Cognitive, On-road, and Simulator-based Driving Assessment after Stroke

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Driving is a complex activity that requires intact cognitive, behavioral, and motor function. Stroke is one of the most prevalent neurologic impairments and can affect all of these functions. However, diagnosis of stroke is not a definitive indicator of driving impairment. Determining fitness to drive after stroke is a very complex process and is typically based on cognitive assessments, on-road performance, simulator-based assessment, or a combination of the three. The aim of this review was to provide (1) a systematic review of the literature on cognitive, on-road, and simulator assessment after stroke, and (2) address the existing limitations and inconsistencies in stroke and driving research. Our results indicated that of 1413 total stroke patients, 748 definitively passed and 367 definitely failed an on-road assessment, with minimal information provided about clinical presentation. In addition, although the Stroke Driver Screening Assessment, the Useful Field of View Test, and the Rey-O Complex Figure test may have some utility in predicting driving performance, most cognitive measures have been inconsistently and minimally explored. Several limitations were observed across studies such as procedural inconsistencies, including outcome variables used (eg, driving cessation and pass/fail classification) and the heterogeneity of patient samples (eg, time since stroke and stroke location). Due, in part, to the larger variability in results of cognitive, on-road, and simulator-based assessment, there is no consensus regarding a valid and reliable driving assessment for physicians. Future studies should assess poststroke driving fitness by differentiating different stages, severities, and locations of stroke. **Key Words:** Stroke—driving—driving simulation—on-road—cognitive—assessment.

Introduction

Stroke is one of the leading causes of death and disability in North America.[1-3] More than two thirds of individuals exhibit some degree of cognitive impairment poststroke,[4-6] and with the aging of the population, the number of drivers and patients with stroke and cognitive impairment is expected to increase substantially.

Cognitive impairment is one of the major factors that influences driving performance. For many individuals, the ability to drive is an important source of independence and quality of life[7]; however, approximately 48% of stroke

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patients do not receive driving advice, and 87% do not have a formal assessment of driving ability.[8] The impairments associated with stroke, such as visual field defects, hemiplegia, impairments in visual-spatial ability, attention, and executive function,[1,4,5] may preclude individuals from driving poststroke. In cases where impairments are more subtle and may be compensated for by other cognitive–behavioral functions, determining fitness to drive is much more challenging. Evaluating driving fitness in patients with neurologic deficits, specifically those who have experienced a stroke, as well as addressing their needs and the safety of the community, has been a significant challenge for health professionals.[9]

Limited information is available in the literature regarding fitness to drive after stroke. There is a need for a driving assessment method with high reliability and validity that is able to accurately determine whether individuals poststroke are fit to drive or whether their licenses should be revoked or restricted. Our objective was to (1) provide a systematic review on the 3 most common methods of driving assessment (ie, cognitive, on-road, and simulator) after stroke and (2) address the current limitations and inconsistencies in stroke and driving research.

Methods

Search Strategy

Three reviewers (M.A.H., T.A.S., and G.S.) conducted a literature search of MEDLINE, EMBASE, and PsycInfo in July 2013. Computer searches based on keywords (both individuals and/or in combination) were conducted including the following: "stroke," "driving," "assessment," "performance," "road," "neuropsychological," and "simulator". References from previously retrieved articles were also searched. The search yielded 197 possible studies.

Study Selection

Peer-reviewed articles that were published within the past 15 years (January 1998-July 2013) and had used cognitive/neuropsychologic measures, on-road tests, and/or simulator technology to assess the driving performance of stroke patients were included. The following articles were excluded: (1) articles not relevant to driving and/or stroke (n = 113); (2) non-English publications (n = 6); (3) case/pilot studies (n = 6); (4) studies that used a method of assessment (eg, self-report and caregiver indices) other than cognitive tests, on-road evaluations, or simulator scenarios (n = 26); (5) review articles (n = 10); (6) editorials, commentaries, or replies (n = 5); (7) studies that compared cognitive assessments with cognitive assessments (n = 2); and (8) studies that pooled patient populations together (n = 13). Data were extracted to a form that included the following information: first author, year of publication, study population characteristics, driving assessment or fitness method, and results.

Results

The literature search yielded 22 articles that met inclusion criteria, of which 16 involved cognitive assessment, 17 involved on-road assessment, and 3 involved simulator assessment. In general, there was a high degree of heterogeneity of patients across and within studies in terms of stroke location, time since onset of stroke, stroke type, history of neurologic impairment, presence or absence of visual impairment, years of driving experience, and so forth (Table 1). For example, 82% of studies[10-27] (n = 18) reported the presence or absence of visual defects, such as visual field loss (eg, quadrantanopia and hemianopia) and neglect, in patient samples. Of the studies reporting quadrantanopia and/or hemianopia (n = 12), 58% excluded all patients presenting with these defects,[11,16,19,20,22,26,27] whereas 42% included patients who presented with these impairments and were deemed able to safely perform a driving evaluation[13-15,21,25] based on an expert assessment (eg, ophthalmologist). None of the studies that assessed individuals with visual impairment reported the outcome of these individuals on the driving assessment (eg, pass/fail classification, fitness to drive, and so forth).

Cognitive Assessment

Multiple studies attempted to determine which cognitive measures are predictive of the driving performance of stroke patients by correlating cognitive scores with on-road performance,[10-16,22,23,25,26,28,29] simulator performance,[30] or driving status[17,24] (Table 2).

Twelve studies have reported that cognitive tests are predictive of driving,[10-12,14,15,17,22-26,29] whereas 5 studies report little or no predictive value.[14,16,22,28,30] The Stroke Driving Screening Assessment (SDSA) was developed as a screening assessment for drivers poststroke and contains 4 tests: (1) Dot Cancellation Test, (2) Square Matrices Directions, (3) Square Matrices Compass, and (4) Road Sign Recognition Test (refer to Lincoln, Radford, & Nouri).[31] Results suggest that the SDSA is relatively successful in predicting pass/fail classification of an on-road evaluation ($P < .05$[10]; 78.9% agreement with the principal evaluator[13]; sensitivity, 71.4%[10]-79.3%[13]; specificity, 77.8%[10,13]), although further replication is required. Lundberg et al[11] and Selander et al[28] investigated the ability of the Nordic version of the SDSA to predict on-road performance. Results suggested that the Nordic version of the SDSA is not as accurate as the SDSA in predicting driving performance (Dot Cancellation, $P < .05$[11]; Directions, $P < .0001$[11]; Compass, $P < .0001$[11]; Road Sign Recognition, $P < .0001$[11]; sensitivity, 48%[28]; specificity, 76%[28]).