Driving After Stroke

Hannes Devos, Carol A. Hawley, Amber M. Conn,
Shawn C. Marshall, and Abiodun E. Akinwuntan

1 Introduction

From childhood to older ages, there remains a constant, societal fascination with driving. At each stage of life, the autonomy of a motor vehicle provides for independence, freedom and is even in many ways a symbol of success and vitality. Throughout the world, motor vehicles have been entrenched in our lifestyle, our communities, and even our entertainment. In 2013, across 180 countries, there were 947 million registered passenger cars and numbers continue to grow (World Health Organisation 2016). It is from this perspective that persons who have sustained a stroke often find that their inability to return to driving is a major barrier or disappointment along the road to recovery.

From the patient and family perspective, driving allows for independence in the community and the ability to leave the home. Driving is essentially a daily skill taken for granted where 87% of Americans over the age of 16 have a driver's license (Federal Highway Administration 2011). In the United Kingdom, there are 45.5 million licensed drivers representing 74% of the adult population (Driver and Vehicle Licensing Agency 2015). Contrarily, only 25% of the adult Chinese

H. Devos · A. M. Conn · A. E. Akinwuntan

School of Health Professions, University of Kansas Medical Center, Kansas City, KS, USA

e-mail: hdevos@kumc.edu; aakinwuntan@kumc.edu

C. A. Hawley (✉)

Mental Health and Wellbeing, Division of Health Sciences, Warwick Medical School,

University of Warwick, Coventry, UK

e-mail: C.A.Hawley@warwick.ac.uk

S. C. Marshall

University of Ottawa, Ottawa, ON, Canada

Ottawa Hospital Research Institute, Ottawa, ON, Canada

Bruyere Research Institute, Ottawa, ON, Canada

e-mail: smarshall@toh.ca

population have driver's licenses; however, this represents over 303 million drivers (National Bureau of Statistics 2016). From a clinical perspective, patients who have recovered from the effects of stroke will often ask about driving, or not recognize that driving ability could be affected. Inability to return to driving can have a negative impact on overall health in relation to isolation from community and resources (Waller 1991).

The role of jurisdictions is to keep roadways safe for all drivers. From an administrative perspective, there is an emphasis on public safety versus a focus on having individuals return to driving post-stroke. The evidence for increased crash risk post-stroke is inconclusive (Charlton et al. 2010; Devos et al. 2011). However, there is little doubt that ability to drive for many persons following stroke is clearly affected due to severe impairments that affect patients at an even more basic level of ability to provide self-care. Many countries have policies in relation to need for physician reporting and subsequent assessment prior to return to driving (Charlton et al. 2010). Administrative and financial barriers of paying for assessments are factors that may make it challenging for a patient post-stroke to return to driving.

From the perspective of the healthcare providers, there is often a balance between patient safety and autonomy that must be considered. While patients may want to return to driving post-stroke, there are clear impairments that can affect driving ability. Stroke impairments can be myriad, affecting everything from vision such as diplopia or visual field defects to motor impairments such as hemiparesis or ataxia as common examples. The less well-recognized impairments of visual neglect, cognition impairments, and even behavioral changes post-stroke can also have significant impact on driving ability. In this context, depending on the healthcare provider's jurisdiction, some states, provinces, and countries have reporting laws requiring physicians and other healthcare providers to identify persons who may be at risk to drive due to health reasons. This need to report can often have negative effects on the physician-patient relationship (Jang et al. 2007; Marshall and Gilbert 1999).

The impact of impairments from stroke on an individual can have significant implications for return to driving. This scenario is often counter to the more common scenario for physicians who may need to determine when health impacts for older drivers are at a point where driving cessation needs to be considered. Following stroke in most instances, patients are immediately unable to drive. Through recovery, they may reach a point where their abilities, while not fully recovered, may be at a stage where they are able to resume driving safely. Visual, physical, cognitive, and behavioral impairments post-stroke may all impact the ability to return to driving. It is often the healthcare provider who must make decisions if the patient has recovered enough to resume driving or be further assessed for their potential to return to driving.

While these health factors can affect the ability to drive, it is not only health that plays a role in the ability to return to driving. Using Michon's hierarchical model of driving (Fig. 1), driving can be broken down into stages each with inherent risks (Michon 1985). At the strategic level, drivers make general plans about their driving about destination, routes, identifying driving conditions such as weather and then

Fig. 1 Michon's hierarchical model of driving (Michon 1985). (Reproduced with permission)

formulating a plan. At this stage, the driver is accepting the risks associated with the driving task. The next level is the tactical level where the driver maneuvers in relation to the driving task and is essentially taking risk. For example, a driver exceeds the speed limit in inclement weather or performs maneuvers such as tailgating or aggressive passing. These actions may put the driver or others at increased risk of collision. In the final operational level of Michon's model, the driver is dealing with acute danger or risk and must take action to avoid a collision. The ability to avoid collision in this instance relies on factors such as reaction time, agility, and past experience of how to successfully control the vehicle in relation to actions such as steering and braking.

Often patients who have had a stroke have significant past driving experience; however, driving experience and ability are highly variable, and confidence may be high since driving is almost an overlearned and automatic task with most elements considered routine. For example, professional drivers or persons who have specialized driving training such as police or ambulance drivers would most likely have a higher skill set for driving compared to individuals who primarily use driving on a leisure or commuting basis. Many people are confident in their driving ability; however, as collision rates for young drivers demonstrate, experience and risk taking do play a role in driving risk (National Research Council US 2007).

Ultimately, return to driving post-stroke is seen by patient and family as both an indicator of recovery and an even more needed ability to compensate for newly reduced mobility. Clinicians typically are expected to advocate for return to driving but must do so responsibly for both the safety of the patient and the society. Many patients will be able to return to driving post-stroke, and the decisions faced by clinicians will be to determine when the patient has reached the ability to be considered for return to driving and what evaluations or rehabilitation interventions can be reliably used. The aim for both patient and healthcare provider is to have a safe return to driving, if possible, in the most expedient manner. The determination of this is critical for patient safety, autonomy, and health.

2 Evidence-Based Practice in Driving Screening, Assessment, and Interventions

A PubMed database search conducted on November 27, 2018 using the medical subject headings (MeSH) key terms “automobile driving” and “stroke” revealed 105 studies on driving after stroke. Research on this topic has seen an exponential increase in the last decade, with more than half (58) of the research articles being published since 2010. This growing body of evidence may assist healthcare professionals in the evidence-based practice (EBP) of assessing fitness-to-drive after stroke. EBP is a clinical decision-making process within a specific healthcare setting that integrates the best available scientific evidence with the best available clinical expertise from a multidisciplinary team of healthcare providers (Sackett et al. 1996). EBP considers internal and external influences on practice and encourages critical thinking in the judicious application of such evidence to the care of individual patients, a patient population, or a system (Newhouse et al. 2005).

In this section, we will provide an evidence-based overview of three critical issues related to driving after stroke: (1) screening; (2) assessment; and (3) interventions. Later, we will show how the evidence drives clinical decision-making for fitness-to-drive after stroke using an actual case scenario.

2.1 Screening for Fitness-to-Drive

The goal of a clinical screening tool is to identify individuals who meet the legal criteria for driving, but exhibit functional deficits that may adversely affect their fitness-to-drive. A fail performance on the screening battery warrants a more detailed assessment at a specialized driving clinic. The clinical utility of these screening tools depends on their efficacy in predicting on-road driving outcomes, the administration time, the ease of use, and the costs to purchase the tools. Although most screening tools lack face validity, some batteries have been developed particularly for fitness-to-drive screening after stroke. The Stroke Drivers Screening Assessment (SDSA) is one of such screening tools that was originally developed in the United Kingdom (Nouri and Lincoln 1993), but has successfully been adopted for use in other European countries (Selander et al. 2010; Lundberg et al. 2003), Australia (George and Crotty 2010), Israel (Lincoln et al. 2016), Korea (Park et al. 2013), and the United States (Akinwuntan et al. 2013). The SDSA consists of four subtests: (1) Dot Cancellation, (2) Directions, (3) Compass, and (4) Road Sign Recognition. A prediction equation algorithm that includes the results of each of the subtests shows the likelihood of passing or failing an on-road driving assessment (Selander et al. 2010; Lundberg et al. 2003; Nouri and Lincoln 1993; Akinwuntan et al. 2013; Park et al. 2013). However, these prediction equations suffer from methodological limitations such as subject and cultural bias and have rarely been validated in independent cohorts. No information is available on the prediction rates of the SDSA and other screening tools in developing countries.

One way to bypass these limitations is to pool all evidence on screening tools for fitness-to-drive after stroke. In our PubMed search, we identified four systematic reviews listing the most accurate screening tools for fitness-to-drive after stroke (Hird et al. 2014; Murie-fernandez et al. 2014; Devos et al. 2011; Marshall et al. 2007). None of the proposed screening tools are perfect in predicting on-road driving performance. Yet, four tests emerged from the systematic reviews to best predict the likelihood of failing an on-road driving assessment: (1) the Compass and (2) Road Sign Recognition tests of the SDSA; (3) the Trail Making Test (TMT) B; and (4) the Rey-Osterrieth Complex Figure (ROCF). Table 1 shows the psychometric properties, cutoff values, approximate administration time, training required, and approximate cost of these four tests. We also assigned the Oxford Centre for Evidence-Based Medicine—Levels of Evidence (OCEBM Levels of Evidence Working Group 2011) and Grades of Recommendation (Schünemann et al. 2013; Platz 2017) for each of the four tests. The description of the levels and quality of evidence and grades of recommendations is detailed in chapter “Clinical Pathways in Stroke Rehabilitation: Background, Scope, and Methods” (Chap. 2). The Compass, Road Sign Recognition, and Trail Making Test B showed acceptable sensitivity at the expense of specificity.

2.2 Assessment of Fitness-to-Drive

Compared to the screening process, an assessment of fitness-to-drive is a more formal, elaborate procedure that typically involves clinical (off-road) assessments of motor, cognitive, and visual abilities prior to a practical on-road driving test. The procedure for assessment of fitness-to-drive varies across countries depending on the legal framework, the licensing systems, and the resources available. Fitness-to-drive assessments take many shapes depending on location and include: medical tests, purpose-built driving assessment centers, clinical off-road and practical on-road comprehensive tests performed by driving assessors, healthcare workers, and/or driving licensing agencies. The driving-related functions commonly tested after stroke include: memory, attention, visuospatial perception, spatial neglect, sensory and motor functions, and vision (e.g., hemianopia). These assessments are usually conducted by physicians, psychologists, occupational therapists, or physical therapists with specialized training in fitness-to-drive assessments. Both the clinical off-road and on-road assessment protocols reported in the literature differ between studies, usually due to the country in which the study was conducted (Devos et al. 2011). Although there is still no commonly accepted standardized and validated battery to determine the fitness-to-drive of stroke survivors, many studies have identified some common cognitive, visual, and motor skills that predict performance on an on-road driving test (Ranchet et al. 2016; Devos et al. 2014; Aslaksen et al. 2013; Ponsford et al. 2008).

Apart from being the assessment used officially in countries around the world for licensing novice drivers, the on-road test is the only assessment that bears similarity and face validity to real-world driving. As such, the on-road assessment was used as

Table 1 Clinical utility of the screening tools^a

Tool	Reliability ^b	Validity ^c	OCEBM LOE	GOR	Cutoff score ^d	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Admin time	Training required	Equipment	Cost
Compass	$r_s = 0.73$ (Lincoln and Fanthome 1994)	ES = 1.06 (0.74–1.39) (Devos et al. 2011)	1a	B+	25	85% (74–93%)	54% (43–65%)	56% (50– 62%)	84% (74– 91%)	5 min	Minimal	Board and cards	\$200 ^e
Road Sign Recognition	$r_s = 0.67$ (Lincoln and Fanthome 1994)	ES = 1.22 (1.01–1.44) (Devos et al. 2011)	1a	B+	8.5	84% (72–92%)	54% (44–65%)	56% (50– 62%)	83% (73– 90%)	3 min	Minimal	Board and cards	\$200 ^e
Trail Making Test B	$r = 0.67$ (Tucker et al. 1981)	ES = 0.81 (0.48–1.15) (Devos et al. 2011)	1a	B+	90s	80% (66–90%)	62% (42–79%)	78% (69– 85%)	64% (49– 77%)	5 min	Minimal	Paper and pencil	\$50 for 100 copies
Rey- Osterrieth Complex Figure	ICC = 0.94 (Tupler et al. 1995)	ES = 0.80 (Akinwuntan et al. 2007)	1a	0	N/R	N/R	N/R	N/R	N/R	No time limit	Minimal	Paper and pencil	Free

CI confidence interval; ES effect size, calculated as the absolute difference in mean values on the test of interest between the pass and fail groups, divided by the pooled variance; GOR grades of recommendation; ICC intra-class coefficient; LOE levels of evidence; N/R not reported; NPV negative predictive value; OCEBM Oxford Centre for Evidence Based Medical scale; PPV positive predictive value; r Pearson correlation coefficient; r_s Spearman rho correlation

^aInformation was partly extracted from references Devos et al. (2011) and Burns et al. (2018)

^bTest–retest reliability

^cCriterion validity against on-road driving outcome

^dFrom Devos et al. (2011)

^eCost of the SDSA battery provided by publisher on 12/2017

the criterion for assessing driving performance in most studies reported on driving after stroke (Nouri and Lincoln 1993; Lundqvist et al. 2000; Akinwuntan et al. 2006). Yet, the use of the on-road assessment as the best indicator of fitness-to-drive of stroke survivors remains controversial. Some of the concerns include lack of repeatability of traffic events, reduced access to dual operated vehicle, the inability to assess driving ability during hazardous traffic situations or inclement weather conditions, the large variation in traffic demands and routes, different scoring systems, and low inter-rater reliability due to inconsistencies in judging the on-road driving performance by experts. These concerns prompted researchers to investigate the usefulness of novel assessment methods, including driving simulation technology, as indicators of the true driving capabilities of stroke survivors (Blane et al. 2017; Hird et al. 2015; Kobayashi et al. 2016; Park 2015). Many recent studies have reported on the use of driving simulators in the assessment of fitness-to-drive of stroke survivors (Akinwuntan and Devos 2017).

2.3 Interventions for Fitness-to-Drive

The body of literature on interventions to improve driving after stroke is sparse (George et al. 2014). The authors of this Cochrane review concluded that based on four randomized controlled trials and 245 participants, there was insufficient evidence that a driving rehabilitation program was effective in improving driving skills after stroke.

It is nevertheless reasonable to assume that any training is better than no training at all. Different methods of training can be categorized as (1) non-contextual training using paper and pencil, computerized-video or specialized equipment or (2) contextual training in a simulator or on the road. Hence, the related evidence will be summarized next.

2.3.1 Non-contextual Training

Non-contextual training is a remedial form of training that targets the visual, motor, and cognitive deficits underlying impaired on-road driving performance in stroke survivors. Although the benefits from the training program are purported to generalize to improvements in on-road driving performance, there is little evidence to support the claim.

Cognitive training using specialized equipment such as the Useful Field of View® (UFOV) or Dynavision® generally show benefits of training on on-road driving skills after stroke in non-randomized or pilot randomized controlled trials (RCTs) (Klavara and Warren 1998; Mazer et al. 2001). However, in the only RCT comparing the effect of 18 sessions of Dynavision® training ($n = 13$) with a non-active control group ($n = 13$), no differences in pass rates on the on-road test (77% vs. 46%; $p = 0.23$) were found after training (Crotty and George 2009). Although the study was likely underpowered due to the small sample size, a difference in pass percentages of 31% in favor of the Dynavision® training group appears clinically relevant. Likewise, Mazer et al. (2003)

compared 20 sessions of visual attention training using the UFOV training ($n = 47$) with traditional computerized visuoperceptual training ($n = 50$). Although no differences on on-road driving were found between the UFOV (39%) and control intervention (33%; $p = 0.53$), stroke survivors with right-sided lesions (52%) were almost twice more likely to pass the road test after UFOV training compared to those with left-sided lesions (29%) (Mazer et al. 2003).

In addition, cognitive skills that were specifically targeted in the intervention program show greater improvement compared to a control intervention. Crotty and George (2009) demonstrated a significant improvement in the Dynavision® group compared to the control group on visual neglect task ($p = 0.007$) and a response time task ($p = 0.03$; no measures of central tendency reported). Mazer et al. (2003) could not corroborate a differential effect of UFOV® training with other visuoperceptual training on any of the cognitive outcomes.

2.3.2 Contextual Training

With the advent of more realistic graphic images, higher fidelity of the driving simulator steering wheel and pedals, and the improving flexibility of interactive programming language, the use of driving simulators has sparked great interest in the scientific and clinical community to retrain driving-related skills after stroke. One RCT found that 15 h of training in a driving simulator was superior to a non-contextual training program that included paper-and-pencil route finding activities and board games in 73 stroke survivors. Participants who received simulator training were more likely to succeed on a formal on-road driving test at 3 months after training compared to those who received non-contextual training (73% versus 42%; $p = 0.03$) (Akinwuntan et al. 2005). The encouraging benefits of simulator training were confirmed in a more recent trial that compared 16 h of training in the driving simulator ($n = 23$) with no training ($n = 22$) (Mazer et al. 2015). Following completion of training, 6 out of 7 (86%) participants with moderate stroke-related deficits who were trained in the driving simulator passed an on-road test whereas only 1 out of 6 (17%) in the control group passed the same on-road test ($p = 0.03$, effect size = 0.63). However, there were no differences for those with severe impairments (Mazer et al. 2015).

It is logical to assume that training of driving skills on a real road, in a real car, in real traffic, will result in most generalization of benefits from training to driving performance in real traffic. In a small study that included 15 participants with stroke who initially failed an on-road test, 13 eventually passed the test after 6–12 h of on-road driving training. However, authors doubt if the on-road training program led to improvement in driving skills since there were no associated improvements in any visuo-cognitive functions. The authors surmised that the natural recovery of stroke, awareness of driving difficulties, or familiarization with the test process led to passing the driving test after the intervention program (Soderstrom et al. 2006).

3 Adaptive Driver Assistance Systems and Car Modifications

There is emerging research on the impact of Advanced Driver Assistive Systems (ADAS) for older adults with and without medical conditions (Shaheen and Niemeier 2001; Davidse 2006; Davidse et al. 2009). These studies show that some ADAS systems, including but not limited to—*lane departure warnings, lane keeping support, automated cruise control, collision avoidance systems, pedestrian crash avoidance mitigation, night vision systems, driver fatigue warning systems, turning assist, surround view, and traffic sign recognition*—could extend the older drivers' mobility and have the capacity to improve road safety. In a driving simulator study, Dotzauer et al. (2013) studied the effects of an intersection ADAS on driving in healthy older adults. Equipped with ADAS, drivers allocated more attention to the center of the road and crossed intersections in shorter time, but also engaged in higher speeds and accepted more risk in taking left turns against oncoming vehicles. To our knowledge, no studies have evaluated the use of ADAS to improve driving safety in drivers with stroke.

The other areas of technological aids for driving are disability vehicle adaptations that are used to maintain or improve the functional capabilities of an individual with disabilities. Common examples of this are a spinner steering driving knob which enables one-handed steering and a left-side accelerator that can assist someone with hemiparesis to resume driving of an automatic transmission vehicle.

4 Clinical Pathway

Rules for fitness-to-drive vary between countries, states, and provinces. It is important for healthcare providers to familiarize themselves with the specific licensing requirements and clinical guidelines for driving after stroke in their own locality. Figure 2 below offers a framework for driving assessment and intervention after mild stroke which is based on best evidence and practice.

Our review of evidence examined screening, assessment, and interventions. Based on this evidence, Fig. 3, along with the following broad-based recommendations, presents a clinical algorithm for fitness-to-drive to aid decision-making. The description of the levels and quality of evidence and grades of recommendations is detailed in chapter “Clinical Pathways in Stroke Rehabilitation: Background, Scope, and Methods” (Chap. 2).

1. Determine that the patient meets the jurisdiction's minimum requirement for driving (if any) (level of evidence/quality of evidence: not applicable (regulatory), A+).
2. If there are specific requirements for driving after stroke in the jurisdiction, refer to it and ensure the patient meets the requirements (level of evidence/

Fig. 2 Framework for driving assessment and intervention after stroke based on best evidence and practice. (Permission to use from Burns et al. 2018)

Fig. 3 Clinical decision rule for fitness-to-drive after stroke. (Permission to use from De Baets et al. (2018). Complex Case Management. Physical Management for Neurological Conditions)

quality of evidence: not applicable (regulatory), A+). Clinical guidelines for stroke and driving in several countries stipulate a preclusion period of 4 weeks post event (Austroads 2016; Canadian Medical Association 2017; Driver and Vehicle Licensing Agency 2018), although some countries mandate a driving ban up to 6 months after stroke (Devos et al. 2012).

3. If the patient does not meet one or more of the jurisdiction's prescribed requirements, the patient ought to be advised to allow more time for better recovery and/or discuss alternative transportation methods (level of evidence 5, quality of evidence very low, A+).
4. Red flags ought first to be assessed, i.e. risk of recurring stroke, risk of epileptic seizures or severe neglect, and others listed below (level of evidence 5, quality of evidence very low, A+). Red flags are usually exclusion criteria that preclude patients from driving legally. These vary between countries and jurisdictions. It should be noted that this is a non-exhaustive list and healthcare providers should consult medical guidelines for fitness-to-drive which apply locally.
 - (a) Uncontrolled medical status.
 - (b) Uncontrolled epilepsy.
 - (c) Severe neglect.
 - (d) Hemianopia that patients cannot compensate for.
 - (e) Marked cognitive or behavior impairment such as impulsivity, aggression, anosognosia and severe dementia.
5. Then, screening tools such as the ones presented in Table 1 should be used to determine patients whose functional deficit(s) is(are) reason(s) for concerns (level of evidence 1a, quality of evidence moderate, B+).
6. If the outcome of the screening shows concerns, the patient should be referred for a comprehensive fitness-to-drive assessment with a driving rehabilitation specialist, if available (level of evidence 1a, quality of evidence moderate, B+).
7. The off-road part of the fitness-to-drive assessment (e.g., Table 2) ought to include tests of monocular and binocular visual acuities and visual field; cognitive testing to ascertain general cognitive status also needs to be done; finally, basic motor testing of strength, coordination, and range of motion should be assessed. However, there is no consensus on the selection of tests to include in the assessment (level of evidence 5, quality of evidence very low, A+).
8. If the outcome of the off-road assessment shows some, but no serious concern, the patient should be referred for a practical on-road test (if available) to confirm the suitability to resume driving with or without restrictions (level of evidence 5, quality of evidence very low, B+). The driving assessment expert will determine if the patient has enough compensatory skill to be declared fit-to-drive with or without restrictions or fit-to-drive with vehicle aids or will benefit from driving-specific rehabilitation or unfit-to-drive. Not all countries use conditional licensing, and in these cases, driving may only resume if the patient is fit to drive.
9. If driving-specific rehabilitation is warranted, contextual training in a driving simulator is preferred for maximum generalization of benefit, although non-contextual training has also shown moderate benefit (level of evidence 1a, quality of evidence low (imprecision, inconsistency), B+). Retraining can also be offered in the form of lessons with a driving instructor in a dual controlled vehicle (level of evidence 4, quality of evidence very low, 0).

10. If the patient is found unfit to drive, alternative transportation methods should be discussed with the patient (level of evidence 5, quality of evidence very low, A+).

Table 2 Results of Mr. Smith's Driving Assessment (areas of concern are italicized in table)

Physical/sensory	
<i>Range of motion of the neck/torso</i>	<i>Reduced bilaterally, neck and torso</i>
Range of motion of the major joints of upper and lower limbs	110-degree shoulder level (left torn rotator cuff), 100-degree/ slightly reduced hip flexion bilaterally, reduced left ankle flexion. Within functional range for driving
Strength in limbs	4/5 left, 5/5 right
Cylindrical and pincer grip	Within functional range for driving
Balance with static sitting/ dynamic sitting, and static standing/ dynamic standing	Romberg negative: balance within functional range for driving
Barthel Index Score	95/100
Rapid Pace Walk test	7.1 s (>7.5 s = $2.5 \times$ risk, >9 s = $3 \times$ risk) (Mielenz et al. 2017)
Brake reaction test (using driving simulator)	3.57 s, inside of the corresponding age-based average normal value on the same task (Akinwuntan et al. 2009)
Other; coordination, vehicle transfers, proprioception, sensation, tremor, response speed, tone, pain	All normal
Visual assessment using a visual screening apparatus, no visual aids used with test.	
^a Far acuity, contrast sensitivity, glare recovery, ^a peripheral horizontal visual field	Satisfactory
<i>Stereopsis (depth)</i>	60%, Level 3, unsatisfactory
Cognitive/Perceptual	
SDSA	–
Dot cancellation	Time 721 s, 12 errors, 1 false positive
Directions	28/32
^b Compass	22/32 (cut off score is 25, Devos et al. 2011)
^b Road Sign Recognition	9/12 (cut of score is 8.5, Devos et al. 2011)
Prediction of pass or fail	Difference Value: + 0.951 pass (Akinwuntan et al. 2013)
Trail Making Test A	51 s (age-based norm value = 42 ± 15 s) (Tombaugh 2004)
^b Trail Making Test B	150 s (age-based norm value = 101 ± 44 s) (Tombaugh 2004)
^b Rey-Osterrieth Complex Figure (copy)	30/36 (age-based norm value = 31 ± 4) (Fastenau et al. 2010)
MoCA	25/30, lost 1 point for recall, 2 for attention, and 2 for visuospatial/executive (≤ 26 = possible impairment) (Nasreddine et al. 2005)
Maze test	Time seconds 38, risk category: safe risk (<60 s) (Barco et al. 2014)

Table 2 (continued)

Physical/sensory	
<i>Useful Field of View (UFOV)</i>	–
<i>Processing speed</i>	<i>14.8 ms suggestive of normal processing speed</i>
<i>Divided attention</i>	<i>258 ms suggesting some difficulty with divided attention</i>
<i>Selective attention</i>	<i>500 ms suggesting severe difficulty with selective attention</i>
<i>Category risk report</i>	<i>Risk category: moderate risk, 3 (Visual Awareness Research Group 2009)</i>
<i>Other; Insight, communication, endurance, praxis</i>	<i>Reduced insight into driving limitations</i>
On-road Practical Test	
Competencies	Demonstrated following competencies: pedal/steering control, follow distance, gap selection, lane position, mirror/indicator use, stop signs, signage, intersections, and road rule knowledge
Performance	Slow cautious driving performance, demonstrating problem-solving, and anticipatory responses. Overtook vehicles and blocked road obstacle in appropriate manner. Too slow at times and demonstrated some difficulties with parking
<i>Non-critical errors</i>	<i>2× driving too slow, driving 45 km/h in 60 km/h zone. Parking: Unable to turn adequately to check if clear for reversing of car; however used mirrors satisfactory Disoriented when trying to find exit point from carpark</i>
Critical errors	Nil observed

The tests used here are a select few of a multitude available
MOCA Montreal Cognitive Assessment, SDSA Stroke Drivers Screening Assessment
^aRegulatory standard
^bEvidence-based screening tools

5 Case Example: Mr. Smith’s Driving Assessment

A 75-year-old male sustained a right-hemispheric stroke lesion. Pre-stroke comorbidities included history of smoking, mild osteoarthritis of the spine, and hypertension. As per the hospital medical guidelines, Mr. Smith was advised not to drive for 1 month post event. In a follow-up visit with his neurologist, Mr. Smith was asked if he could resume driving; however, in that same visit, Mr. Smith’s wife expressed concerns about this. The neurologist conducted a clinical assessment that included physical, visual, and cognitive tests. His visual acuity was tested as within the visual driving standards of 6/12 (20/40) in both eyes, and a confrontation visual field test did not suggest any peripheral difficulties. Mr. Smith scored 25/30 on the Montreal Cognitive Assessment (MoCA) indicating impairment (≤ 26 cutoff) (Nasreddine et al. 2005). The neurologist determined that Mr. Smith has ongoing mild left-sided hemiparesis and executive and visuospatial issues. He was uncertain about Mr. Smith’s functional ability to drive, so referred him to a driving assessor for a fitness-to-drive determination.

Three weeks later, Mr. Smith underwent an off-road, clinical assessment and an on-road, practical assessment. The off-road clinical evaluation examines physical, visual, sensory, and cognitive abilities specific to driving and identifies any problem

skill areas for the on-road test to focus on. Prior to both assessments, Mr. Smith's demographic data, driving particulars, relevant medical history was obtained, and he reviewed and signed the informed consent and release of information form. His driver's license was valid and standard, he drove a medium-sized automatic transmission car, avoided busy traffic times, and had been driving about 16,000 km annually prior to stroke event. He reported no history of traffic violations or motor vehicle crashes in the past 5 years. His falls history was documented as falls in older adults is associated with significantly increased risk of subsequent crash risk (Scott et al. 2017).

A battery of off-road tests was administered and some of these results are outlined in Table 2.

The on-road practical test took place on a separate day with the same occupational therapist driving assessor in a dual operated car. The test took 50 min to complete and included a standardized route with a residential area, strip mall with pedestrian crossings, traffic light intersections, stop sign intersections, roundabout, change of lanes, left and right-hand turns, and a forward single space car park between two parked cars. A competency and error checklist were used to record Mr. Smith's performance and covered: gap selection, follow distance, lane position, brake reaction, indicator/mirror use, speed observance, parking, intersections, road rule knowledge, driver interventions, and critical and non-critical errors.

5.1 Interpretation of Results

Physically, client is generally within functional standards for driving task. Range of motion issues was detected related to neck and torso turns which affect ability to safely perform over shoulder checks and looking behind vehicle for reversing.

Client meets visual standards in terms of visual acuity. Mildly impaired depth perception apparent.

Satisfactory cognitive results in relation to, Trail Making Test A, Rey Osterrieth Complex Figure, Road Sign Recognition, overall pass value of the SDSA, and Snellgrove Maze test. The results of Trail Making Test B, MoCA, Compass, and UFOV (divided and selective attention) demonstrated mild-to-moderate impairments in areas of visuospatial, memory, planning, attention, problem-solving, task switching, and mental flexibility.

Mr. Smith performed well on the on-road practical car test, demonstrating safe skills. He experienced difficulties with parking and was unable to turn and safely check rearview when reversing car, however, demonstrated satisfactory use of his mirrors. Could not remember the entry/exit point of carpark. Client has an older vehicle with no reverse sensor or camera technology and already has a disability parking card.

Recommendations:

1. Due to issues with range of movement in neck and torso, depth perception, planning, problem-solving, memory, and reduced attentional ability, the following is recommended: local area restriction, automatic transmission, blind spot mirrors, and reverse sensors or reverse camera technology installed. Mr. Smith was pro-

vided with contact details for purchase of equipment and a mechanic to install the recommended equipment.

2. Mr. Smith is to be provided with 3–4 rehabilitation training sessions to educate him on driving with specialized mirrors and reversing technology and practice parking.
3. Contingent on successful completion of rehabilitation training sessions, the following driving recommendations are provided to Mr. Smith: automatic transmission only, 10-km radius restriction from place of residence, and installation of blind spot mirrors and reverse technology.¹
4. Reevaluation in 1 year or sooner if Mr. Smith's medical condition deteriorates or he experiences a secondary stroke.

Copies of the assessment report were sent to: Mr. Smith, Neurologist, and driving licensing agency (if appropriate).

6 Summary

The decision-making process of fitness-to-drive after stroke is multidisciplinary and complex. We recommend the use of evidence-based screening tools such as the Compass test, Road Sign Recognition Test, Trail Making Test B, and the Rey-Osterrieth Complex Figure to determine who should undergo a formal driving evaluation. A final decision on fitness-to-drive should be made after an on-road driving test, preferably complemented with a detailed battery of visual, motor, cognitive, and behavioral tests. If training is required, contextual training in a driving simulator may be more beneficial than non-contextual cognitive training.

References

- Akinwuntan AE, Devos H (2017) Simulated driving performance of stroke survivors. In: Classen S (ed) *Driving simulation for assessment, intervention, and training: a guide for occupational therapy and health care providers*. AOTA Press, Bethesda, pp 251–261
- Akinwuntan AE, De Weerd W, Feys H et al (2005) Effect of simulator training on driving after stroke: a randomized controlled trial. *Neurology* 65:843–850
- Akinwuntan AE, Feys H, De Weerd W et al (2006) Prediction of driving after stroke: a prospective study. *Neurorehabil Neural Repair* 20:417–423
- Akinwuntan AE, Devos H, Feys H et al (2007) Confirmation of the accuracy of a short battery to predict fitness-to-drive of stroke survivors without severe deficits. *J Rehabil Med* 39:698–702
- Akinwuntan AE, Tank R, Vaughn I et al (2009) Normative values for driving simulation parameters: a pilot study. In: *Proceedings of the fifth international driving symposium on human factors in driver assessment, training and vehicle design*. Public Policy Centre, Iowa, pp 161–168
- Akinwuntan AE, Gantt D, Gibson G et al (2013) United states version of the stroke driver screening assessment: a pilot study. *Top Stroke Rehabil* 20:87–92

¹If the country's system provides for license conditions or restrictions, then X radius restriction and vehicle aids and equipment would be valid items to add to driver's license.

- Aslaksen PM, Orbo M, Elvestad R et al (2013) Prediction of on-road driving ability after traumatic brain injury and stroke. *Eur J Neurol* 20:1227–1233
- Austroroads (2016) Assessing fitness to drive for commercial and private vehicle drivers: medical standards for licensing and clinical management guidelines. National Transport Commission, Sydney
- Barco PP, Wallendorf MJ, Snellgrove CA et al (2014) Predicting road test performance in drivers with stroke. *Am J Occup Ther* 68:221–229
- Blane A, Lee HC, Falkmer T et al (2017) Assessing cognitive ability and simulator-based driving performance in poststroke adults. *Behav Neurol* 2017(1378308):1–9. <https://doi.org/10.1155/2017/1378308>
- Burns SP, Schwartz JK, Scott SL et al (2018) Interdisciplinary approaches to facilitate return to driving and return to work in mild stroke: a position paper. *Arch Phys Med Rehabil* 99:2378–2388
- Canadian Medical Association (2017) CMA driver's guide: determining medical fitness to operate motor vehicles, 9th edn. Joule Inc., Ontario
- Charlton JL, Koppel S, Odell M et al (2010) Influence of chronic illness on crash involvement of motor vehicle drivers. Report nr 300, 2nd edn. Monash University Accident Research Centre, Victoria
- Crotty M, George S (2009) Retraining visual processing skills to improve driving ability after stroke. *Arch Phys Med Rehabil* 90:2096–3002
- Davidse R (2006) Older drivers and adas—which systems improve road safety? SWOV Institute for Road Safety Research, Hague
- Davidse RJ, Hagenzieker MP, van Wolfelaar P, Brouwer WH (2009) Effects of in-car support on mental workload and driving performance of older driver. *Hum Factors* 51:463–476
- De Baets L, Ashford S, Devos H et al (2018) Complex case management. In: Stokes E, Stack E (eds) *Physical management for neurological conditions*, 3rd edn. Elsevier, London
- Devos H, Akinwuntan A, Gelinas I, George S, Nieuwboer A, Verheyden G (2012). Shifting up a gear: considerations on assessment and rehabilitation of driving in people with neurological conditions. An extended editorial. *Physiotherapy Research International* 17:125–131
- Devos H, Akinwuntan AE, Nieuwboer A et al (2011) Screening for fitness to drive after stroke: a systematic review and meta-analysis. *Neurology* 76:747–756
- Devos H, Tant M, Akinwuntan AE (2014) On-road driving impairments and associated cognitive deficits after stroke. *Cerebrovasc Dis* 38:226–232
- Dotzauer M, Caljouw SR, de Waard D, Brouwer WH (2013) Intersection assistance: a safe solution for older drivers? *Accid Anal Prev* 59:522–528
- Driver and Vehicle Licensing Agency (2015) How many people hold driving licences in the UK, Swansea. <https://www.gov.uk/government/organisations/driver-and-vehicle-licensing-agency>. Accessed 3 May 2018
- Driver and Vehicle Licensing Agency (2018) Assessing fitness to drive: a guide for medical professionals. Swansea, UK
- Fastenau PS, Denburg NL, Hufford BJ (2010) Adult norms for the Rey-Osterrieth complex figure test and for supplemental recognition and matching trials from the extended complex figure test. *Clin Neuropsychol* 13:30–47
- Federal Highway Administration (2011) Our nation's highways 2011, Washington, DC. <https://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/>
- George S, Crotty M (2010) Establishing criterion validity of the useful field of view assessment and stroke drivers' screening assessment: comparison to the result of on-road assessment. *Am J Occup Ther* 64:114–122
- George S, Crotty M, Gelinas I et al (2014) Rehabilitation for improving automobile driving after stroke. *Cochrane Database Syst Rev* 2014(2):CD008357
- Hird MA, Vetivelu A, Saposnik G et al (2014) Cognitive, on-road, and simulator-based driving assessment after stroke. *J Stroke Cerebrovasc Dis* 23:2654–2670
- Hird MA, Vesely KA, Christie LE et al (2015) Is it safe to drive after acute mild stroke? A preliminary report. *J Neurol Sci* 354:46–50

- Jang W, Man-Son-Hing M, Molnar FJ et al (2007) Family physicians' attitudes and practices regarding assessments of medical fitness to drive in older persons. *J Gen Intern Med* 22:531–543
- Klavora P, Warren M (1998) Rehabilitation of visuomotor skills in poststroke patients using the dynavision apparatus. *Percept Mot Skills* 86:23–30
- Kobayashi Y, Omokute Y, Mitsuyama A et al (2016) Predictors of track test performance in drivers with stroke. *Turk Neurosurg* 27:530–536
- Lincoln NB, Fanthome Y (1994) Reliability of the stroke drivers screening assessment. *Clin Rehabil* 8:157–160
- Lincoln NB, Radford KA, Nouri FM (2016) Stroke drivers screening assessment—SDSA manual (hebrew version). <https://www.nottingham.ac.uk/medicine/documents/publishedassessments/sdsa-hebrew-translation.pdf>. Accessed 7 Dec 2017
- Lundberg C, Caneman G, Samuelsson SM et al (2003) The assessment of fitness to drive after a stroke: the nordic stroke driver screening assessment. *Scand J Psychol* 44:23–30
- Lundqvist A, Gerdle B, Rönnerberg J (2000) Neuropsychological aspects of driving after a stroke ± in the simulator and on the road. *Appl Cogn Psychol* 14:135–150
- Marshall SC, Gilbert N (1999) Saskatchewan physicians' attitudes and knowledge regarding assessment of medical fitness to drive. *CMAJ* 160:1701–1704
- Marshall SC, Molnar F, Man-son-hing M et al (2007) Predictors of driving ability following stroke: a systematic review. *Top Stroke Rehabil* 14:98–114
- Mazer BL, Sofer S, Korner-bitensky N (2001) Use of the UFOV to evaluate and retrain visual attention skills in clients with stroke: a pilot study. *Am J Occup Ther* 55:552–557
- Mazer BL, Sofer S, Korner-bitensky N (2003) Effectiveness of a visual attention retraining program on the driving performance of clients with stroke. *Arch Phys Med Rehabil* 84:541–550
- Mazer B, Gélinas I, Duquette J et al (2015) A randomized clinical trial to determine effectiveness of driving simulator retraining on the driving performance of clients with neurological impairment. *Br J Occup Ther* 78:369–376
- Michon J (1985) A critical view of driver behavior models: what do we know, what should we do? In: Evans L, Schwing RC (eds) *Human behaviour and traffic safety*. Springer, Boston, pp 485–524
- Mielenz TJ, Durbin IL, Cisewski JA et al (2017) Select physical performance measures and driving outcomes in older adults. *Inj Epidemiol* 4:14
- Murie-fernandez M, Iturralde S, Cenoz M (2014) Driving ability after a stroke: evaluation and recovery. *Neurologia* 29:161–167
- Nasreddine ZS, Phillips NA, Bedirian V et al (2005) The Montreal Cognitive Assessment, MOCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc* 53:695–699
- National Bureau of Statistics (2016) Number of registered drivers in china 2007–2016. <https://www.statista.com/statistics/278430/number-of-drivers-in-china/>. Accessed 7 Dec 2017
- National Research Council US (2007) Preventing teen motor crashes: contributions from the behavioural and social sciences. National Academies Press, Washington
- Newhouse R, Dearholt S, Poe S et al (2005) Evidence-based practice: a practical approach to implementation. *J Nurs Adm* 35:35–40
- Nouri M, Lincoln NB (1993) Predicting driving performance after stroke. *BMJ* 307:482–483
- OCEBM Levels of Evidence Working Group (2011). The Oxford 2011 levels of evidence. Oxford centre for evidence-based medicine. <http://www.cebm.net/index.aspx?o=5653>. Accessed 7 Feb 2018
- Park MO (2015) A comparison of driving errors in patients with left or right hemispheric lesions after stroke. *J Phys Ther Sci* 27:3469–3471
- Park M, Son J, Shin HK (2013) Development of the Korean stroke drivers screening assessment: a pilot study for adapting road sign recognition subtest. *Jpn J Ergon* 49:s463–s466
- Platz T (2017) Practice guidelines in neurorehabilitation. *Neurol Int Open* 01(03):E148–E152. <https://doi.org/10.1055/s-0043-103057>
- Ponsford AS, Viitanen M, Lundberg C et al (2008) Assessment of driving after stroke: a pluridisciplinary task. *Accid Anal Prev* 40:452–460

- Ranchet M, Akinwuntan AE, Tant M et al (2016) Fitness-to-drive agreements after stroke: medical versus practical recommendations. *Eur J Neurol* 23:1408–1414
- Sackett DL, Rosenberg WM, Gray JA et al (1996) Evidence based medicine: what it is and what it isn't. *BMJ* 312:71–72
- Schünemann H, Brożek J, Guyatt G, Oxman A (2013) GRADE handbook for grading quality of evidence and strength of recommendations. The GRADE Working Group. Updated October 2013. www.guidelinedevelopment.org/handbook
- Scott KA, Rogers E, Betz ME et al (2017) Associations between falls and driving outcomes in older adults: systematic review and meta-analysis. *J Am Geriatr Soc* 65:2596–2502
- Selander H, Johansson K, Lundberg C et al (2010) The Nordic stroke driver screening assessment as predictor for the outcome of an on-road test. *Scand J Occup Ther* 17:10–17
- Shaheen SA, Niemeier DA (2001) Integrating vehicle design and human factors: minimizing elderly driving constraints. *Transp Res Part C* 9:155–174
- Soderstrom ST, Pettersson RP, Leppert J (2006) Prediction of driving ability after stroke and the effect of behind-the-wheel training. *Scand J Psychol* 47:419–429
- Tombaugh TN (2004) Trail making test a and b: normative data stratified by age and education. *Arch Clin Neuropsychol* 19:203–214
- Tucker DM, Bigler ED, Chelune GJ (1981) Reliability of the Halstead-Reitan battery in individuals displaying acutely psychotic behavior. *J Behav Assess* 3:311–319
- Tupler IA, Welsh KA, Asare-Aboagye Y (1995) Reliability of the Rey-Osterrieth complex figure in use with memory-impaired patients. *J Clin Exp Neuropsychol* 17:566–579
- Visual Awareness Research Group (2009) UFOV User's guide, version 6.1.4. www.visualawareness.com/Pages/UFOV_Manual_V6.1.4.pdf
- Waller PF (1991) The older driver. *Hum Factors* 33:499–505
- World Health Organisation (2016) Statistics of drivers worldwide 2006–2015. Statista. <https://www.statista.com/topics/1197/car-drivers/>. Accessed 7 Dec 2017

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits any noncommercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if you modified the licensed material. You do not have permission under this license to share adapted material derived from this chapter or parts of it.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.