Research Article

Development and Clinical Validity of a Mild Vascular Cognitive Impairment Assessment Tool for Korean Stroke Patients

Hyun Soo Oh, PhD, RN,1 Ji Sun Kim, RN,1 Eun Bi Shim, RN,2 Wha Sook Seo, PhD, RN1,∗

1 Department of Nursing, Inha University, Incheon, South Korea
2 Incheon Regional Cardio-Cerebro-Vascular Center, Inha University Hospital, Incheon, South Korea

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S U M M A R Y

Purpose: The present study was conducted to develop a mild vascular cognitive impairment (MVCI) assessment tool for patients with stroke and to examine its validity, reliability, and clinical adequacy.

Methods: Items of this tool were developed based on previously verified cognitive assessment tools. Face, content, and criterion (concurrent) validities, optimal cut-off score for differentiation of MVCI and normal cognitive function, clinical adequacy, internal consistency, and inter-rater reliability of the assessment tool were determined in 60 stroke patients at a university hospital located in Incheon, South Korea.

Results: The devised MVCI assessment tool contains 20 items which were designed to assess seven cognitive domains: orientation, memory, language, attention, reasoning/abstraction, visuospatial perception, and executive function/problem solving. Content, face, and construct validities were well supported. Clinical adequacy testing revealed that the overall probability of correctly discriminating MVCI using the MVCI assessment tool for stroke was 90.0%, which was statistically significant. Furthermore, a score of 23 was found to be the optimal cut-off score for MVCI. Internal consistency and inter-rater reliability were also well supported.

Conclusions: The findings of this study indicate that the developed MVCI assessment tool for stroke could serve as a clinically useful tool for detecting MVCI and for properly assessing degree of cognitive impairment in stroke patients.

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Introduction

Vascular cognitive impairment is a spectrum of cognitive impairments caused by various diseases, such as hypertension, diabetes, arteriosclerosis, transient ischemic attack, and stroke [1]. Stroke is one of the most common causes of vascular cognitive impairment [2]. The term cognitive impairment covers a wide variety of conditions ranging from the mildest form of cognitive impairment to overt dementia [1,3–5]. Poststroke cognitive impairment may lead to dementia (vascular dementia), but it often exhibits mild deficiencies in cognitive function (mild vascular cognitive impairment; MVCI) [6], which is referred to as “vascular cognitive impairment, no dementia”. Despite great differences between studies, the highest incidence rate of 64.0% for MVCI among stroke survivors was reported by Jin, Di Legge, Ostbye, Feightner, and Hachinski [7]. Few studies have been conducted on the MVCI incidence rate in Korea. Only one study reported an incidence rate of 39.0% (n = 156) for mild cognitive impairment among 396 Korean stroke patients [8].

According to Wentzel et al [9], approximately half of patients with MVCI develop dementia within 5 years of stroke. The common cognitive domains associated with MVCI in stroke patients are short-term memory (31.0%), long-term memory (23.0%), visuospatial ability (37.0%), executive functions (25.0%), and language (14.0%) [10]. In addition, MVCI following stroke has been shown to be significantly associated with early death and decrease in quality of life for patients and their families [6].

The assessment of MVCI is important because the early detection of cognitive impairment may facilitate intervention targeting the prevention of dementia in stroke patients [11,12]. In addition, proper assessment can provide precise information to stroke patients and their families, and enable the development of effective cognitive rehabilitation plans that improve outcomes and quality of

∗ Correspondence to: Wha Sook Seo, RN, PhD, Department of Nursing, College of Medicine, Inha University, YongHyun Dong 253, Incheon, 22212, South Korea.
E-mail address: wschang@inha.ac.kr

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life. Therefore, development of a well-validated cognitive assessment tool is important for the establishment of nursing care and rehabilitation plans for stroke patients.

Backgrounds

It has been consistently reported that MVCI occurs frequently in patients with stroke [13,14]. According to Nys, van Zandvoort, de Kort, Jansen, de Haan, and Kappelled [15], a high proportion of stroke survivors develop MVCI within 3 months of stroke, especially if the cerebral cortex is involved (74.0%). Patients suffering from vascular dementia often present with cognitive decline and memory impairment severe enough to interfere with daily activities [1]. On the other hand, MVCI is characterized by slight cognitive impairments in only a few cognitive domains and does not significantly impact daily functioning [16–18]. Nevertheless, MVCI may lead to dependence on others for daily activities, adversely affecting patient quality of life, and increases family burden [6].

Of the cognitive domains, executive functioning and visual perception are most commonly associated with MVCI, and short-term and long-term memory, attention, and language are also frequently involved [15]. Furthermore, it has been reported that the severities of deficits in executive functioning, language, verbal memory, and abstract reasoning are more pronounced following left than right cortical stroke [15].

Investigators have consistently asserted no consensus has been reached regarding the definition of mild cognitive impairment, and that the boundary between normal cognitive function and mild cognitive impairment has not been clearly defined [18,19]. However, distinguishing between pathological mild cognitive impairment and normal cognitive function is important when determining therapeutic options [18].

The Mini-Mental State Examination (MMSE) is the test most widely applied to screen cognitive impairment in clinics [20]. However, although the MMSE has been shown to be useful for screening Alzheimer's type dementia, it is inadequate for evaluating mild cognitive impairment because of its insensitivity to visuospatial and executive functional deficits [21–23].

The Cambridge Examination for Mental Disorders of the Elderly (CAMCOG) was originally designed to diagnose primary degenerative dementia. This test has the advantage that it covers a broader range of cognitive functions than other tests do [24], and has been shown to be a more accurate screening tool than the MMSE, especially for elderly stroke patients [24]. However, little is known about the diagnostic value of the CAMCOG for MVCI screening.

The Telephone Interviews for Cognitive Status (TICS) was initially developed to assess cognitive function in elderly patients with Alzheimer's type dementia. The TICS is a brief test (takes 5–10 minutes) and known to be sensitive and specific [25]. However, this test was considered unsuitable for screening MVCI following stroke because it covers only orientation, memory, attention, and language domains of cognitive function [25].

The Montreal Cognitive Assessment (MoCA) tool, which was recently introduced, was developed to detect mild cognitive impairment, and has been shown to be more sensitive for detecting mild cognitive impairment than the MMSE [11,26]. The MoCA includes several cognitive domains that have been reported to be most commonly associated with MVCI following stroke in clinical research studies, and several studies have confirmed its high sensitivity and specificity and determined optimal cut-off values by receiver operating characteristic (ROC) curve analysis [27]. Furthermore, the MoCA has been translated into 36 languages including Korean and Chinese, and is now the most popular cognitive screening tool for detecting mild cognitive impairment [28]. The greatest advantage of the MoCA is its ability to discriminate between patients with mild cognitive impairment and patients with dementia or healthy controls [29]. In addition, the MoCA is a brief, simple tool that can be applied within 10 minutes and places more emphasis on visuo-motor-speed and executive abilities than other tools do [30].

Based on a review of related literature, we considered the MoCA to be the most suitable measure for screening mild type cognitive impairment. However, the MoCA was unlikely to be used for long-term follow-up examinations and repeated measures because it includes many items that require evaluations of animal pictures or naming cards in a face-to-face manner. In addition, the MoCA does not contain items that assess problem-solving ability, one of the most common cognitive domains associated with MVCI in stroke patients [31]. Accordingly, we recognized the need for MVCI assessment tool which addresses major cognitive domains associated with stroke and can be administered using diverse approaches including face-to-face and telephone-based administrations.

Study purpose

The present study was conducted to develop and verify a MVCI assessment tool for Korean stroke patients. The specific study aims were (1) to review other cognitive assessment tools and develop qualified items sensitive to MVCI that are capable of identifying the specific cognitive domains involved and applicable using different approaches (face-to-face and telephone interviews) for long-term follow-up examinations; (2) to evaluate the content and criterion validities of the MVCI assessment tool for stroke; (3) to conduct ROC curve analysis to examine construct validity and clinical adequacy by determining an optimal cut-off for differentiation of MVCI and normal cognitive function, and (4) to evaluate the reliability (internal and inter-rater reliability) of the MVCI assessment tool for stroke.

Methods

Study design

The present study adopted a nonexperimental, cross-sectional correlation design to develop a MVCI assessment tool for stroke and examine its validity and reliability.

Item development procedure

Developing a brief, simple MVCI assessment tool that can be administered in different ways was the prime goal of the present study. As a preliminary step, we reviewed the literature regarding cognitive impairment after stroke. In particular, an extensive literature review on previously verified cognitive assessment tools able to assess diverse cognitive domains was performed. Finally four cognitive assessment tools of fair quality were identified with simple and brief features (completed within 5–10 minutes without professional aid). These were MMSE (Korean version), CAMCOG, TICS, and MoCA (Korean version).

The MMSE uses simple tasks to assess a number of cognitive domains: orientation, memory, attention, language, and complex demands. Orientation tasks measure sense of current year, month, date, day of the week, and season. Memory tasks assess ability to repeat the names of three objects, which are spoken by an examiner at a rate of one per second, immediately (registered memory) and after a set time (delayed memory). Attention tasks measure the ability to count by subtracting 7 from 100. Language tasks assess the ability to name an object, repeat a given phrase/sentence, follow a three-stage command as written, read and repeat a given
sentence, and make up and write a sentence about anything. Complex demand tasks measure the ability to copy two intersecting pentagons.

The CAMCOG assesses orientation, language (comprehension and expression), memory (remote, recent, and new learning memory), attention and calculation, praxis, abstract thinking, and perception (tactile and visual recognition, unusual view, and person recognition). Individual tasks in each domain of the CAMCOG are similar to those in the MMSE.

The TICS was developed for use in situations unsuitable for in-person cognitive screening. This test was originally designed for administration by telephone, but it can also be administered face-to-face. The cognitive domains tested by the TICS are orientation, memory, attention, and language. Orientation tasks consist of questions about current time, age, and address. Memory tasks measure abilities to repeat 10 words immediately and after a set time, and to recall recent and long-term memories. Attention tasks assess ability to count by subtracting 7 from 100, and to repeat numbers spoken by an examiner in reverse order. Language tasks measure sentence repetition, verbal fluency, and comprehension abilities.

The MoCA assesses visuospatial perception, executive functions, language, memory, attention, abstraction, and orientation. Visuospatial perceptions and executive functions are assessed simultaneously using a trail making task (drawing a line from letters to numbers), a clock-drawing task (drawing the contour of a clock and positioning numbers and hands to tell the commanded time), and a cube coping task. The language tasks consist of questions asking the names of animals on drawing cards (vocabulary), to repeat a sentence (repetition), and to recite more than 11 objects that can be purchased at a market (fluency). Memory tasks assess ability to repeat five words spoken by an examiner immediately (no point awarded) and after a set time. Attention tasks assess the ability to repeat five numbers in the order named, to repeat another three numbers in reverse order, to count by subtracting 7 from 100, and to tap every time an examiner says the letter “A”. Abstraction tasks assess ability to explain what pairs of words have in common. Orientation tasks measure the sense of current year, month, date, day of week, and place.

Taken together, it was found that cognitive domains and tasks included in the four assessment tools were fairly similar (Table 1): orientation, memory, language, attention, reasoning/abstract thinking, and visuospatial perception. Furthermore, they cover most of the common cognitive domains known to be associated with MVCI, that is short-term and long-term memory, attention, language, executive functioning, and visuospatial perception [15–17]. However, it was noted only the MoCA contains items that assess executive functioning.

Based on the findings of the review, we developed the MVCI assessment tool for stroke. The tool comprises seven cognitive domains of orientation, memory, language, attention, reasoning/abstraction, visuospatial perception, and executive function/problem solving (Table 2). In particular, we devised an item to assess executive function/problem solving based on empirical evidence that the severities of deficits in more complicated cognitive abilities, such as, problem solving, are more pronounced following stroke [31].

<table>
<thead>
<tr>
<th>Domains</th>
<th>Assessment tools</th>
<th>Tasks or assessment items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>MMSE</td>
<td>Ask to tell current date, day of the week, season, age, telephone number, &amp; address</td>
</tr>
<tr>
<td></td>
<td>CAMCOG</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TICS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MoCA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAMCOG</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TICS</td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>MMSE</td>
<td>Ask to immediately repeat five words spoken by an examiner</td>
</tr>
<tr>
<td></td>
<td>MoCA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAMCOG</td>
<td>Ask to repeat the five words after all other tests are completed</td>
</tr>
<tr>
<td></td>
<td>TICS</td>
<td></td>
</tr>
<tr>
<td>Language</td>
<td>MMSE</td>
<td>Ask to recite more than three words that start with the letter “A”</td>
</tr>
<tr>
<td></td>
<td>CAMCOG</td>
<td>Ask to repeat a sentence that is difficult to pronounce</td>
</tr>
<tr>
<td></td>
<td>TICS</td>
<td>Ask to tell names of animals on drawing cards or after listening to descriptions of the animals</td>
</tr>
<tr>
<td></td>
<td>MoCA</td>
<td>Ask to listen to short sentences &amp; answer questions</td>
</tr>
<tr>
<td>Attention</td>
<td>MMSE</td>
<td>Ask to repeat five numbers spoken by an examiner</td>
</tr>
<tr>
<td></td>
<td>MoCA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAMCOG</td>
<td>Ask to count backwards from 20</td>
</tr>
<tr>
<td></td>
<td>TICS</td>
<td>Ask to clap whenever an examiner says days of the week in the correct sequence</td>
</tr>
<tr>
<td>Reasoning/Abstraction</td>
<td>MoCA</td>
<td>Ask to explain what each pair of words has in common (bicycles-train or rose-lily)</td>
</tr>
<tr>
<td>Visuospatial perception</td>
<td>MoCA</td>
<td>Ask to copy a drawing of a cube</td>
</tr>
<tr>
<td></td>
<td>CAMCOG</td>
<td>Ask to correctly draw a clock showing the time stated by an examiner</td>
</tr>
<tr>
<td></td>
<td>MoCA</td>
<td>Ask to draw a line from letters to numbers (trail making)</td>
</tr>
<tr>
<td>Executive function</td>
<td>MoCA</td>
<td>Ask to count by subtracting 7 from 100</td>
</tr>
</tbody>
</table>

Note. CAMCOG – the cambridge examination for mental disorders of the elderly; MMSE – mini-mental state examination; MoCA – montreal cognitive assessment; TICS – telephone interviews for cognitive status.
disorganized or unreasonable approach (1 point), 3 represented a simplistic approach in a childish manner (2 points), 4 represented an immature approach considering his/her age (3 points), and 5 represented a systematic and reasonable approach (4 points). Two research assistants had practiced presenting all items to stroke patients over a 2-week period before data collection. During this period, the two assistants were given two typical example situations, and practiced how to categorize expected responses into the five response options. Such pre-training sessions were set up simultaneously for the two assistants to decrease individual differences related to response category selection. Because the example situations were made of having definite answers, no difficulties in the selection of response category were found during data collection. To increase accuracy in assessing executive function/problem solving ability, the two example situations were given to each study participant and both responses were comprehensively assessed.

Pretest

A pretest was conducted on five stroke patients to ensure that, (1) it was understandable, (2) respondents could complete it within 5–10 minutes, and (3) that cognitive function scores obtained when the MVCI assessment tool was administered face-to-face or by telephone were similar. In general, the time period required between two assessments is 2 weeks to avoid recall bias in healthy adult participants. However, 1-week interval between testing via face-to-face and telephone interview seemed to be appropriate considering the characteristics of our participants (elderly stroke patients who might have cognitive impairments) in the present study.

During the pretesting, we noticed that five respondents were sufficient for pretesting purposes. The pretest was conducted by two research assistants. One was a nursing graduate student and the other had participated in several clinical research projects. Pretesting indicated that the devised tool was understandable and had no potential problems regarding the assessment of MVCI in stroke patients. In addition, the cognitive function scores when administered face-to-face or by telephone interview were similar. The time taken to administer this tool during pretesting was 5–13 minutes.

Study participants

The study participants comprised 60 stroke patients treated at a university hospital located in Incheon, South Korea. Only participants who satisfied the following criteria were recruited: (1) stroke diagnosed by a neurologist or neurosurgeon based on neuro-imaging findings within 3 months of stroke onset, (2) an age of greater than 19 years, (3) no history of previous cognitive disability, and (4) no difficulty regarding voluntary hand movement (required for drawing). Stroke patients with expressive/receptive dysphasia were included in the present study because language ability assessment is one of the most important purposes of a cognitive assessment tool. The MVCI assessment tool was also designed to test language ability.

We realized that study participants drawn from one hospital might limit the generalizability of the results obtained. However, the university hospital at which the data collection was conducted had been appointed as a regional Cardio-Cerebro-Vascular Center.

Table 2  MVCI Assessment Tool for Stroke Devised in Present Study.

<table>
<thead>
<tr>
<th>Domains</th>
<th>Subdomains</th>
<th>Score</th>
<th>Items/tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Time &amp; place</td>
<td>6</td>
<td>— Ask to tell current date, day of the week, season, phone number, address, &amp; age</td>
</tr>
<tr>
<td>Memory</td>
<td>Immediate memory</td>
<td>0</td>
<td>— Ask to repeat five words spoken by an examiner after 30 seconds</td>
</tr>
<tr>
<td></td>
<td>Remote/recent memory</td>
<td>2</td>
<td>— Ask to tell past history</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>— Ask to recall the latest events</td>
</tr>
<tr>
<td></td>
<td>Prospect memory</td>
<td>1</td>
<td>— Ask to recall any event (doctor’s appointment, family affair, or personal affairs) scheduled on the next day or week</td>
</tr>
<tr>
<td></td>
<td>Delayed memory</td>
<td>5</td>
<td>— Ask to repeat five words spoken by an examiner after a set length of time</td>
</tr>
<tr>
<td>Language</td>
<td>Repetition</td>
<td>1</td>
<td>— Ask to repeat a sentence that can be difficult to follow</td>
</tr>
<tr>
<td></td>
<td>Verbal fluency</td>
<td>1</td>
<td>— Ask to tell more than three words start with the Korean letter “ㄱ”</td>
</tr>
<tr>
<td></td>
<td>Comprehension</td>
<td>1</td>
<td>— Ask to answer questions about common sense</td>
</tr>
<tr>
<td>Attention</td>
<td>Counting numbers</td>
<td>2</td>
<td>— Ask to count backwards from 20</td>
</tr>
<tr>
<td></td>
<td>Calculation task</td>
<td>4</td>
<td>— Ask to count backwards from 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>— Ask to count by subtracting 7 from 100</td>
</tr>
<tr>
<td>Reasoning/abstraction</td>
<td>Similarities</td>
<td>2</td>
<td>— Ask to explain what each pair of objects or living things in has in common (animals, flowers, instruments, or modes of transportation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>— Ask to make a pair of objects (pencil &amp; notebook)</td>
</tr>
<tr>
<td>Visuospatial ability</td>
<td></td>
<td>1</td>
<td>— Ask to tell the time indicated on a wall clock</td>
</tr>
<tr>
<td>Executive function/Problem solving</td>
<td>Situation play</td>
<td>4</td>
<td>— Ask to explain how to manage a given situation commonly confronted in daily life (4-score scale)</td>
</tr>
</tbody>
</table>

Total score 30

Note. MVCI = mild vascular cognitive impairment.

Figure 1. ROC curve of the MVCI assessment tool for stroke. The area under curve b is 0.90 (Table 4), indicating that the probability of correctly discriminating cognitive impairment using the MVCI assessment tool is 90.0%. Note. MVCI = mild vascular cognitive impairment; ROC = receiver operating characteristic. *Random chance line; **ROC curve.
by the Korean Ministry of Health and Welfare. Thus, as a leading hospital with respect to the treatment of acute/sub-acute stroke, this hospital was considered appropriate in terms of regional representativeness.

The minimum sample size required for testing the validity of the MVCI assessment tool for stroke was computed using the MedCalc-13.0 program (MediCalc Software, Ostend, Belgium). The findings obtained indicated a minimum sample size of 28 with an z value of .05, a power (1 – β) of 0.80, an area under curve (AUC) of 0.80, and a ratio of cognitive impairment to normal cognitive function of 1.28 based on a study that reported a maximum prevalence rate of 64.0% for vascular cognitive impairment after stroke [7]. In the present study, AUC was used for ROC curve analysis and the value of 0.80 was derived based on an average AUC value of the MoCA (0.75–0.85) reported by Pendlebury et al [32].

Although the minimum sample size required for the present study was found to be 28, data was actually collected from 60 participants based on expectations of missing data and erratic responses due to cognitive impairment.

Ethical consideration

This study was approved by the human research committee of the university the authors were affiliated with (IRB No. 140213-1A). We made it clear to all participants that they were free not to participate and could withdraw from the study at any time without prejudice. We also explained that information would be collected anonymously and that data would be presented as mean values (not as individual values). Study purposes and procedures were explained and participants were then allowed to decide whether to participate or not. Written informed consent was obtained from patients who agreed to participate. When a patient was unable to provide consent, written informed consent was also obtained from family members.

Face and content validity testing

Face and content validities were tested by an expert panel comprised of three nursing professors with experience of developing cognitive rehabilitation programs for stroke patients, and four nurses (3 with 5–10 years of neurological intensive care unit experience and 1 with 3 years of experience in rehabilitation outpatient clinics). All four nurses were especially trained to perform physical and cognitive assessments at the Cardio-Cerebro-Vascular Center of the study university hospital for face and content validity testing, and three were graduate students in nursing.

Face and content validities were tested by evaluating whether cognitive domains and tasks included in the four cognitive assessment tools (as summarized in Table 1) could properly assess mild type cognitive impairment. In addition, the expert panel estimated the level of difficulty posed by the words used in each task or question, particularly in memory, language, and reasoning/abstraction domains. Most items commented to be in need of modification by the members of the expert panel were revised. Notably, one item assessing problem solving/executive functioning was devised using examples of real-world situations as suggested by the expert panel (fire alarm ringing; taking cash from an ATM). Discussions regarding discrepancies were continued until an acceptable level of agreement was reached.

The expert panel evaluated whether completed 20 items of the MVCI assessment tool could properly assess mild cognitive impairment using a 3-point scale (1, not valid; 2, valid; 3, highly valid). The content validity index (CVI) was computed as the number of items that the experts gave a rating of either 2 or 3 divided by the total numbers of item. In the present study, the CVI of the MVCI assessment tool for stroke was 0.91, which supported its face and content validities. That is, items of the MVCI assessment tool for stroke appeared to be adequate for measuring band each item corresponded with items of the other four valid cognitive assessment tools.

Measurements for criterion validity testing

To test the criterion validity of the MVCI assessment tool for stroke, the first step was selecting an adequate criterion tool. Based on reviews of related literature, we considered the MoCA to be the most suitable measure for screening mild type cognitive impairment due to its wide applicability and good validity and reliability [29,30,32], and because it covers several cognitive domains (orientation, language, memory, attention, abstract thinking, and visuospatial/executive function). Accordingly, the criterion validity of the MVCI assessment tool was examined by comparing results obtained with those of the MoCA. The purpose of this comparison was to examine whether the performance of the MVCI assessment tool, which consists of written questions requiring verbal responses, matches that of the MoCA, which consists of written and pictorial items, in terms of detecting MVCI. In addition, the MoCA was also used to estimate a cut-off score for ROC curve analysis.

Construct validity of the original version of the MoCA was examined by the developers [27], who reported a sensitivity of 100.0% and a specificity of 97.0% based on ROC analysis. However, they did not determine the reliability of the MoCA. Recently, Tu et al [28] confirmed good internal consistency and inter-rater reliability for the MoCA. The MoCA was translated into Korean by Lee et al [29]. Since then, the validity and reliability of the Korean version has been consistently tested [sensitivity 89.0%, specificity 84.0%, Cronbach α = .81–.84, and test-retest reliability r = .75 (p < .001)]. Cronbach α of the Korean version of the MoCA in the present study was .85.

Data collection

Data collection was performed by the two research assistants that conducted pretesting. Both had worked as educational nurses in a regional Cardio-Cerebro-Vascular Center and were educated about the purposes of the present study and the structure of the MVCI assessment tool for stroke. In addition, both had practiced presenting all items to stroke patients over a 2-week period. To evaluate inter-rater consistency, the two assistants independently assessed cognitive functions of 20 stroke patients selected from the 60 study participants. Data collection was conducted in patient rooms or outpatient clinics.

Data analysis

Statistical analysis was performed using SPSS/PC version 21.0 (IBM SPSS Statistics-Korea, Seoul, Korea). Descriptive analysis was used to describe general subject characteristics and major variables. Content and criterion (concurrent) validities of the MVCI assessment tool for stroke were evaluated using CVI values and by correlation analysis, respectively.

In general, factor analysis, known group method, multitrait multimethod, or nomological analysis can be used to examine construct validity of a measurement tool [33,34]. Although the most frequently used method to examine construct validities is factor analysis, it was not considered appropriate for the present study because four domains (attention, reasoning/abstraction, visuospatial ability, and executive function/problem solving) of the MVCI assessment tool consist of only one or two items.
The specific methods to verify construct validity may depend on the characteristics of a measurement tool. For a binary classifier, such as the presence or absence of a particular disease (MVCI in the present study), it is important to select optimal cut-off values. In this context, ROC curve analysis offers a powerful means of evaluating the performance of a binary classifier and for determining cut-off values [29,32]. In the present study, ROC curve analysis was conducted to determine optimal cut-off values and the sensitivity/specificity (construct validity) of the MVCI assessment tool for stroke.

Using ROC curve analysis, we calculated the AUCs, sensitivities, specificities, positive predictive values (PPVs), and negative predictive values (NPVs) of different candidate cut-off scores. To test the reliability of the MVCI assessment tool, its internal consistency and inter-rater reliability were evaluated using Cronbach’s α and Spearman’s ρ, respectively.

**Results**

**Descriptive statistics of participant characteristics**

Mean age of the 60 study participants was 64.07 years (±13.46), and 48 (80.0%) were male and 12 (20.0%) female. Overall, 23 (38.4%) participants had lesions of the basal nuclei, 9 (15.0%) of the pons, 8 (13.3%) of the right/left middle cerebral artery, 5 (8.3%) of the cerebellum, 3 (5.0%) of the diencephalon, 3 (5.0%) of the parietal lobe, and 9 (15.0%) of other areas (subarachnoidal hemorrhage, intraventricular hemorrhage, right/left posterior cerebral artery, and multiple infratentorial infarction). Eleven (18.3%) of the study participants had hematoma and the mean amount of bleeding was 27 mL (±8.72). Regarding surgical modalities related to stroke, 3 patients (5.3%) underwent surgery, such as craniotomy, clipping, or coiling (Table 3).

Brain injury severity was assessed using the Glasgow Coma Scale (GCS) or the National Institute of Health Stroke Scale (NIHSS), as determined by the department involved. The GCS and NIHSS were applied to 23.3% and 77.6% of the participants, respectively. The mean GCS and NIHSS scores at admission were 12.21 (±3.07)/16 and 6.06 (±4.23)/42, respectively, indicating moderate severity. Mean cognitive impairment scores determined using the MVCI assessment tool for stroke and the MoCA were [22.39 (±6.04)/30] and [22.69 (±6.48)/30], respectively (Table 3).

**Criterion validity testing**

The criterion validity test is widely used to establish the validity of measurement tools. In general, criterion validity can be demonstrated by comparing the selected measure with another valid measure; similarity between measures can be quantified using correlation coefficients. The correlation coefficient between the cognitive impairment scores determined using the MVCI assessment tool and the MoCA was 0.88 (p < .001), indicating a high degree of correlation (Table 4). Domain scores in orientation (r = .79, p < .001), memory (r = .62, p < .001), language (r = .70, p < .001), attention (r = .81, p < .001), and visuospatial ability (r = .63, p < .001) were found to be significantly related between the two scales (Table 4).

**Construct validity and clinical adequacy testing**

ROC curve analysis was conducted to evaluate the construct validity and the clinical adequacy of the MVCI assessment tool for stroke. A potential cut-off score for MVCI was estimated based on cut-offs reported for the MoCA, which ranged from 21 to 27 [28,35–37], and averaged 24. Accordingly, participants with an MVCI score ≥ 24 or ≤ 23 were allocated a normal cognitive function group or a cognitive impairment group.

AUCs provide a numerical summary of ROC curves, and are considered suitable for quantifying the abilities of measurement tools to differentiate disease and nondisease states (i.e., MVCI and normal cognitive function in the present study). AUC values can be interpreted as probabilities, and range from 0.5 (incapable of discriminating) to 1.0 (perfect ability to discriminate). In the present study, the AUC of the MVCI assessment tool for stroke was 0.90 with a 95% confidence interval (CI) of 0.78–1.00 (p < .001, Table 4, Figure 1), indicating a probability of correctly identifying MVCI of 90%, which is considered excellent [38].

To determine the optimal cut-off score for the MVCI assessment tool for stroke, its sensitivities, specificities, PPVs, and NPVs at candidate cut-off points of 23 and 24 (from the average cut-off score of the MoCA) were determined. At a cut-off of 23, its sensitivity was 0.92, specificity was 0.89, PPV was 93.5% (95% CI [80.29, 98.96]), and NPV was 86.6% (95% CI [65.35, 97.19]). At a cut-off of 24, its sensitivity was 0.82, specificity was 0.89, PPV was 92.8% (95% CI [78.17, 98.86]), and NPV was 74.1% (95% CI [53.35, 89.16]) (Table 4). Because of its higher sensitivity, we subsequently used a score of 23 as the optimal cut-off.

### Table 3 Descriptive Statistics for Participant Characteristics.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Frequencies (%)/M ± SD</th>
<th>Variables</th>
<th>Frequencies (%)/M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>64.07 ± 13.46</td>
<td>Gender</td>
<td>Male 48 (80.0)</td>
</tr>
<tr>
<td>Site of lesion</td>
<td>Basal ganglia 23 (38.4)</td>
<td>Presence of hematoma</td>
<td>Yes 11 (18.3)</td>
</tr>
<tr>
<td></td>
<td>Pons 9 (15.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MCA 8 (13.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cerebellum 5 (8.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diencephalon 3 (5.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parietal lobe 3 (5.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Else^a 9 (15.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of hematoma (mL)</td>
<td>27.00 ± 8.72</td>
<td>Surgery</td>
<td>Yes^b 3 (5.3)</td>
</tr>
<tr>
<td>Scales used for assessing severity</td>
<td>NIHSS 14 (23.3)</td>
<td>Level of severity</td>
<td>NIHSS 12.21 ± 3.07 (total 16)</td>
</tr>
<tr>
<td></td>
<td>GCS 46 (76.6)</td>
<td></td>
<td>6.06 ± 4.23 (total 42)</td>
</tr>
<tr>
<td>MVCI score</td>
<td>22.39 ± 6.04 (total 30)</td>
<td>MoCa score</td>
<td>22.69 ± 6.48 (total 30)</td>
</tr>
</tbody>
</table>

Note: GCS = glasgow coma scale; MCA = right/left middle cerebral artery; MoCA = montreal cognitive assessment; MVCI = mild vascular cognitive impairment assessment tool for Stroke; NIHSS = national institutes of health stroke scale.

^a Including subarachnoidal hemorrhage; intraventricular hemorrhage; right/left posterior cerebral artery; multiple infratentorial infarction;

^b Including craniotomy, clipping, and coiling surgery.
Reliability testing

The internal consistency of the MVCI assessment tool for stroke was well supported by the present study. The inter-total correlation for the 20 items ranged from .48 to .74, and most values were above the critical value of .40 of the summated rating scale [39]. Cronbach $\alpha$ (A coefficient of internal consistency) was high at .89, while its inter-rater reliability was confirmed by a Spearman $\rho$ of 0.93 ($p \leq .001$, Table 4).

Discussion

According to Leys, Henon, Mackowiak-Cordoliani, and Pasquier [40], the prevalence of poststroke dementia ranges from 21.0% to 32.0%, which is higher than the prevalence of nonstroke dementia (11.0%) [41]. Furthermore, the risk of dementia is markedly increased after recurrent stroke [26]. Dementia can be easily detected because it affects the activities of daily life, but mild cognitive impairment is often difficult to diagnose [18]. According to Jin et al [7], 64.0% of stroke survivors had some form of cognitive impairment, and usually this amounts to a mild type of cognitive impairment. Furthermore, individuals with mild impairments progress to dementia faster than age-matched healthy controls [42].

In the present study, we developed the 20-item MVCI assessment tool, which can be administered face-to-face or by telephone interviews to enable long-term follow-up assessments, based on previously validated cognitive assessment tools. The items were designed to assess seven cognitive domains that have been consistently reported to be affected by stroke [25,26,43]. These seven domains include orientation, language, attention, memory, executive function and problem solving, reasoning/abstraction, and visuospatial ability.

According to Oh and Seo [31], stroke patients may experience diverse types of mild cognitive disabilities that involve impairments of language, memory, problem solving, and/or safety and social behavior. In this previous study, mild cognitive impairments were found in 23.3%–35.4% of patients during the first month after stroke, and at 6 months after stroke, the proportion of patients with a language or memory impairment decreased to 6.1%–10.2%, but the proportion with a problem solving, safety behavior, or social behavior impairments remained high (20.2%–20.4%). Oh and Seo [31] concluded that such differences in recovery rates might be related, in part, to levels of complexity, that is, more complex cognitive abilities, such as, problem solving, safety behavior, and social behavior, are probably more severely affected after stroke.

In the present study, the validity of the MVCI assessment tool for stroke was examined using content, face, and criterion validity tests. An expert panel conducted content and face validity testing and found that all 20 items were adequate for measuring MVCI. Each item corresponded with the conceptual definition of poststroke cognitive impairment and with the items of other valid cognitive assessment tools, which indicated that the content and face validities of the MVCI assessment tool for stroke were well supported.

The criterion validity of the MVCI assessment tool for stroke was tested by comparing its results with those of the MoCA, which was used as a criterion tool due to its relatively good sensitivity for detecting mild type cognitive impairment and its ability to assess diverse cognitive domains associated with stroke [11,36]. In the present study, we found cognitive scores determined by the MVCI assessment tool and MoCA were highly correlated.

ROC curve analysis was conducted to assess the clinical adequacy of the MVCI assessment tool for stroke. Initially, we considered using a cut-off score of 24, which was the average of previously reported MoCA cut-off values. However, at a cut-off of 23, the fractions of participants with MVCI that the MVCI assessment tool correctly identified as having such a condition was 92.0% (sensitivity of 0.92), the fractions of participants with normal cognitive function that the MVCI assessment tool correctly identified as having normal cognitive function was 89.0% (specificity of 0.89). In addition, the overall probability of correctly diagnosing MVCI using the MVCI assessment tool for stroke was 90.0%. On the other hand, when a cut-off of 24 was used, sensitivity decreased to 0.82, but specificity was maintained (0.89).

At a cut-off of 23, 93.5% (PPV) of the participants with cognitive impairment (identified using the MVCI assessment tool) were found to actually have cognitive impairment (identified using the MoCA). In addition, 86.6% (NPV) of the participants with normal cognitive function (identified using the MVCI assessment tool) were found to actually have normal cognitive function (identified using the MoCA). On the other hand, at a cut-off of 24, PPV and NPV were markedly reduced to 92.7% and 74.1%, respectively. Based on these findings, a score of 23 was taken to be an optimal cut-off with respect to sensitivity and specificity.

Pendlebury et al [37] reported a sensitivity and specificity of 77.0% and 83.0%, respectively, for the detection of mild cognitive impairment using the MoCA at a cut-off score of 25. These authors also reported a sensitivity and specificity of 83.0% and 73.0%, respectively, for Addenbrooke’s Cognitive Examination Revised (ACE-R), at a cut-off score of 94. These findings demonstrate that the sensitivities and specificities of the MoCA and ACE-R for

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Table 4  Validity, Reliability, and Clinical Adequacy of the MVCI Assessment Tool for Stroke.

<table>
<thead>
<tr>
<th>Test</th>
<th>Types</th>
<th>Statistical Methods</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validity</td>
<td>Criterion validity</td>
<td>Correllational analysis</td>
<td>Overall: $r = .88$ ($p \leq .001$)</td>
</tr>
<tr>
<td>Reliability</td>
<td>Internal consistency</td>
<td>Correllational analysis (item total correlation)</td>
<td>Orientation: $r = .79$ ($p \leq .001$)</td>
</tr>
<tr>
<td></td>
<td>Inter-rater reliability</td>
<td>Reliability analysis (Cronbach $\alpha$)</td>
<td>Memory: $r = .62$ ($p \leq .001$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nonparametric correlational analysis</td>
<td>Language: $r = .70$ ($p \leq .001$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ROC curve analysis</td>
<td>Attention: $r = .81$ ($p \leq .001$)</td>
</tr>
<tr>
<td>Clinical adequacy</td>
<td>Discriminant ability</td>
<td></td>
<td>Visuospatial: $r = .63$ ($p \leq .001$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AUC ($p$)</td>
<td>$r = .48$–.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cut-off value</td>
<td>$\alpha = .89$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensitivity</td>
<td>$p = .93$ ($p \leq .001$)</td>
</tr>
</tbody>
</table>

Note. AUC = area under curve; CI = confidence interval; MVCI = mild vascular cognitive impairment; NPV = negative predictive value; PPV = positive predictive value; ROC = receiver operating characteristic.
detecting mild cognitive impairment are lower than those obtained using the MVCI assessment tool for stroke devised in the present study. Pendlebury et al [37] detected mild cognitive impairment using the Neuropsychological Assessment Battery, whereas we used the average cut-off score of the MoCA, and this difference between the criteria used to diagnose mild cognitive impairment may have contributed to the sensitivity and specificity differences observed between the two studies. The Neuropsychological Assessment Battery used by Pendlebury et al [37] assesses executive function, attention, language, visuospatial, and memory domains, and includes six specific tests (the Trail Test, the Symbol Digit Modalities Test, the Rey-Osterrieth Complex Figure Copy Test, the Hopkins Verbal Learning Test—Revised, and letter and category fluency tests) and takes approximately 50–60 minutes to apply. Accordingly, it is considerably more complex and probably more accurate at detecting mild cognitive impairment than the MVCI assessment tool for stroke.

In the present study, 63.0% of the 60 stroke patients were found to have mild cognitive impairment according to the MVCI assessment tool, which concurs with the rate determined by Jin et al [7], who found that 64.0% of stroke survivors had cognitive impairment.

**Nursing implication**

The early detection of MVCI in stroke patients is important for facilitating intervention, delaying or preventing the onset of dementia, and for developing effective cognitive rehabilitation plans that improve outcomes and quality of life. A well-validated cognitive assessment tool containing accurate and simple items would benefit nursing care and the development of rehabilitation plans for stroke patients in acute and subacute stages. To meet such needs, we designed the MVCI assessment tool for stroke, which can be completed in only 10 minutes but yet addresses the major cognitive domains associated with stroke. Our findings showed that the MVCI assessment tool for stroke has excellent criterion and construct validity and relevant clinical applicability with high sensitivity and specificity. We believe that the MVCI assessment tool offers clinically useful means for detecting MVCI and for properly assessing degrees of cognitive impairment in stroke patients. In addition, the 20 items of the MVCI assessment tool are written questions requiring verbal responses. This allows the MVCI assessment tool to be administered over the telephone or by face-to-face interview, and thus, facilitate longitudinal follow-up examinations of patterns of cognitive changes after stroke.

**Conclusion**

The present study was conducted to develop an MVCI assessment tool for stroke and to determine its validity, reliability, and clinical adequacy. The 20 items of the MVCI assessment tool for stroke were developed based on valid, pre-existing cognitive assessment tools, and designed to assess seven cognitive domains including orientation, memory, language, attention, reasoning/abstraction, visuospatial perception, and executive function/problem solving. The present study supports the content, face, and construct validities of the MVCI assessment tool for stroke. Clinical adequacy testing revealed that the overall probability of correctly discriminating vascular cognitive impairment using the MVCI assessment tool for stroke was 90.0%, which was statistically significant. A score of 23 was found to be an optimal cut-off point for maximizing in sensitivity and specificity. Our evaluation of the reliability supported its internal consistency and inter-rater reliability. Furthermore, our findings indicate that the MVCI assessment tool for stroke offers a clinically useful means for detecting MVCI and for properly assessing degrees of vascular cognitive impairment in stroke patients.

**Conflicts of interest**

No conflict of interest has been declared by the authors.

**Acknowledgment**

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**References**


