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DRIVING IN PARKINSON'S DISEASE

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Key Points

- Driving is impaired in the majority of patients with Parkinson's disease due to motor, cognitive, and visual dysfunction.
- Driving impairments in PD result in early driving cessation with loss of independence and may increase risk of crashes.

- Drivers with Parkinson's disease should undergo comprehensive evaluations to determine fitness to drive with periodic follow up evaluations as needed.
- Research in rehabilitation of driving and automation to maintain independence of patients with PD is in progress.

Synopsis

Driving is impaired in the majority of patients with Parkinson's disease due to motor, cognitive, and visual dysfunction. Driving impairments in PD result in early driving cessation with loss of independence and may increase risk of crashes. Drivers with Parkinson's disease should undergo comprehensive evaluations to determine fitness to drive with periodic follow up evaluations as needed. Research in rehabilitation of driving and automation to maintain independence of patients with PD is in progress.

DRIVING IN PARKINSON'S DISEASE

Parkinson's disease (PD) impairs driving due to motor, cognitive, and visual dysfunction. The aim of this review is to summarize the evidence on current driving assessment and rehabilitation practices for drivers with PD.

EPIDEMIOLOGY OF DRIVING ISSUES IN PD

The crash risk in PD is not well established.¹ A large survey from Germany indicated that 15% of drivers with PD were involved in car crashes within the last 5 years.² Despite reports of increased crash risk, especially in advanced stages of PD,³ epidemiological studies on older drivers^{4,5} and a recent meta-analysis⁶ showed that PD was not associated with higher risk of crashes, consistent with a prospective cohort study.⁷ Possible explanations include self-regulation using compensatory strategies (e.g. avoiding difficult situations) or early driving cessation.⁷

NEUROLOGICAL SUBSTRATES OF DRIVING ISSUES

Studies on brain activation patterns during driving simulation using functional magnetic resonance imaging or positron emission tomography revealed a network of active brain regions associated with vision, perception, visuomotor integration motor control, and executive functions. Different regions were activated based on the task and driving circumstances. Alcohol or distraction led to disturbances in the activations patterns of these networks that correlated with impairments of driving performance.⁸

PD pathology involves many regions in the brain, leading to multiple cognitive, visual, and motor impairments that can interfere with driving performance at different levels. For example, decreased decision making ability/executive dysfunction due to frontostriatal dysfunction can lead to poor strategic and tactical choices such as driving under challenging conditions and making risky maneuvers. Impairments in attention, visual perception, memory, executive functions, motor speed, and self-monitoring can lead to driver errors at operational level with difficulty in maintaining lane position and keeping a safe distance from other vehicles, and reacting to sudden hazards.⁸

NATURALISTIC STUDIES

Naturalistic studies are complementary to on-road and simulator studies. This approach examines the driving habits and behaviors of drivers in normal and critical situations. Self-regulation practices may also be observed. To date, only one naturalistic study has been conducted in drivers with PD to examine whether they show more restrictive patterns than age- and gender-matched controls.⁹ Participants were driving in their own vehicle. For two weeks, information regarding their driving was recorded with electronic devices such as distance traveled, duration and speed. Patients restricted their driving practices to a greater extent than controls. They drove significantly less overall, closer to home, less at night, and on days with bad weather. They adjusted their travel route by avoiding high-speed roads.⁹

SIMULATOR STUDIES

Driving simulators assess driving behavior in a controlled and reproducible environment. Patients with PD had increased reaction time, greater inaccuracy of steering, slower speed of movement,^{10,11} and more collisions than age-matched controls.¹² PD drivers had poorer vehicle control compared to controls under normal lighting conditions, but their ability deteriorated much further in low visibility setting (fog), and they had slower reactions and more collisions in response to an illegally incurring vehicle at an intersection.¹³ They approached traffic signals at a slower speed, with delayed deceleration,¹⁴ which suggest that they drove more cautiously than controls. They traveled slower around curves, with difficulties maintaining lane positions and difficulties stopping in time.¹⁴⁻¹⁶ The presence of a concurrent task while driving a simulator negatively impacted driving behavior of both healthy older individuals and patients.¹⁵ Tests of updating information in working memory and mental flexibility while driving a simulator showed specific impairments of executive functions in PD.¹⁷ In the updating task, patients with PD recalled fewer road signs than controls while driving, suggesting an updating impairment in mild to moderate stages of PD. These results on driving simulator were consistent with those obtained from the neuropsychological tests. Repeat testing of the same cohort two years after the initial assessment showed that patients with PD had a significant greater decline in cognitive flexibility than controls.¹⁸ Furthermore, significant decline in flexibility was associated with deterioration in their driving. Driving simulators may also be useful to predict fitness to drive decisions in patients with PD. In addition to a screening battery, scores on the driving simulator helped to better discriminate drivers who passed or failed a formal driving evaluation.¹⁹

ROAD STUDIES

Drivers with PD committed more driving errors on a standardized on-road driving test compared to control drivers, leading to higher fail rates.²⁰ The fail rate of drivers with PD

ranged between 30% and 56%, whereas the fail rate of control drivers ranged between 0% and 24%.^{21–28} Compared with controls, drivers with PD experienced more problems including the use of signals,^{29,30} pedals,³⁰ and steering wheel.^{29,30} As a result, drivers with PD had more difficulties maintaining lane.^{21,31,32} Drivers with PD also showed more difficulties adapting their speed to the traffic flow,^{27,29,32} and drove slower than controls.³³ These difficulties with speed adaptation particularly emerged when driving while distracted.³⁴ The most important driving performance predictors of failure in the road test were difficulties in turning left at intersections, lane maintenance at low speed, and speed adaptations at high speed.³⁵ Clinical predictors of failure were older age, higher motor impairment, postural instability/gait disorder subtype, and impaired visual acuity, scanning, information processing speed and attention,³⁵ and executive dysfunction, especially impaired updating and mental flexibility.²⁷ Furthermore, drivers with PD anticipated and responded less accurately to road signs,^{21,30,31} traffic lights,³⁰ other road users,²¹ and potentially dangerous road situations.²¹ Drivers with PD also exhibited difficulties navigating intersections,^{21,29,32} particularly at T-junctions.^{29,30} They also made more errors making left turns^{24,25,31} and right turns against traffic.²⁴ Drivers with PD had more difficulties negotiating roundabouts,²⁷ maintaining headway distance,²⁷ merging into traffic,^{24,25} and changing lanes.^{24,31,32} They checked their mirrors and blind spots less frequently,^{21,29,32} and identified less road signs and landmarks along a strip.³⁴ Additionally, drivers with PD were more likely to get lost in traffic while driving a memorized route.³³ A longitudinal cohort study showed that driving safety of patients with PD declined significantly steeper compared to controls although the patients who returned for repeat testing 2 years later had a similar performance to controls at baseline and had performed better than the PD drivers who did not return for repeat testing.³⁶

DRIVING REHABILITATION

Driving rehabilitation strategies include training underlying abilities (e.g., motor function, information processing speed, or executive functions) or focusing on driving skills. Research on training underlying abilities with driving as an outcome measure in PD is limited. However, driving simulator training has been investigated as a tool to retrain driving and related cognitive skills in several pilot studies in PD. The focus of simulator-based training programs is to expose drivers to different driving situations in dynamic and realistic conditions, aiming to improve the impaired driving skills, or lead to strategies that compensate for impaired driving skills.³⁷ The simulator training program follows the same principles of motor learning, in which a task-specific driving activity is trained repetitively and intensively. These driving scenarios can be tailored to the needs of the drivers and increase in difficulty to continue challenging the drivers throughout the training sessions. Immediate feedback can be

provided through video replay functions so that the drivers can actively participate in identifying their challenges and provide solutions to overcome these challenges.³⁷ A potential issue of simulator training is the simulator adaptation syndrome (SAS, similar to motion sickness) due to mismatch between the simulator's visual cues of movement and the subject's kinesthetic and vestibular cues of being stationary.³⁷

In the first pilot study,³⁸ drivers with PD completed training sessions in a driving simulator that mimicked multiple intersections of varying visibility and traffic load where an incurring vehicle posed a crash risk. After training, participants had fewer crashes and responded faster to the incurring vehicle. Yet, it is impossible to ascertain at this stage whether these improvements are the result of an actual training effect or rather familiarity with the simulated environment and scenarios. In a follow-up study by the same group, four drivers with PD who performed poorly on an on-road driving test completed sessions using the same scenarios reported before³⁸ as well as various scenarios on decision making, hazard perception and response behavior. All participants improved their performance on the simulator tasks after training. In addition, the majority of participants completed the on-road driving test with fewer errors.³⁹ In another pilot study, drivers with PD completed 10 hours of simulator training, individually customized according to their pre-training performance on specific on-road driving skills.⁴⁰ After training, participants performed better on a general test of cognitive functions and a test of visual scanning. Moreover, clinically relevant improvements in on-road driving were observed on individual level. The individuals who passed the road test prior to training passed at post-training as well. Few individuals who did not pass at pre-training, were cleared to drive after training.⁴⁰

POLICY ISSUES

There are currently no uniform legal criteria to guide individuals with PD and health care professionals on fitness-to-drive. Consensus statement by an Expert Panel Group involving the National Highway Traffic Administration and the American Occupational Therapy Association⁴¹ provided general recommendations on fitness-to-drive decision making according to PD disease severity. Individuals with low motor severity and no/few risk factors (e.g., age>75) are usually deemed fit to drive. A comprehensive baseline driving evaluation is recommended to establish baseline fitness-to-drive with annual follow-up driving evaluations. Retirement from driving is recommended for patients in an advanced motor stage and multiple risk factors. This advice should be conveyed to the driver and reporting to the driving license agencies should be considered according to the local jurisdiction. Continued consultation on transportation alternatives should be provided to patient and caregiver. For the at-risk group, i.e. those individuals with moderate symptoms of PD, comprehensive driving evaluations and planning for driving retirement should be continued. Research is still ongoing to identify the

best predictors that determine fitness-to-drive. Each patient should be evaluated individually using a comprehensive battery testing motor function, cognition, vision, and incorporating other non-motor aspects such as sleep, mood, and autonomic dysfunction.

FUTURE OF DRIVING IN PD

With population aging, the advances in autonomous vehicle technology offers promise for maintaining or improving safe transportation, mobility and quality of life. The International Society of Automotive Engineers (SAE International)⁴² and the National Highway Safety Administration (NHTSA)⁴³ define six levels of driving automation, ranging from no driving automation (level 0) to full driving automation (level 6). In all levels of automation other than full automation, the driver will need to drive the vehicle at least under some conditions. In the level 1, the vehicle has a single aspect of automation that assists the driver with Adaptive Driver Assistance Systems(ADAS). In level 2, the vehicle is able to automate certain parts of the driving experience with more than one ADAS aspect. The effect of ADAS on intersection behavior, speed, and headway control was compared in nine drivers with PD and nine controls. Both groups showed more confidence using ADAS after several training sessions. Drivers with PD had longer minimum time to collision (TTC) to crossing traffic and crossed less often with a critical TTC to oncoming traffic than older drivers.⁴⁴ In the speed and headway control experiment, the speedometer changed color when drivers exceeded the speed limit by more than 10% or 15%. Headway warnings showed up on the screen when drivers were following too close to the lead vehicle. Although ADAS improved outcomes in both groups, removing ADAS after short-term exposure led to deterioration of performance in all speed measures in the PD group.⁴⁵ To date, few studies in older adults investigated highest level of automation, such as the level 3 where the participant needs to take-over control of the vehicle.⁴⁶⁻⁴⁹ Future research should include different age group of older drivers including those with PD to investigate both their opinions regarding vehicle automation and their behavior during the transition phase between manual driving and automated driving.

CONCLUSION

Driving is impaired in majority of patients with PD and progressively worsens resulting in early driving cessation and possibly increased risk of crashes. While general guidelines on fitness to drive have been proposed, each patient should be evaluated individually with periodic follow up. Research on rehabilitation of driving skills in PD and automation of driving to maintain vehicular mobility is in progress.

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