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REVIEW ARTICLE

Driving and Alzheimer's dementia or mild cognitive impairment: a systematic review of the existing guidelines emphasizing on the neurologist's role

Petros Stamatelos[1] · Alexandra Economou[2] · Leonidas Stefanis[1] · George Yannis[3] · Sokratis G. Papageorgiou[1]

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Abstract

Background Driving is a complex task requiring the integrity and the cooperation of cognition, motor, and somatosensory skills, all of which are impacted by neurological diseases.

Objective Identification of neurologist's role when assessing fitness to drive of cognitively impaired individuals.

Methods We performed a systematic review of the guidelines/recommendations (G/Rs) regarding the evaluation of driving fitness of patients with mild cognitive impairment (MCI) and/or dementia. Emphasis was put on the neurological and neuropsychological aspects of the evaluation.

Results Eighteen G/Rs were included in the review (9 national guidelines, 5 recommendation papers, 3 consensus statements, and 1 position paper). All G/Rs referred to drivers with dementia and 9/18 referred to drivers with MCI. A common approach among G/Rs is the initial trichotomization of patients in safe to drive, unsafe to drive, and undetermined cases, which are referred to a second-line evaluator. First-line evaluators are general practitioners in 10/18 G/Rs; second-line evaluators are neurologists in 7/18 G/Rs. Specific neuropsychological tests are proposed in 11/18 G/Rs and relative cut-off values in 7/18. The most commonly used tests are the MMSE, TMT, and CDT. A thorough neurological examination is proposed in only 1/18 G/R.

Conclusion Although extensive multi-disciplinary research has provided useful information for driving behavior of cognitively impaired individuals, we are still far from a widely accepted approach of driving ability evaluation in this increasing population. A comprehensive assessment from a multi-disciplinary team in which the neurologist plays a critical role seems to be required, although this has not yet been implemented in any G/Rs.

Keywords Alzheimer's disease · Mild cognitive impairment · Neuropsychology · Cognitive disorders and dementia · Driving guidelines · Neurologists

Introduction

Driving is a very complex task requiring the integrity and the cooperation of various functions [1]. These include cognition and behavior and motor and somatosensory skills, all of which are subject to neurological diseases [2]. The numerous methods proposed to evaluate an individual's fitness to drive [3–5] can be divided in two broad categories: (a) indirect methods, which evaluate the above-mentioned functions, which are considered to be necessary for safe driving and consequently indirectly evaluate driving capacity. These comprise neuropsychological [6, 7] and neuropsychiatric assessment [8] along with sensory and motor assessment [9, 10] and driving profile questionnaires [11, 12], and (b) direct methods, which directly evaluate driving capacity and

✉ Sokratis G. Papageorgiou
sokpapa@med.uoa.gr

1 1st Department of Neurology, National and Kapodistrian University of Athens, Eginition Hospital, 72 Vas. Sofias Ave, 11528 Athens, Greece

2 Department of Psychology, National and Kapodistrian University of Athens, Athens, Greece

3 School of Civil Engineering, Department of Transportation Planning and Engineering, National Technical University of Athens, Athens, Greece

include on-road tests [13, 14] and driving simulator tests [15, 16].

Nowadays, driving is an essential part of almost every person's life [17]. Especially for the elderly, it not only contributes to their everyday autonomy and quality of life, but it also boosts their self-esteem and their feeling of usefulness, for example, when they transport their grandchildren [18–20]. Driving cessation has been associated with adverse psychological effects, including social isolation and depressive symptomatology [17, 21, 22]. However, among the elderly drivers, quite a high percentage, up to 25%, suffers from cognitive impairment [23, 24]. This impairment may be mild, as in mild cognitive impairment (MCI) [25, 26], or serious, as in dementia, most commonly due to Alzheimer's disease (AD), interfering with instrumental activities of daily living [27, 28]. The driving ability of cognitively impaired patients is of great clinical and public health importance, and extensive research has been conducted in this field [29–34]. Beyond the cognitive [35, 36], and neuropsychiatric symptoms [37, 38], patients with MCI or AD often present motor symptoms [10, 39, 40]. Thus, a thorough and comprehensive evaluation is required to decide whether a patient suffering from MCI or mild dementia is capable to drive [41, 42].

Many countries acknowledge the need for an official evaluation of a demented person's driving ability and have proposed national guidelines and regulations [43–45]. In these guidelines, common patterns can be seen, such as the need for neuropsychological evaluation; frequent re-evaluation of driving fitness; and conditional driving licenses with certain restrictions, e.g., driving only during daylight or in prespecified familiar routes. Nevertheless, so far, no international consensus has been reached regarding the appropriate procedure needed to evaluate fitness to drive and the appropriate medical specialty responsible for this evaluation. Given the nature of the diseases (AD and MCI) and the parameters examined, which include cognition, behavior, and mobility, the evaluation is based on neurological and neuropsychological assessment. Therefore, neurologists should be well informed of the driving evaluation protocol in their country and should play a critical role in driving evaluations of these patient groups.

The aim of the current article is to identify the neurological aspects of fitness to drive evaluation among patients with AD or MCI. Thus, we critically review guidelines emphasizing on the neurologist's role.

Methods

We designed the present systematic review article adhering to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines [46], taking into account both the PRISMA checklist and the PRISMA flow diagram [47]. The search was initially applied to the US National Library of Medicine database (MEDLINE via Pubmed) using terms to identify cognitive impairment ("dementia" or "cognitive impairment" or "Alzheimer's" or "Mild Cognitive Impairment") in combination with terms referring to driving ("driving" or "automobile driving" or "motor vehicles" or "road safety") and guidelines ("guidelines" or "consensus" or "statement" or "recommendation"). Then, we broadened our search to Google Scholar, keeping the abovementioned search strategy. We did so in order to retrieve guidelines or consensus statements which may have not been published as scientific papers and thus may not be indexed in MEDLINE. Finally, we searched through the reference lists of the selected articles to identify articles meeting the inclusion criteria.

The articles included met the following criteria:

1) They were consensus statements, recommendation papers, official guidelines, articles reviewing the abovementioned guidelines or position papers, written by:

   i. A national committee or authority (e.g., Canadian Council of Motor Transport Administrators).
   ii. An international working group or a scientific society (e.g., American Academy of Neurology).
   iii. An expert on the subject "Driving and Cognitive Impairment".

2) The recommendations included referred to the following categories:

   i. Individuals with MCI.
   ii. ii) Individuals with AD or suffering from dementia not further specified.

3) Only recommendations referring to active drivers of private vehicles were included, that is, commercial vehicle drivers were excluded.

To keep our search up to date, the most recent edition of each recommendation paper was included if more than one edition had been published. Articles published before 2008 and articles with no full text in English were excluded from further analysis. Last literature update was made in June 2020.

Figure 1 shows the procedure to obtain studies meeting our inclusion criteria (as described in PRISMA flow

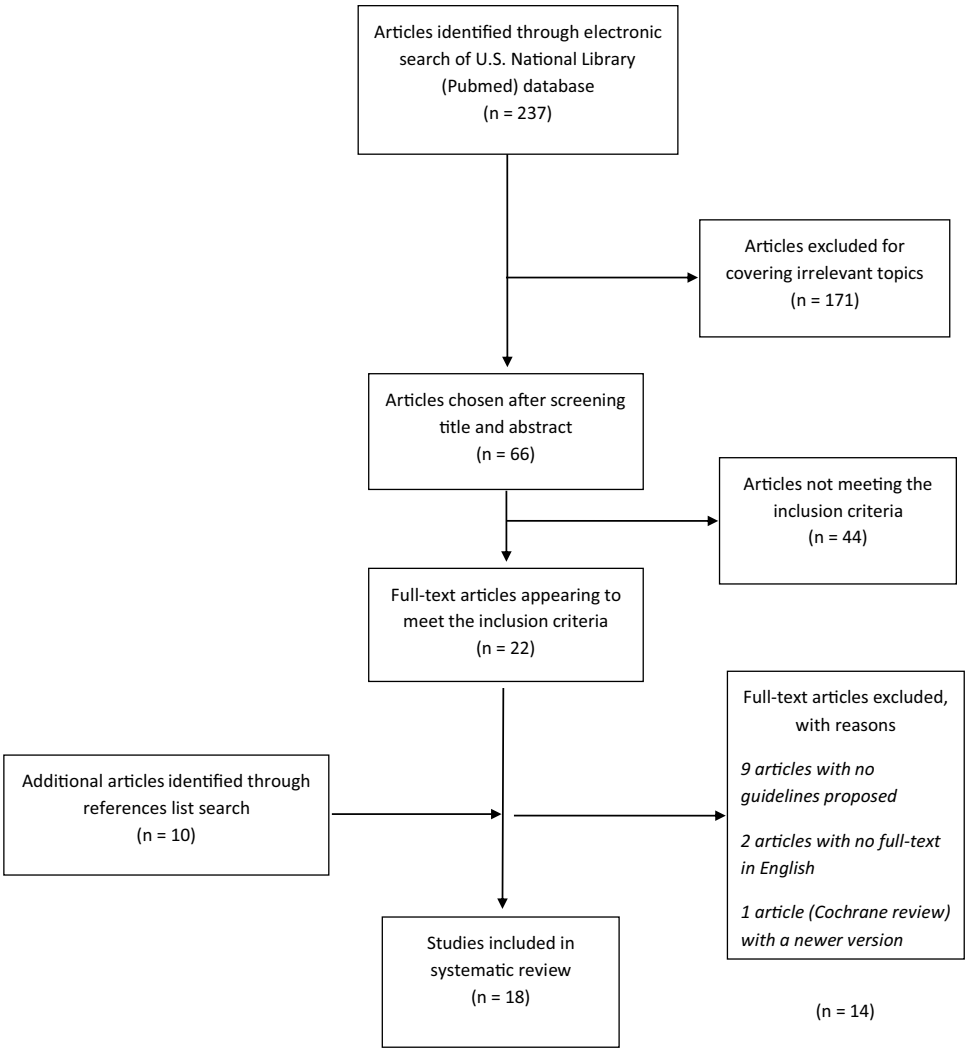

Fig. 1 The procedure to obtain studies meeting our inclusion criteria, based on PRISMA guidelines

diagram). Through our initial search, we identified 237 articles, and after screening the titles and abstracts, we excluded 171 of them as they referred to irrelevant topics. We obtained full text of the remaining 66 articles, and we excluded 44 of them because they did not meet the inclusion criteria. We thoroughly assessed the 22 remaining articles, keeping 8 and excluding 14 of them due to various reasons. After inclusion of 10 additional articles, which were identified through the references list search, 18 articles were finally included in our systematic review.

After collecting the articles meeting our criteria, we performed a critical review and evaluation of the selected articles so as to answer the following questions: (1) Who are the authors or the authority responsible for each study and what is the type of each study (e.g., national guidelines, consensus paper)? (2) Which is the proposed procedure to evaluate driving fitness and what are the professions of the proposed evaluators? (3) What are the neurological or neuropsychological components of the evaluation? With respect to the last question, we focused on whether there were any specific neuropsychological tests proposed and any relative cut-off values.

Results

Of the 18 articles that were included in our systematic review, nine (50%) were national guidelines from:

1. Australia [43] (Austroads and National Transport Commission, endorsed by Australian and New Zealand Association of Neurologists).
2. Belgium [44] (dementia experts and the Belgian Road Safety Institute, endorsed by the Belgian Medical Association).
3. Canada (one paper from the Canadian Medical Association [48]).
4. Canada (one paper from the Canadian Council of Motor Transport Administrators [49]).

5. Ireland [50] (National Office for Traffic Medicine, Royal College of Physicians of Ireland and Road Safety Authority).
6. New Zealand [51] (New Zealand Transport Agency).
7. UK [52] (Driver and Vehicle Licensing Agency with advice from Honorary Medical Advisory Panels).
8. USA (one paper from the American Medical Association[53]).
9. USA (one paper from the National Highway Traffic Safety Administration and the American Association of Motor Vehicle Administrators[54]).

We also included five recommendation papers (28%) [55–59], three consensus statements (17%) [60–62], and one position paper (5%) [63].

All articles (18/18, 100%) referred to drivers with dementia. Six of them (34%) referred to dementia due to AD [43, 44, 54, 55, 59, 61], whereas in twelve articles (66%), the cause of dementia was not further specified. Interestingly, only nine articles (50%) referred to drivers with MCI [44, 48–50, 52, 55, 57, 61, 62].

Description of the complete procedure of fitness to drive evaluation proposed in each article is beyond the goals of this paper. However, we need to highlight an approach which is proposed in eleven articles [43, 44, 48, 50, 51, 53–56, 58, 62] and seems to be the most commonly used approach in the literature [64]. According to this, patients are trichotomized by the initial evaluator in three groups: (a) safe to drive, (b) unsafe to drive, and (c) undetermined cases.

Patients of the first group need a regular follow-up of driving fitness, while those of the second group need no further assessment. Patients of the third group are referred to the second-line evaluator (as described below). In two more articles [49, 52], patients are referred to transportation authorities upon diagnosis to make a final decision about fitness to drive, while in five articles [57, 59–61, 63], driving evaluation procedure is not analyzed. The need of frequent reevaluation of safe-to-drive patients is recognized in thirteen articles [43, 44, 48–50, 52, 54–58, 60, 63] (72%), and the proposed interval until re-assessment ranges from 6 months to 1 year. Restricted or conditional licenses are recommended in five articles [43, 44, 50, 55, 61] for drivers with cognitive impairment. Limitations include driving in a restricted perimeter, driving only in daylight, prohibited driving in highways, prohibited driving big vehicles, and maximum permitted speed of 80 km/h. On the other hand, in four articles [48, 49, 54, 63] (31%), conditional licenses as well as driving with a co-pilot are not regarded as protective measures and thus are contraindicated for drivers with cognitive impairment. This discrepancy depicts the lack of consensus in the literature, putting the issue of conditional licenses into a gray zone.

The proposed initial (first-line) and second-line evaluators (for undetermined cases) are presented in Table 1 for each article.

As far as the neurological and neuropsychological assessment is concerned, the need of cognitive evaluation is unanimously recognized in all included articles (100%). Nevertheless, specific neuropsychological tests or scales are proposed in only eleven articles [23, 43, 44, 48, 49, 53, 55–58, 62] (55%).

Among the neuropsychological tests, the Mini Mental State Examination (MMSE) is the most commonly used test, as it is proposed in seven articles [44, 48, 49, 54, 55, 57, 58] (39%), followed by the Trail Making Test (TMT) in six articles [48, 49, 53–56] (33%), the Clock Drawing Test (CDT) in five articles [48, 49, 53, 55, 62] (28%), and the Montreal Cognitive Assessment (MOCA) in four articles [48, 55, 58, 62] (22%).

The following tests are proposed in only one article each: the Ruler Drop Reaction Time Test (RDRT) [56], the Useful Field Of View Test (UFOV), the Judgment of Line Orientation Test (JLO), the Block Design Test (BDT), the Benton Visual Retention Test (BVRT), the Complex Figure Test (CFT), and the Facial Recognition Test (FRT) [54] (5%).

Regarding the functional scales used, the Clinical Dementia Rating Scale (CDR) and the Instrumental Activities of Daily Living Scale (IADL) are proposed in three articles each ([54, 55, 57] and [55, 56, 60], respectively).

Cut-off values for the above-mentioned neuropsychological tests are proposed in only seven articles (38%). Cut-off values for the MMSE are proposed in four articles [44, 54, 57, 58] (22%), and a score below 25/30 is generally considered as an indicator of unsafe driving. Cut-off scores for the TMT [53, 56] and the CDT [53, 62] are proposed in two articles each (11%) and for the MOCA [62] and the RDRT [56] in one article each (5%). The above-mentioned findings are summarized and analyzed further in Table 2.

Concerns of caregivers or relatives during the interview about patient's fitness to drive are included in the assessment in nine articles [53–58, 60–62] (50%).

It is worth noting that a full neurological evaluation when assessing an individual's fitness to drive is proposed in only one article, written by the American Medical Association (AMA) [53]. AMA proposes a tool called "Assessment of Driving related Skills" (ADReS), which assesses not only cognition but also motor/somatosensory function and vision. In one more article, the history of falls in drivers with cognitive impairment is recognized as a possible risk factor for unsafe driving [54]. Evaluation of functions necessary for safe driving (motor, sensory, vision, hearing) is proposed in seven articles [43, 49–51, 56, 57, 62] (39%). However, these recommendations are quite general and refer to every driver regardless of the underlying medical condition.

Table 1 Main characteristics of the articles included in the systematic review, along with an overview of driving fitness evaluation procedure proposed in each article

Ref	Year	Type	Country (author)	Population	Initial evaluator	2nd line evaluator	Suggested follow-up	Suggested conditional licenses
[43]	2017	National guidelines	Australia (Austroads)	AD	GP	• → Dementia expert • → Driving assessment	12 m	Yes (area restriction)
[44]	2017	National guidelines	Belgium (Versijpt et al.)	MCI and AD	GP	• → Transportation authorities • → Driving assessment	6–12 m	Yes (area restriction/road type/circumstances)
[48]	2012	National guidelines	Canada (Canadian Medical Association)	MCI and dementia	GP	• → Dementia expert • → Driving assessment	6–12 m	Contraindicated
[49]	2017	National guidelines	Canada (Canadian Council of Motor Transport Administrators)	MCI and dementia	GP	• → Transportation authorities	6–12 m	Contraindicated
[50]	2017	National guidelines	Ireland (Road Safety Authority)	MCI and dementia	GP	• → Dementia expert • → Driving assessment	12 m	Yes (area restriction/vehicle type/circumstances/speed restriction)
[51]	2014	National guidelines	New Zealand (NZ Transport Agency)	Dementia	GP	• → Dementia expert	-	-
[52]	2018	National guidelines	UK (Driver and Vehicle Licensing Agency)	MCI and dementia	Physicians (not further specified)	• → Transportation authorities • → Driving assessment	12 m	-
[53]	2010	National guidelines	USA (American Medical Association)	Dementia	GP	• → Dementia expert • → Driving assessment	-	-
[54]	2009	National guidelines	U.S.A (American Association of Motor Vehicle Administrators)	AD	Neurologist	• → Dementia expert • → Driving assessment	6–12 m	Contraindicated
[55]	2017	Recommendation paper	Canada (Cameron et al.)	MCI and mild AD	GP	• → Transportation authorities	6–12 m	Yes
[56]	2009	Recommendation paper	Canada (Byszewski et al.)	Dementia	GP	• → Dementia expert • → Transportation authorities • → Driving assessment	6–12 m	-
[57]	2010	Recommendation paper	USA (Iverson et al.)	MCI and dementia	Physicians (not further specified)	-	6 m	-
[58]	2011	Recommendation paper	New Zealand (Hoggarth et al.)	Dementia	GP	• → Dementia expert • → Driving assessment	6 m	-
[59]	2013	Recommendation paper-Cochrane review	UK (Martin et al.)	AD	-	-	-	-
[60]	2018	Consensus paper	Canada (Rapoport et al.)	Dementia	-	-	6–12 m	-

Table 1 (Continued)

Ref	Year	Type	Country (author)	Population	Initial evaluator	2nd line evaluator	Suggested follow-up	Suggested conditional licenses
[61]	2014	Consensus paper	USA (Wheatley et al.)	MCI and AD	Occupational Therapists	-	-	Yes (area restriction/road type/circumstances)
[62]	2014	Consensus paper	Canada (Rapoport et al.)	MCI and dementia	Physicians not further specified	•→Transportation authorities •→Driving assessment	-	-
[63]	2010	Position statement	Australia and New Zealand (Australian and NZ Society for Geriatric Medicine)	Dementia	Geriatrician	-	6 m	Contraindicated

Discussion

This study aimed to make a systematic review of the existing guidelines/recommendations worldwide, regarding the evaluation of driving ability among patients with AD or MCI.

Our extensive review revealed a discrepancy between the great volume of research in the expanding field of assessing fitness to drive of patients with cognitive deficits and the small number of published guidelines/recommendations for this population. Although the extensive research uses a wide spectrum of methodologies such as driving simulator experiments and on-road tests, the existing published guidelines do not provide clear-cut indications for assessing driving abilities in everyday clinical practice. This is possibly due to methodological differences and inconclusive or inconsistent findings from the existing studies, which provide no clear-cut conclusions.

Eighteen articles met our inclusion criteria (Table 1) for guidelines/recommendations, coming from only seven countries which have published official guidelines. In these articles, the directives regarding the evaluation procedure and the recommended expertise of the evaluator of driving ability are highly heterogeneous. In addition, in two cases, published guidelines produced by certain National or International Scientific Working Groups [57, 58], are not further adopted in the official national guidelines [51, 53].

The concept of trichotomization of patients in three groups regarding their driving ability, safe to drive, unsafe to drive, and undetermined cases is a common pattern in 6 of the 18 articles of guidelines/recommendations (Fig. 2). The issue of the suggested initial evaluator remains controversial as GPs, occupational therapists, neurologists, and geriatricians are all found to be proposed as first-line evaluators across studies. Nevertheless, among them, GP is by far the most commonly encountered initial evaluator in guidelines/recommendations (10/18).

Neurologists are proposed in only one study as initial evaluators, whereas they are proposed as second-line evaluators in 40% of guidelines/recommendations, either alone or as members of a multi-disciplinary team.Concerning the utility of neuropsychological tests across the guidelines/recommendations, they are recommended in 11/18 publications. However, even in the publications where specific tests or scales are proposed, these recommendations are either empirical arbitrary or based on highly heterogeneous evidence, and relative cut-off values are frequently lacking. In addition, the neuropsychological tests proposed vary considerably (see Table 2) in 1/3 of the articles that include them. Thus, when assessing fitness to drive, no consensus has been reached either for the most appropriate neuropsychological tests or for the cut-off scores, even of the most commonly used tests, such as the MMSE and the TMT.

Table 2 Neuropsychological tests, functional scales, and cut-off values in the articles included in the systematic review

Test	Articles	Cut-off values	Based on: (references)
1. MMSE	Versijpt et al. 2017 [44]	< 19 = unsafe > 24 = safe 19–24 = 2nd line evaluation	[57, 73, 74]
	Cameron et al. 2017 [55]	-	[75–78]
	Iverson et al. 2010 [57]	< 24 = increased risk for unsafe driving	[75, 79, 80]
	American Association of Motor Vehicle Administrators 2009 [54]	< 17 = unsafe < 24 = increased risk for unsafe driving	[79, 80]
	Hoggarth et al. 2011 [58]	≤ 25 = increased risk for unsafe driving	-
	Canadian Medical Association 2012 [48]	-	[81]
	Canadian Council of Motor Transport Administrators 2017 [49]	-	-
2. TMT	Cameron et al. 2017 [55]	-	[13, 76, 82]
	Byszewski et al. 2009 [56]	TMT-A: > 2' or ≥ 2 errors = unsafe TMT-B: < 2' and < 2 errors = safe > 3' or ≥ 3 errors = unsafe 2–3' or 2 errors = unsure	-
	American Medical Association 2010 [53]	TMT-B: > 3' = unsafe	[83–86]
	American Association of Motor Vehicle Administrators [54]	-	[75, 80, 87–93]
	Canadian Medical Association 2012 [48]	-	[81]
	Canadian Council of Motor Transport Administrators [49]	-	-
3. CDT	Cameron et al. 2017 [55]	-	[13]
	American Medical Association 2010 [53]	Any abnormal element = 2nd line evaluation	[94, 95]
	Rapoport et al. 2013 [62]	Any abnormal element + caregiver concern = 2nd line evaluation	
	Canadian Medical Association 2012 [48]	-	[81]
	Canadian Council of Motor Transport Administrators [49]	-	-
4. MOCA	Cameron et al. 2017 [55]	-	-
	Rapoport et al. 2013 [62]	< 19 + caregiver concern = 2nd line evaluation	
	Hoggarth et al. 2011 [58]	-	
	Canadian Medical Association 2012 [48]	-	[81]
5. RDRT	Byszewski et al. 2009 [56]	6–9" = normal 2 failed trials = abnormal	-
6. UFOV, JLO, BDT, BVRT, CFT, FRT	American Association of Motor Vehicle Administrators [54]	-	UFOV [93] JLO [89, 96] BDT [89, 92] BVRT [88] CFT [92] FRT [92]
7. CDR	Iverson et al. 2010 [57]	-	[87, 97–99]
	Cameron et al. 2017[55]		[77]
	American Association of Motor Vehicle Administrators [54]	-	[87, 97, 98, 100]
8. IADL	Rapoport et al. 2018 [60]	-	-
	Cameron et al. 2017[55]	-	-
	Byszewski et al. 2009[56]	-	-

Last column contains the references for each test or scale from every included article

MMSE Mini Mental Status Examination, *TMT* Trail Making Test, *CDT* Clock Drawing Test, *MOCA* Montreal Cognitive Assessment Battery, *RDRT* ruler drop reaction time, *UFOV* useful field of view, *JLO* judgment of line orientation, *BDT* Block Design Test, *BVRT* Benton Visual Retention Test, *CFT* Complex Figure Test, *FRT* Facial Recognition Test, *CDR* clinical dementia rating, *IADL* instrumental activities of daily living

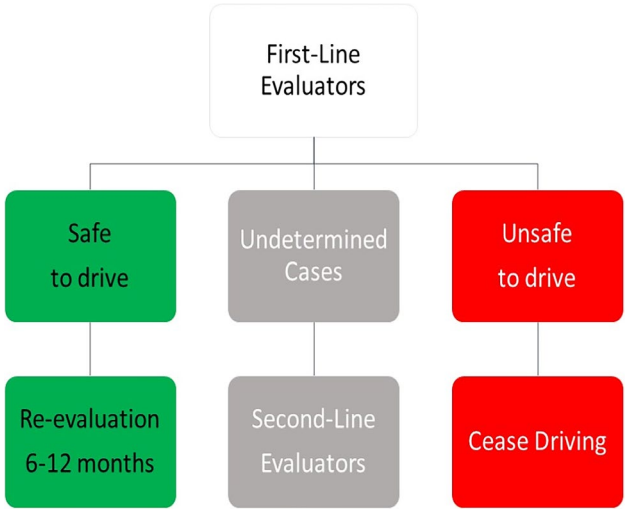

Fig. 2 The concept of trichotomization of patients regarding their driving fitness by the initial evaluator

Furthermore, we need to highlight the complete absence in all articles (except for the AMA guidelines [53]) of a thorough neurological examination, in terms of motor and somatosensory skills evaluation. While a brief examination may be adequate for healthy elderly drivers, it is obvious that a full neurological assessment is crucial when evaluating the driving ability of a patient with cognitive impairment. Cognitive and motor impairment often co-exist, either as a single clinical entity (AD, normal pressure hydrocephalus, Parkinson's disease, Lewy body dementia) or as a co-morbidity, especially among the elderly (degenerative arthritis, chronic heart failure, etc.) with more than one third of AD patients having also motor symptoms [65]). However, motor examination is neglected in memory clinics worldwide [66], and our review of guidelines/recommendations supports that finding, showing that neurological examination is neglected during the evaluation of driving fitness, as well.

Taking into consideration the progresses in the fields of cognitive neurology, neuropsychology, traffic science, and human factors psychology and the above-mentioned findings, a comprehensive assessment from a multi-disciplinary team in which the neurologist plays a critical role seems to be reasonable at the second level of assessment. However, our study depicts that this has not yet been implemented in the existing guidelines/recommendations. This multi-disciplinary team could consist of a GP [67], responsible for the various medical issues of the elderly other than those pertaining to dementia, e.g., vision or hearing impairment, heart problems; a transportation or occupational therapy expert [61], to address performance during an on-road or simulated driving test; a neuropsychologist [68], to perform and interpret neuropsychological tests relevant to driving fitness; and a neurologist [57, 69], responsible for evaluating motor-somatosensory skills, behavior, and cognition and integrating the results of the various assessments in a clinical judgment.

Thus, the "ideal" evaluation depends on each different situation. In the 1st level assessment, an initial general assessment, performed by the GP, followed by an assessment of key elements of safe driving, performed by the neurologist, may be sufficient in clear-cut cases. Nevertheless, this assessment must be based on (1) a complete neurological examination, (2) a short test of global cognition (e.g., MMSE, MoCA), (3) questioning the caregiver regarding patient's everyday functionality (e.g., using the IADL scale), and (4) an interview with the patient and the caregiver focusing on patient's driving status (history of crashes or near crashes during last year, worries about driving ability, etc.). If the 1st level assessment reveals abnormalities putting into question the driving ability, the patient should undergo 2nd level assessment including a comprehensive neuropsychological evaluation, mostly focused on executive and visuospatial functions. Tests that have been shown to be helpful in such cases include CDT, TMT-A and TMT-B, FAB, and JLO (Table 2). If there is still a doubt about driving fitness, a 3rd level assessment is warranted including either an on-road or a driving simulator test. Finally, it is important to note that even if fitness to drive is preserved, a re-assessment after 6 months is necessary for any patient with MCI or mild AD. This need for a frequent re-assessment is also evidenced by the high percentage of patients ceasing driving each year [25, 70].

An important issue that needs to be emphasized is the driving ability of patients with MCI. Despite their cognitive impairment, individuals with MCI remain relatively functional in their everyday life. However, many studies have shown that their driving ability is impaired, as even mild cognitive impairment may create difficulties with the complex and challenging task of driving [4, 11, 33, 37, 71]. Guidelines for drivers with MCI were included in only nine of the 18 articles. Most of them a priori approved MCI as a condition compatible with driving, provided that a more frequent re-assessment is performed in these patients. Nevertheless, recent knowledge coming from driving studies in this population has shown mild impairments in driving, suggesting that certain individualized restrictions could be applied in this at-risk population, such as, for example, driving at night-time and in highways [43, 44].

In conclusion, although extensive multi-disciplinary research has provided useful information for driving behavior of cognitively impaired older persons, we are still far from a widely accepted approach of driving ability evaluation in this increasing population [72].

Author contribution All authors contributed to the study conception and design. Data collection and analysis were performed by Petros Stamatelos and Sokratis G. Papageorgiou. The first draft of the manuscript was written by Petros Stamatelos, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval None.

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