can be shown to predict the likely outcome and may assist in the decision process. This is the largest series of consecutive patients seen at a driving assessment centre reported to date, and the first to devise a scoring system for on-road driving assessment.

Parkinson's disease (PD) is a progressive neurological disorder predominantly affecting motor function, although cognitive impairment can also be a major feature.[1] Features such as motor slowness and involuntary movements means that it is an important condition with regard to road safety.[2 3] Patients may be unable to make rapid, multiple sequential or simultaneous movements in response to obstacles; may have attention, concentration or perceptual impairments, or may be subject to excess daytime sleepiness related to medication.[4 5] In a mild form there may be little effect, but severe PD is potentially dangerous in a road user. At the same time, driving is often an essential component of continuing independence in later life, and barring individuals from driving may accelerate ageing, aggravate depression and restrict social interaction.[2 6 7]

Considerable efforts have been made to devise tools for the assessment of suitability to drive in PD, but there is no agreement on the best method and there is no gold standard.[8]

A MEDLINE search found no reports of a driving centre's experience of patients with PD using a combination of clinical examination, driving assessment and cognitive tests to assess driving skills. Most reports found were small studies, predominantly in volunteers.

Static driving rigs show that drivers with PD have increased reaction times, fail to react more often and make more errors than their peers,[9] but there are doubts as to whether such rigs are good predictors of driving ability.[10 11] No driving rig can recreate the complex interplay of sensory inputs, motor and cognitive function that is necessary in driving. A recent study found a lack of clinical correlates to driving[12] and the associated editorial highlighted the need for larger studies.[13] We report on our experiences of using a full driving assessment to assess suitability for driving in patients with PD. Our study is unique in that patients constitute a consecutive series of referrals to a driving assessment centre and we have devised a scoring system for in-car driving assessment. We also looked at possible car modifications that may help overcome impairments.

METHODS

The Scottish Driving Assessment Service (SDAS) provides an evaluation of the driving ability of people with medical conditions or disabilities referred by their general practitioner, hospital specialist or Driving and Vehicle Licensing Agency (DVLA). The records of patients with PD referred over a 15-year period (1989–2004) were examined. All assessments were made by a team consisting of a doctor and an occupational therapist. The majority of assessments were made by one of the authors (JH) and four different occupational therapists over a period of 15 years.

A full history and features of the disease were noted, including physical severity, duration, driving history and medication. Comorbidities were defined as diseases that could affect driving ability—for example, stroke or rheumatoid arthritis. The severity of physical disease was graded by the Hoehn and Yahr scale[14] (H&Y). As dementia is of particular concern in an elderly patient group, we analysed these data separately from other medical conditions. Cognitive assessment consisted of a Mini-mental State Examination,[15] road sign recognition, visuospatial construction (a cube copying subtest of a Rivermead Perceptual Battery), trailmaking test, forward and reverse digit span, and a story recall (for verbal memory). The assessment has been described before.[16] No one test was taken to be indicative of dementia, but it was decided by the team on the basis of the results of all the tests together. A static driving rig was used to measure reaction times for braking usually with the right foot, but, when required, alternative controls to utilise the best limb could be installed. The mean of 3–8 readings was taken.

An integral part of the assessment was to take the subject out in a dual control car with the assessor. After a short period in hospital grounds to get accustomed to the vehicle, the subject then took the car into the surrounding streets which afford a variety of driving challenges. This test is not a driving test as used to obtain a licence but focuses on road

Abbreviations: H&Y, Hoehn and Yahr; PD, Parkinson's disease

safety issues and takes up to 15 min. Driving performance was rated on 17 different parameters including physical control, response to other drivers, lane discipline, managing a roundabout, braking and merging with traffic, where 0 = satisfactory, 1 = doubtful and 2 = unsatisfactory. The range of scores is therefore 0–34. It is difficult to give a cut-off for an acceptable total score. Although any item score over 0 indicates less than optimal driving, a total score up to 5 may indicate only minor errors of judgement. However, making serious errors in just one critical area such as braking may be judged to be enough to preclude driving on its own. The driving assessor was not blind to the results of the previous clinical tests.

From a combination of the clinical tests, examination and driving assessment, the team made a decision regarding driving suitability, and this was the main outcome measure used. No single factor alone made this decision.

Using all the data gathered and the outcome measure of driving suitability, we analysed the possible predictors of driving suitability: age, driving history, duration of PD, stage of PD, medication, reaction time, score of in-car driving assessment, dementia and other medical conditions.

Initially the factors that may have influenced driving ability were compared individually with outcome using SPSS by means of either a χ^2 or a Mann–Whitney test for categorical and interval data, respectively.

All the above factors were then tested in a Stepwise Discriminant analysis to ascertain those factors that were most important in determining driving suitability. Three indicator or dummy variables were used to indicate the three stages for H&Y classification individually. Single indicator variables for other medical conditions and presence of dementia, and indicator variables for each level of the two-way interactions between H&Y stage, other medical condition, dementia and medication were included. It was therefore possible to ascertain those factors that were most important in determining driving outcome.

RESULTS

Demographics

Over the 15-year period, 154 patients were seen, of whom 92 (59.7%) were over 65 years old and 20 (13%) were women. Mean age was 67.6 years and mean length of driving history was 42.1 years.

In all, 17 (10.9%) patients stated that they had stopped driving by themselves before assessment as a precaution, and they underwent the same assessment as the others. The mean duration of PD was 5.9 years, and 10 individuals were referred within only 3 months of diagnosis. Mean Hoehn and Yahr stage was 1.9, with no patients in stage 4. The majority of the patients, 109 (70.8%), were taking levodopa with a peripheral dopa decarboxylase inhibitor (counted as one drug), 76 (49.3%) patients were taking more than one drug and 27 (17.3%) patients were not taking any drugs for PD. Three patients, none of whom could drive, reported dyskinesias as a complication of treatment. In all, 10 patients described motor fluctuations including the on–off phenomenon, 2 (20%) of whom improved after modification of treatment, and the remaining 5 (50%) were able to continue driving. No patients reported daytime sleepiness as a concern even on direct questioning.

Seventy-one (46.1%) patients had another significant condition defined as diseases that potentially affect their ability to drive, for example, rheumatoid arthritis, stroke.[17]

The majority of referrals were from general practitioners, but 12 (7.8%) referrals were from neurologists and geriatricians.

Results of driving assessment

Reaction times for emergency braking in the test rig were available for 135 patients and the mean (SD) time was 0.77 (0.25) s. The upper limit of acceptable reaction time is usually taken as 1 s and 16 patients had a time over 1 s.

On-road assessment scores were available for 118 individuals. The mean score for all subjects was 4.1 (out of 34), whereas 41 (34.7%) patients had a score >5.

On the basis of all the in-car, physical and cognitive assessments, the team judged that 50 of the 154 (32.5%) patients were unsuitable for driving because of concerns over road safety. Of the 104 patients who were suitable for driving, 46 were already driving or were advised to drive an automatic car. A further 10 (6.5%) patients were able to use car adaptations that allowed them to continue driving—for example, steering knob or hand-control braking. Two patients who wanted to maintain Class 2 licences were informed that they were not skilled enough for this, but were advised to contact the DVLA, who make decisions on Class 2 licences, which require more stringent criteria.

Predictors of poor outcome

Table 1 illustrates the differences between those judged suitable/unsuitable to drive.

Age, brake reaction time, disease severity, score on in-car assessment, duration of PD and medical comorbidities were significantly different between those with an adverse driving outcome and those who were able to drive. Length of driving history and medication for PD (>1 drug) showed no significant difference between the groups.

Further analysis of those suitable to drive showed that combining the presence of another medical condition with H&Y stage 2, provided a means of differentiating suitability between those with moderate disease (table 2). As subjects most difficult to assess fall into this moderate severity group, this provides an improved means of differentiating the ability to drive.

Stepwise discriminant analysis was used to ascertain which of the variables differentiated between suitability and unsuitability to drive using the 105 cases, with complete information for each variable. The most significant variables were Hand Y stage 3, score of in-car assessment, and H&Y stage 2, if associated with another medical condition and reaction time (table 3). Using only these variables, 92% of the patients could be correctly classified using cross-validation. Of those incorrectly classified, two patients who were suitable to drive were classified as unsuitable, both having H&Y stage 3 and 6 patients who were unsuitable were classified as suitable.

DISCUSSION

There are no reports in the literature of a driving assessment centre's experience with patients with PD. In part, this may be because there is no universally accepted gold standard to assess driving suitability. We have confirmed that a combination of a driving assessment and clinical testing can be an effective way of gauging driver safety. Our results show that the majority of patients with PD referred to a driving assessment service are capable of driving safely, and are contrary to previous reports[12] that a combination of clinical and in-car assessments and a test drive is an effective way of differentiating suitability for driving. Indeed, even among those found to be unsafe at assessment initially, 10 (20%) patients had modifications made to their cars to compensate for physical problems with controls and 3 (6%) patients were retrained by means of further courses of driving instruction. Patients with PD often have motor problems predominantly on one side. The less affected side can often be retrained to compensate for this and utilise appropriate modifications. Examples include a change to automatic car,

Table 1 Differences in groups suitable/not suitable for driving

Feature	Suited to drive(104) (%)	Not suited (50) (%)	Test statistic, p Value
H&Y Stage 1	57 (56)	2 (4)	$\chi^2=80$, df=2, p=0**
Stage 2	42 (40)	13 (26)	
Stage 3	5 (4)	35 (70)	
Age mean (SD) (years)	65.4 (9.7)	72.1 (9.3)	MW, z=−3.8, p=0**
Significant other medical condition	36 (35	35 (70)	$\chi^2=5.0$, df=1, p=0.026**
PD treatment (>1 drug)	49 (47)	27 (54)	$\chi^2=0.8$, df=1, p=0.43
Dementia present	4 (4)	18 (36)	$\chi^2=28.5$, df=1, p=0**
Mean (SD) reaction time (s)	0.68 (0.13), n=92	0.88 (0.34) n=43	MW, z=−5.3, p=0**
Mean (SD) duration of PD (years)	4.8 (3.9)	8.4 (5.1)	MW, z=−4.3, p=0**
In-car test score (score out of 34, SD)	1.7 (2.4) n=85	8.8 (5.5) n=33	MW, z=−7.4, p=0**
Driving history (years, SD)	41.4 (10.9)	44.6 (11.3)	MW, z=−0.8, p=0.07
On/off phenomenon	5 (5%)	5 (10%)	$\chi^2=1.49$, df=1, p=0.29

H&Y, Hoehn and Yahr.
**p<0.001

right-hand gear stick, left-foot accelerator and brake, steering wheel knob control and hand-controlled brakes. A degree of innovation and initiative is often useful; in one patient, tremors were reduced by keeping the foot dorsiflexed by means of a 5-cm wedge, and another overcame lack of head movements by placing extra mirrors to aid visual field and depth.

Not surprisingly, many patients were much better drivers in an automatic car, which reduces the number of motor act initiations required.

Some patients ease the burden of driving by only going short distances near their home so that the roads are familiar, or they avoid rush hour. This is a common tactic employed by ageing drivers who manage to continue driving in familiar surroundings but who would struggle to cope in a new environment.

Problems frequently encountered in patients with PD are often similar to those of the ''elderly driver'', and include inappropriate speed for the conditions, poor positioning at junctions and roundabouts, driving in the centre of the road, and a tendency to brake late and sharp. We have also noted the tendency of many patients with PD to drive slowly and extremely cautiously. Although much of this will be down to the ''test'' nature of the assessment, many spouses confirmed that their partners are indeed very cautious on the road. Hence, many patients with PD may compensate for their diminished motor performance by driving more slowly and carefully, although this cannot be tested. Other problems seen were difficulty in initiating movements, such as starting from stationary position and tremor affecting manoeuvring. Dyskinesia was seen rarely, as was the on/off phenomenon. Half of those with the on/off phenomenon who could predict the timing accurately were able to continue driving. Those with unpredictable timing were advised not to drive.

Recently, controversy has surrounded the phenomenon of daytime sleepiness in up to 22% of patients taking dopamine agonists.[4 5] However, none of our patients reported this even on direct questioning.

Table 2 Suitability to drive related to severity of Parkinson's disease and in subgroups with or without other medical comorbidities

	H&Y stage		
	1 (%)	2 (%)	3 (%)
All cases	59	55	40
Number suitable to drive (%)	57 (97)	42 (76)	5 (12)
PD plus another medical condition (% suitable to drive)	26/28 (93)	10/18 (56)	0/25 (0)
PD only (% suitable to drive)	31/31 (100)	32/37 (86)	5/15 (33)

H&Y, Hoehn and Yahr; PD, Parkinson's disease.

Analysis of the 47 patients considered unsafe to drive even after re-training and car modification revealed some interesting features. These individuals were older, had more severe physical disease (H&Y stage), slower reaction times, longer duration of PD and a higher incidence of other medical conditions (3.3 vs 2.1), especially dementia, compared with those fit to drive (table 1).

H&Y stage predicted the likelihood of driving for the most severe stage in our study. Previously, much smaller studies showed that H&Y[18] and Webster scale[19 20] did not correlate to driving ability but that the Unified Parkinson's Disease Rating Scale [9] did. Our results in a much larger, consecutive group suggests that even a simple staging tool successfully predicts driving skills, although the scale is too narrow to be used by itself in predicting the prospects for individual patients. Most uncertainty will occur in patients with moderate stage, and stepwise discriminant analysis found that combining the presence of another medical condition with moderate stage disease was a good predictor of ability. This would help differentiate between patients with moderate impairment, and is particularly true for dementia.

Our model suggests that the most important predictive features are H&Y stage 3, the patient car test score, H&Y stage 2 if associated with another medical condition and reaction time on a test rig. Very few cases were misclassified on this basis.

The main weaknesses of our study are that it is not prospective but is a review of cases. The outcome measure of driving suitability is a subjective decision, albeit one made by an experienced, multidisciplinary team on the basis of substantial information. This outcome is furthermore not independent of the predictor variables that are then assessed. The in-car assessor was not blinded to the clinical evaluation beforehand, so there will be some bias.

Previous studies looking at a combination of clinical/cognitive tests or a driving rig to assess safety have often been

Table 3 Factors best predicting driving suitability (stepwise discriminant)

Factor	F to remove at final step	Significance of F to remove	Wilks λ	Coefficient*
(correlation†)				
H&Y stage 3	40.5	0	0.404	0.7 (0.71)
Car test score	18.0	0	0.339	0.51 (.68)
H&Y stage 2 and other condition	11.6	0.005	0.321	0.32 (.55)
Reaction time to brake	11.2	0.008	0.320	0.31 (.45)

*Standardised canonical discriminant function coefficient.
†Pooled within-group correlations between the discriminating variables and standardised discriminant function.

small or based on a survey of volunteers. Furthermore, there is inconsistency in their findings. Reaction times in a simulator correlated well to performance on driving.[18–20] But neurologists' assessment overestimated patients' ability to drive, as did the patients' assessment of themselves.[19] Cognitive impairment was positively correlated in one study,[21] but not another.[22] In contrast with our findings, other smaller studies have found little link with clinical features and driving ability.[12 18]

In general, elderly drivers and those with dementia contribute little to road accidents.[23 24] Drivers with PD have been found to have a higher accident rate per mile travelled, especially those with severe disease,[21] and even patients considered to be taking optimal drug treatment made errors on assessment.[19] The progressive nature of PD and the variable response to treatment over time means that patients may need to be reassessed whenever the condition and the degree of motor impairment change.

The main weakness of all but one previous study is the small number of patients involved, and that study was based on a survey of volunteers.[21] We have looked at all 154 patients who have been referred to our service and therefore reflect driving assessment practice. However, this population may well have more severe physical disease, and we accept that this is not a representative sample of all PD. It is interesting that our figure of 32% unsuitable to drive is similar to the only other study of similar size.[21]

We feel that unsuitable drivers constitute a minority and we would dispute the suggestion that individuals with PD are often unsafe and are a risk on the road. We have found that most patients seen at a driving centre are in fact safe to drive. Those about whom there are initial reservations are often able to continue limited driving on familiar routes around their home or by means of vehicle modification.

Giving up driving prematurely will exacerbate the social ageing that many patients encounter. Up to 70% of patients with PD who have ever driven gave up because of PD.[25] We feel that we should actively encourage patients with PD to continue to drive for as long as it is safe to do so. The benefits received extend far beyond increased mobility, has the benefit of social inclusion, and enhances the sense of mental well-being and self-pride.

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RS is the author. BP corrected the manuscript and JH thought of the original idea for the project and also redrafted the manuscript. JH is the guarantor. FP helped with statistical analysis and advised on writing.

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