6 Cognitive Evaluation in Patients with Vascular Cognitive Impairment

Jae-Sung Lim

6.1 Introduction

Cognitive function testing is divided into screening tests and comprehensive tests, depending on the objective. The former is intended for screening patients with a cognitive problem, usually consists of tests that can be performed within 5–15 min, and is used mainly in large-scale epidemiological research. The latter is a collection of individual tests used to examine for more subtle cognitive dysfunction or to evaluate for abnormalities within specific cognitive domains. Generally, two or more tests are performed for each cognitive domain.

6.1.1 Conduction of Neuropsychological Evaluation

Before looking at each test individually, let us first look at the common principles that need to be applied when conducting any test. Cognitive testing should be performed in an environment where the patient and the examiner can focus on the examination. In order to prevent interference by the caregiver, only the patient and the examiner should participate. Any necessary clinical information can be obtained from the caregiver before or after the evaluation. The examiner should create a comfortable atmosphere that allows the patient to follow the instructions and to fully focus on the neuropsychological tests. If proper evaluation of the patient is not possible due to physical problems such as a hearing difficulty or decreased visual acuity, then these physical barriers should be overcome with hearing aids or glasses. In addition, if you suspect that the test has been affected for any other reason than cognitive impairment during the test, it is necessary to specify this information so that there is no error when interpreting the results later.

In patients with post-stroke cognitive impairment, the timing of when tests are usually performed is between 1 month and 6 months after the index stroke in order to avoid the interfering effects of the acute stroke. Several cohorts, including CASPER, CogFAST, DEDEMAS, GRECOG-VASC, STRIDE, and STROKDEM, perform testing at the aforementioned times [1]. The Canadian Stroke Best Practices recommendations state that all stroke patients should be regularly screened for cognitive impairment, although when this should occur is not specified [2]. Screening tests for cognitive impairment in acute stroke in high risk groups have also been proposed. Taking the symptoms of patients with

J.-S. Lim (✉)
Department of Neurology, Hallym University Sacred Heart Hospital, Hallym Neurological Institute, Hallym University College of Medicine, Anyang-si, Gyeonggi-do, South Korea
e-mail: jaesunglim@hallym.ac.kr

S.-H. Lee, J.-S. Lim (eds.), *Stroke Revisited: Vascular Cognitive Impairment*, Stroke Revisited,
https://doi.org/10.1007/978-981-10-1433-8_6

neurological sequela, such as hemiparesis, into consideration, tests that can be conducted entirely verbally were designed, and their usefulness was reported on in several studies [3, 4].

6.1.2 Interpretation of Neuropsychological Evaluations

Interpretation of cognitive function tests involves the following four steps: (1) adjustment of cognitive score for demographic factors, (2) the type of score combination, (3) the statistical index used to determine a cutoff, and (4) the selection of the cutoff [5].

The abnormalities identified in a cognitive function test are interpreted by referring to the control study conducted in that language and region. As reported in a recent study, a single cutoff score is not universally applicable to all patients [6]. Depending on the age, sex, and level of education, patient abnormalities will vary, even if the patients receive the same score. With former diagnostic criteria, including the NINDS-AIREN criteria, the definition of cognitive impairment was not specified, and different cutoff values were applied at each institution, for example, a decrease by more than −1.5 or −2 standard deviation (SD) from the age- and educational level-adjusted mean. However, the recently published Diagnostic and Statistical Manual of Mental Disorders (DSM-5) and VasCog statements overcame the ambiguity of the diagnosis by specifying criteria for cognitive impairment. The NINDS-AIREN criteria and the AHA-ASA criteria, which were widely used in the past, defined cognitive impairment as a level of impairment that would interfere with daily life [7]. As reported in the DSM-5 recently, a major neurocognitive disorder is described as a decrease of below −2 SD in more than one cognitive domain, while mild neurocognitive disorder is defined as a decrease between −1 SD and −2 SD. The criteria for determining cognitive impairment was extended from −1.5 SD to −1 SD, enabling cognitive impairment to be detected early [7]. The VasCog statement specified the criteria for vascular dementia as a decrease of below −2 SD compared to the average in one or more cognitive domains [8]. However, the above criteria have been presented as a result of consensus by experts for application in general cases; it is necessary to carefully refer to the symptoms and signs of patients and information from caregivers to establish a proper diagnosis in the clinical field. Instead of applying the test scores unconditionally, the diagnosis should be made while considering the effects of the aforementioned environment, the patient's condition on the day of the examination, and any accompanying physical disability.

It is also necessary to use the appropriate testing tools according to the objective of the test, for example, whether it is for the purposes of a community epidemiological survey or for early detection purposes in a tertiary care center. For the purposes of community epidemiological surveys, screening tests that are relatively simple and sensitive in detecting abnormalities may be useful. These tests allow the examiner to determine whether further evaluation is required or whether the cognitive function over time is deteriorating or improving. In order to identify the exact differential diagnosis and specific cognitive decline in tertiary institutions, a more comprehensive cognitive function test should be performed, and, depending on the patient's symptomatology, more detailed and sensitive tests should be added to examine specific cognitive domains.

6.2 Neuropsychological Evaluation Tools

6.2.1 Mini-Mental State Examination (MMSE)

The most widely used screening test is the MMSE [9]. This is a test commonly used in patients with various neurodegenerative dementia diseases, including Alzheimer's disease, and has the advantage of being easy to use, easy to learn for examiners, and ample previous research to refer to. However, it is an examination which was originally designed to assess the cognitive function of

psychiatric patients and, as is well known, is somewhat inadequate in evaluating frontal lobe disorders or executive functions, as the main constituent questions of the MMSE are focused on orientation, memory, and language [10]. As a result, although a high sensitivity and specificity have been reported for diagnosing moderate dementia, a bias against identifying mild cognitive impairment (MCI) is detrimental in situations where an early diagnosis is important [11]. There are also an increasing number of centers that no longer use the MMSE due to copyright issues.

6.2.2 Montreal Cognitive Assessment (MoCA)

The MoCA was originally developed to screen for mild cognitive impairment [12]. It has advantages to supplementing the shortcomings of the MMSE when assessing frontal executive function by including the clock drawing test, modified trail making test, and verbal fluency test. Following the accumulation of many previous studies in patients with vascular cognitive impairment, the National Institute for Neurological Disorders and Stroke-Canadian Stroke Network (NINDS-CSN) vascular cognitive impairment harmonization standard (VCIHS) committee recognized the MoCA as part of the standard neuropsychological assessment when evaluating for VCI.[14] Previous studies have reported that the MoCA is useful for differentiating between normal and vascular cognitive impairment with no dementia (VCIND), as well as normal and vascular dementia [13]. Another advantage is that it can be used without needing permission, free of charge, and can be used for noncommercial purposes by any research or medical institutions (copyright Ziad Nasreddine, MD). On the other hand, the time required for the examination is longer than the MMSE at about 15 min, and the result is significantly influenced by the education level [13].

Several comparative studies that have been conducted up until recently report the MoCA to be superior to the MMSE and Addenbrooke's cognitive examination (to be described later) for identifying cognitive impairment [14]. In addition, the 5-min MoCA, which was proposed as a more abbreviated form of the test, was designed so it can be performed by only answering questions, with no need of drawing or moving a hand. Recent studies have shown that conducting a cognitive assessment telephonically using the 5-min MoCA is useful [15]. Given that many longitudinal clinical studies with cognitive function as a variable suffer from high dropout rates, specific tools that enable telephonic assessments will play an important role in overcoming attrition bias [16]. The MoCA also has the advantage of being widely used because it has been translated into different languages in various countries and has been studied to determine normal standards [17]. In addition, despite only being a screening test, the index score for each cognitive domain can be calculated so that the overall pattern of cognitive impairment can be understood in more detail [18].

6.2.3 Addenbrooke's Cognitive Examination-Revised (ACE-R)

Addenbrooke's Cognitive Examination-Revised (ACE-R) is a 100-point scale that includes the MMSE test and additional items that test for executive function and attention [19]. For this reason, ACE-R may also be a good alternative to evaluate the cognitive prognosis in stroke patients. In a recent study, the sensitivities and specificities of the MMSE, MoCA, and ACE-R for identifying MCI after 1 year of stroke were compared using the NINDS-CSN VCIHS protocol. In this study, the MoCA and ACE-R showed good results, but the MMSE failed to show useful results due to the ceiling effect [14].

6.2.4 Hasegawa's Dementia Screening-Revised

Hasegawa's Dementia Screening-Revised (HDS-R) was originally developed to screen for dementia [20]. It consists of a total of 30 points spread over the following items: orientation to age, time and place, repeating three words, serial subtraction

of 7s, repeating digits backward, delayed recall of three words, and recalling five objects and vegetables. It assigns more points to the memory tests than the MMSE and includes an item to evaluate frontal lobe function. An advantage of the HDS-R is that it can be used in the elderly who have limited physical ability, as it does not include tasks that require physical activity that are typically used for evaluating visuospatial constructional ability and execution function. However, it is currently mainly used in Asian countries.

6.2.5 Telephone Interview for Cognitive Status (TICS)

This is a phone-based cognitive assessment tool similar to the 5-min MoCA mentioned above. It consists of 11 test items, evaluates global cognitive function, and typically takes less than 10 min. TICS has been reported to have a good correlation with the MMSE score, [21] and recent studies also have shown good sensitivity and specificity in distinguishing multiple-domain and single-domain MCI from both the general population and stroke patients [22]. Although it has the advantage of tracking changes in cognitive function over time, it is required to check with the caregiver whether the environment is appropriate before the test is executed for accurate assessment. It is also important to note that when interpreting the test results, there are disadvantages to not being able to perform a test that requires physical activity, including visuo-executive items.

6.2.6 Comprehensive Neuropsychological Protocols

Patients with abnormal results obtained from using the screening tools described above will subsequently receive a more detailed assessment. In general, it is common to use two or more kinds of test tools to evaluate each cognitive domain, such as attention, memory, language, visuospatial function, praxis, executive function, and social cognition. The American Heart Association/American Stroke Association Vascular Cognitive Impairment criteria states a minimum of four cognitive domains should be evaluated, namely, executive/attention, memory, language, and visuospatial function, before diagnosis [23]. Various cognitive test tools have been developed in different countries and translated into numerous languages. These cognitive testing tools, used primarily in VCI patients, can be compared using the recent data from the international consortium STROKOG [24]. This is a consortium studying cognitive dysfunction after strokes, and the authors summarized which cognitive assessment tools were used in each of the participating cohorts. Owing to the participation of large VCI cohorts in this consortium, it reveals which tests are mainly being utilized in current clinical practice and research. The tests conducted in common for each cognitive domain are as follows: trail making test A, digit symbol coding, and digit span forward for attention/processing speed; verbal learning test, Rey complex figure test: recall, story recall for memory; Boston Naming Test, categorical verbal fluency, Token test for language; Rey complex figure test: copy, clock drawing for construction (visuospatial); and trail making test B, phonemic verbal fluency, digit span backward, Stroop test for executive function/abstract reasoning [1]. However, in some cases, the same test is categorized into different cognitive domains according to research groups, requiring caution in interpreting it.

The representative neuropsychology test battery used in clinical practice is the Vascular cognitive impairment harmonization standard-neuropsychological protocol (VCIHS-NP) proposed by the National Institute of Neurological disorders and Stroke-Canadian Stroke Network (NINDS-CSN). The VCIHS-NP was published in 2006 by Hachinski et al. after expert consensus, allowing the use of standard protocol as a way to accelerate the development of this field by making the studies comparable and integrating knowledge [3]. To date, many countries, including France, the UK, South Korea, and Hong Kong, have used this protocol to evaluate patients, and this has been reflected in their studies [14, 24–26]. A list of specific tests can

be found by referring to Table 6.1. The VCIHS-NP was composed with the intention to obtain as much information as possible using well-validated tests, while improving clinical efficiency by using as few tests as possible. For example, asking the patient to generate a list of words from a category provides information on language, activation, processing speed, set shifting, working memory, and executive control. This single short test could evaluate function encompassing multiple cognitive domains and was included in the protocol [3, 27]. In contrast, more detailed tests assessing for semantics and syntax such as Pyramids, the Palm Trees Test, the Token Test, and various tests for evaluating apraxia were not included in the standard protocol but are recommended to be performed if necessary [3].

Table 6.1 Vascular cognitive impairment harmonization standards-neuropsychological protocol

5-min protocol
MoCA subtests
5-word memory task (registration, recall, recognition)
6-item orientation
1-letter phonemic fluency
30-min test protocol
Semantic fluency (animal naming)
Phonemic fluency (Controlled oral Word Association Test)
Digit symbol coding from the Wechsler Adult Intelligence Scale, Third edition
Hopkins Verbal Learning Test
Center for Epidemiologic Studies-Depression Scale
Neuropsychiatric Inventory-Questionnaire Version (NPI-Q)
Supplemental: MMSE, trail making test
60-min test protocol
Executive/activation
Animal naming (semantic fluency)
Controlled Oral Word Association Test
WAIS-III digit symbol coding
Trail making test
List learning test strategies
Future use: simple and choice reaction time
Language/lexical retrieval
Boston Naming Test 2nd Edition, Short Form
Visuospatial
Rey-Osterrieth complex figure copy
Supplemental: complex figure memory
Memory
Hopkins Verbal Learning Test-Revised
Alternate: California Verbal Learning Test-2
Supplemental: Boston Naming Test Recognition
Supplemental: digit symbol coding incidental learning
Neuropsychiatric/depressive symptoms
Neuropsychiatric Inventory-Questionnaire Version
Center for Epidemiological Studies-Depression Scale
Other
Informant Questionnaire for Cognitive Decline in the Elderly, Short Form
MMSE

Revised under the permission of Stroke [3]

In the VCIHS-NP, a 60-min, 30-min, and 5-min protocol were put forward, with the length of the protocol used depending on the purpose. The 60-min protocol is the standard protocol described above. The 30-min protocol consists of some tests of the 60-min protocol, which includes the following tests: semantic and phonemic fluency, digit symbol coding and the revised Hopkins Verbal Learning Test, the Center for Epidemiologic Studies Depression (CES-D) scale, and the Neuropsychiatric Inventory-Questionnaire Version (NPI-Q). The 5-min protocol is designed to be used by primary care physicians, nurses, and other allied health professionals in the office or at the bedside. It is also designed for use in large-scale epidemiological studies or clinical trials and should be easy to apply while also remaining sensitive to identifying cognitive abnormalities. In addition, the 5-min protocol allows all elements of the test to be conducted verbally, which makes it suitable for use over the phone. Among the subtests of the MoCA, the five-word immediate and delayed memory test, six-item orientation task, and one-letter phonemic fluency (the letter F) test are included. In order to supplement the shortcomings of the 5-min protocol, additional items such as the cube and clock drawing task, three-time picture naming task, and short "Trail B" test can be performed, and the original trail making test can be done if necessary. If the MMSE is also required, it is recommended to be performed on another day or at least 1 h after the VCINP 5-min protocol [3].

Furthermore, the Informant Questionnaire for Cognitive Decline in the Elderly (IQCODE) to identify the premorbid cognitive decline [28],

the Geriatric Depression Scale to screen for depression, and the Neuropsychiatric Inventory-Questionnaire Version (NPI-Q) to evaluate behavioral symptoms [29] are also performed together with the standard protocol. Please refer to Hachinski's original *Stroke* paper as to why each test was included and what additional suggestions are there [3].

6.3 Neuropsychological Construct in Patients with Vascular Cognitive Impairment

VCI patients are characterized by a decrease in frontal function, including processing speed, early in the disease process. In a recent study, 404 stroke patients were tested with the VCIHS-NP 6 months after the index stroke, with processing speed and executive function showing the most pronounced decline −1.32 ± 1.36 and −1.29 ± 1.34 z-scores, respectively, followed by a decline in the language domain of −0.87 ± 1.38, and lastly a deterioration in long-term memory and visuo-constructional abilities of −0.50 ± 1.38 and −0.47 ± 1.51 [30]. However, the patterns of these cognitive disorders may vary depending on the location of the lesion. Several cognitive and behavioral syndromes, including various forms of apraxia and disconnection syndrome, have been revealed through studying stroke patients. While the evaluation methods for each cognitive and behavioral syndrome are beyond the scope of this chapter, these symptoms are often difficult to identify properly unless the examiner understands the lesion's characteristics and does a thorough and extensive evaluation.

On the other hand, "behavioral and psychological symptoms of dementia (BPSD)" are also easy to overlook. It has been reported that patients with VCI are more likely to have behavioral symptoms such as depression, anxiety, and aggression, beginning at the early stages of the disease. Therefore, tools are needed to properly assess these symptoms. The most commonly performed NPI-Q is scoring the severity of the symptoms and distress felt by the caregiver, centering around 12 neurobehavioral symptoms frequently observed in patients. The 12 neurobehavioral symptoms are as follows: delusions, hallucinations, agitation/aggression, depression/dysphoria, anxiety, elation/euphoria, apathy/indifference, disinhibition, irritability/lability, motor disturbance, nighttime behaviors, and change in appetite/eating.

The characteristics of these neuropsychological symptoms may vary according to ethnicity or the nature of the underlying vascular disease. Recently, related research has been carried out by the STROKOG consortium, and it is expected to be able to identify the differences in the patterns of cognitive impairment according to ethnicity. Furthermore, we will be able to confirm the differences in cognitive impairment according to the features of the vascular disease (e.g., the cerebral microbleed burden or the presence of cerebral amyloid angiopathy) from various cohorts such as CASPER, CogFAST, DEDEMAS, GRECOG-VASC, STRIDE, and STROKDEM mentioned above.

6.4 Longitudinal Neuropsychological Evaluations

Identification of longitudinal changes in cognitive function is important for the differentiation of the underlying disease processes and prediction of prognosis. Important factors in the assessment are how actively we track and monitor the cognitive function of the patient in question and how appropriately we interpret these results from a time perspective. Levine's results show that the cognitive function changes before and after the index stroke [31]. In terms of global cognition and verbal memory, there is an acute decline compared to the pre-stroke slope followed by an accelerated rate of decline, whereas processing speed also worsens at an accelerated rate but without an acute decline. The global cognitive function after stroke, expressed using the Clinical Dementia Rating-Sum of Boxes (CDR-SB), also varies with time after 3 months, 1 year, and 2 years [32]. Therefore, it is necessary to approach post-stroke cognitive assessments with this point in mind, since it may show different results

depending on when and what evaluation tool is used.

Patients with VCI are often lost to follow-up due to concomitant physical disability and recurrence of vascular events. Recently, Pendlebury et al. shared these difficulties of cognitive study through a series of papers [16]. These papers suggest that it is important to proactively evaluate the prognosis of cognitive function through various methods, i.e., by conducting cognitive evaluation tests via the telephone and confirming progression to dementia using medical records.

Another element is to properly analyze the time-varying data obtained. As the subject grows older (e.g., ages 79–80), the criteria for different age groups are applied to deriving the standard scores (from the norm category of 75–79 to the category of 80–84), which may significantly change the standard scores. In addition, in some cases, each cognitive domain may show different longitudinal progressions. The pattern that begins with frontal dysfunction and subsequently decreases the memory or visuospatial function may be the effect of a neurodegenerative process, such as superimposed Alzheimer's disease or dementia with Lewy bodies. Furthermore, a test that is designed to mainly evaluate one cognitive domain may not only evaluate the domain in question but also related domains, so it is necessary to pay attention when interpreting the results. In the case of memory testing, frontal function is involved in encoding the word list and in the retrieval process. Indeed, considering the interaction that occurs among these cognitive domains, we have found that the results of the analysis vary according to the statistical methods used [33].

Recently, in the area of Alzheimer's disease, the repeated failure of clinical drug trials has raised the question of the suitability of the cognitive assessment to determine treatment effect. A new index, Alzheimer's Diseases Composite Score (ADCOMS) incorporating the two MMSE items and all six CDR-SB items into the four Alzheimer's Disease Assessment Scale-cognitive subscale items, which was used as the outcome variable in previous studies, has been developed and applied to clinical drug trials [34]. Despite these efforts, however, critics point out that the basic assumptions underpinning the current view of dementia drug development are wrong. By analogy, it is said that improving symptoms of diabetic polyneuropathy cannot be the endpoint for deciding on the success of an antidiabetic drug, rather it should be to identify changes in the HbA1c. In other words, although cognitive function is the most important indicator of brain function, we cannot confidently say that it accurately reflects the effects of the therapeutic drug, namely, slowing or halting of the disease process. The US Food and Drug Administration (FDA) understands these concerns and has sought alternatives for evaluating therapeutic effects using surrogate markers such as imaging biomarkers. However, this issue needs further discussion by researchers, the pharmaceutical industry, and health authorities.

Vascular cognitive impairment also shares the same problem as Alzheimer's disease in the absence of an effective treatment. In many clinical trials up to now, various tests have been used as outcome variables and as a result have failed to show significant therapeutic effects. The MMSE and Cognitive Abilities Screening Instrument (CASI) were used in the PROFESS and SPS3 clinical trials to confirm the cognitive protective effect of antithrombotic agents [35, 36]. In clinical trials testing the effects of some antihypertensive agents, diabetic agents, and statins, specific frontal function subtests such as a digit symbol substitution test were used as outcome variables. However, cognitive decline in both the treatment and control groups was not observed as much as expected in the above clinical trials. While there may be an issue with the eligibility criteria, the tool itself used to assess cognitive function may not have been sufficiently sensitive. New indicators are needed to overcome these shortcomings and to more sensitively reflect the changes in cognitive function.

6.5 Future of Neuropsychological Evaluations

Recently, advancements in various technologies have led to the development of numerous forms of cognitive function evaluation. There is a

computerized test that has been designed to track a patient's eyes when performing the trail making test, for use in patients who cannot use their arms due to paralysis [37]. In addition, many tests have been computerized to exceed the limits of conventional paper assessments. Computerized cognitive assessment tools are being developed to evaluate cognitive function not only by implementing existing techniques with a keyboard, mouse, and tablet but also in completely different forms. Some research groups used the Internet of Things (IoT) and virtual reality (VR) to simulate specific situations that the subjects will experience in their daily life in a virtual reality and quantify them to derive cognitive domain scores [38, 39]. Some commercial programs, such as Lumosity and CogniFit, offer a variety of computerized interfaces to assess cognitive function and also strengthen cognitive function in symptom-free healthy subjects. Although not replacing conventional classical paper testing in the near future, human cognition surrogates using computerized cognitive testing, the IoT, and VR in a variety of areas will be applied at the frontline and in research environments.

Acknowledgment This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (Ministry of Science and ICT) (No.2017R1C1B5018132).

References

1. Sachdev PS, Lo JW, Crawford JD, et al. STROKOG (stroke and cognition consortium): an international consortium to examine the epidemiology, diagnosis, and treatment of neurocognitive disorders in relation to cerebrovascular disease. Alzheimers Dement (Amst). 2017;7:11–23.
2. Eskes GA, Lanctot KL, Herrmann N, et al. Canadian stroke best practice recommendations: mood, cognition and fatigue following stroke practice guidelines, update 2015. Int J Stroke. 2015;10(7):1130–40.
3. Hachinski V, Iadecola C, Petersen RC, et al. National Institute of Neurological Disorders and Stroke-Canadian Stroke Network vascular cognitive impairment harmonization standards. Stroke. 2006;37(9):2220–41.
4. Lim JS, Oh MS, Lee JH, et al. Prediction of post-stroke dementia using NINDS-CSN 5-minute neuropsychology protocol in acute stroke. Int Psychogeriatr. 2017;29(5):777–84.
5. Godefroy O, Gibbons L, Diouf M, et al. Validation of an integrated method for determining cognitive ability: implications for routine assessments and clinical trials. Cortex. 2014;54:51–62. Epub 2014/03/19
6. Wong A, Law LS, Liu W, et al. Montreal cognitive assessment: one cutoff never fits all. Stroke. 2015;46(12):3547–50.
7. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders: Diagnostic and Statistical Manual of Mental Disorders, 5th ed. Arlington, VA: American Psychiatric Association, 2013.
8. Sachdev P, Kalaria R, O'Brien J, et al. Diagnostic criteria for vascular cognitive disorders: a VASCOG statement. Alzheimer Dis Assoc Disord. 2014;28(3):206–18.
9. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975;12(3):189–98.
10. Wind AW, Schellevis FG, Van Staveren G, et al. Limitations of the Mini-Mental State Examination in diagnosing dementia in general practice. Int J Geriatr Psychiatry. 1997;12(1):101–8.
11. Tombaugh TN, McIntyre NJ. The mini-mental state examination: a comprehensive review. J Am Geriatr Soc. 1992;40(9):922–35.
12. Nasreddine ZS, Phillips NA, Bedirian V, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005;53(4):695–9.
13. Kang Y, Park J, Yu KH, et al. A reliability, validity, and normative study of the Korean-Montreal Cognitive Assessment (K-MoCA) as an instrument for screening of vascular cognitive impairment. Korean J Clin Psychol. 2009;28(2):549–62.
14. Pendlebury ST, Mariz J, Bull L, et al. MoCA, ACE-R, and MMSE versus the National Institute of Neurological Disorders and Stroke-Canadian Stroke Network Vascular Cognitive Impairment Harmonization Standards Neuropsychological Battery after TIA and stroke. Stroke. 2012;43(2):464–9.
15. Wong A, Nyenhuis D, Black SE, et al. Montreal Cognitive Assessment 5-minute protocol is a brief, valid, reliable, and feasible cognitive screen for telephone administration. Stroke. 2015;46(4):1059–64.
16. Pendlebury ST, Chen PJ, Welch SJ, et al. Methodological factors in determining risk of dementia after transient ischemic attack and stroke: (II) effect of attrition on follow-up. Stroke. 2015;46(6):1494–500.
17. Koski L. Validity and applications of the Montreal cognitive assessment for the assessment of vascular cognitive impairment. Cerebrovasc Dis. 2013;36(1):6–18.
18. Julayanont P, Brousseau M, Chertkow H, et al. Montreal Cognitive Assessment Memory Index Score (MoCA-MIS) as a predictor of conversion from mild

cognitive impairment to Alzheimer's disease. J Am Geriatr Soc. 2014;62(4):679–84.
19. Mioshi E, Dawson K, Mitchell J, et al. The Addenbrooke's Cognitive Examination Revised (ACE-R): a brief cognitive test battery for dementia screening. Int J Geriatr Psychiatry. 2006;21(11):1078–85.
20. Imai Y, Hasegawa K. The revised Hasegawa's Dementia Scale (HDS-R): evaluation of its usefulness as a screening test for dementia. J Hong Kong Coll Psychiatr. 1994;4:20–4.
21. Jarvenpaa T, Rinne JO, Raiha I, et al. Characteristics of two telephone screens for cognitive impairment. Dement Geriatr Cogn Disord. 2002;13(3):149–55.
22. Barber M, Stott DJ. Validity of the Telephone Interview for Cognitive Status (TICS) in post-stroke subjects. Int J Geriatr Psychiatry. 2004;19(1):75–9.
23. Gorelick PB, Scuteri A, Black SE, et al. Vascular contributions to cognitive impairment and dementia: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2011;42(9):2672–713.
24. Chen X, Wong A, Ye R, et al. Validation of NINDS-CSN neuropsychological battery for vascular cognitive impairment in Chinese stroke patients. BMC Neurol. 2015;15:20.
25. Godefroy O, Leclercq C, Roussel M, et al. French adaptation of the vascular cognitive impairment harmonization standards: the GRECOG-VASC study. Int J Stroke. 2012;7(4):362–3.
26. Yu KH, Cho SJ, Oh MS, et al. Cognitive impairment evaluated with Vascular Cognitive Impairment Harmonization Standards in a multicenter prospective stroke cohort in Korea. Stroke. 2013;44(3):786–8.
27. Dichgans M, Leys D. Vascular cognitive impairment. Circ Res. 2017;120(3):573–91.
28. Jorm AF. A short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE): development and cross-validation. Psychol Med. 1994;24(1):145–53.
29. Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res. 1982;17(1):37–49.
30. Barbay M, Taillia H, Nedelec-Ciceri C, et al. Prevalence of poststroke neurocognitive disorders using National Institute of Neurological Disorders and Stroke-Canadian Stroke Network, VASCOG criteria (vascular behavioral and cognitive disorders), and optimized criteria of cognitive deficit. Stroke. 2018;49(5):1141–7.
31. Levine DA, Galecki AT, Langa KM, et al. Trajectory of cognitive decline after incident stroke. JAMA. 2015;314(1):41–51.
32. del Ser T, Barba R, Morin MM, et al. Evolution of cognitive impairment after stroke and risk factors for delayed progression. Stroke. 2005;36(12):2670–5.
33. Lim JS, Noh M, Kim BJ, et al. A methodological perspective on the longitudinal cognitive change after stroke. Dement Geriatr Cogn Disord. 2017;44(5–6):311–9.
34. Wang J, Logovinsky V, Hendrix SB, et al. ADCOMS: a composite clinical outcome for prodromal Alzheimer's disease trials. J Neurol Neurosurg Psychiatry. 2016;87(9):993–9.
35. Diener HC, Sacco RL, Yusuf S, et al. Effects of aspirin plus extended-release dipyridamole versus clopidogrel and telmisartan on disability and cognitive function after recurrent stroke in patients with ischaemic stroke in the Prevention Regimen for Effectively Avoiding Second Strokes (PRoFESS) trial: a double-blind, active and placebo-controlled study. Lancet Neurol. 2008;7(10):875–84.
36. Pearce LA, McClure LA, Anderson DC, et al. Effects of long-term blood pressure lowering and dual antiplatelet treatment on cognitive function in patients with recent lacunar stroke: a secondary analysis from the SPS3 randomised trial. Lancet Neurol. 2014;13(12):1177–85.
37. Hicks SL, Sharma R, Khan AN, et al. An eye-tracking version of the trail-making test. PLoS One. 2013;8(12):e84061.
38. Oliveira CR, Lopes Filho BJ, Sugarman MA, et al. Development and feasibility of a virtual reality task for the cognitive assessment of older adults: the ECO-VR. Span J Psychol. 2016;19:E95.
39. Oliveira CR, Lopes Filho BJP, Esteves CS, et al. Neuropsychological assessment of older adults with virtual reality: association of age, schooling, and general cognitive status. Front Psychol. 2018;9:1085.