

Montreal Cognitive Assessment score correlates with regional cerebral blood flow in
post-stroke patients

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Abstract

Objective: Valid and reliable measures are needed to assess post-stroke cognitive impairment.

The Montreal Cognitive Assessment (MoCA) has been considered a superior screening test to the Mini-Mental State Examination (MMSE) for patients with post-stroke cognitive impairment, particularly in executive function, which may be related to reduction in regional cerebral blood flow (rCBF). In this study, we determined whether MoCA and MMSE scores correlate with rCBF assessed with SPECT in the subacute phase after ischemic stroke.

Patients and Methods: We retrospectively enrolled 28 patients who were admitted to the Red Cross Otsu Hospital with acute cerebral infarction, which was confirmed by magnetic resonance imaging (MRI), if they underwent cognitive assessment (MoCA/MMSE) and ¹²³I-IMP SPECT imaging within 3 weeks post-stroke during a study period of 5 months.

Correlation analyses between rCBF and MoCA or MMSE scores were performed by statistical parametric mapping (SPM) and volume-of-interest (VOI) analyses.

Results: Total MoCA score correlated with the rCBF in the prefrontal cortex, cingulate cortex, caudate nucleus and thalamus by SPM analysis (uncorrected $p < 0.001$; cluster-level corrected $p < 0.05$). Among the subtest scores of MoCA, visuoexecutive function, attention, language and delayed recall scores were positively correlated with rCBF in the prefrontal cortex by

VOI analysis ($p < 0.05$). However, total MMSE score did not correlate significantly with any of the rCBF measures.

Conclusions: Post-stroke cognitive performance assessed with MoCA positively correlated with rCBF in brain regions mainly comprising the prefrontal-subcortical circuits. The findings of this hypothesis-generating study support the notion that MoCA is useful for assessing post-stroke cognitive status.

Keywords: post-stroke cognitive impairment; prefrontal-subcortical circuits; Montreal Cognitive Assessment; cerebral blood flow; statistical parametric mapping; SPECT

1. Introduction

Post-stroke dementia (PSD) is used to define any dementia after stroke, no matter whether the primary cause is vascular, degenerative or mixed [1, 2]. Cognitive impairment without dementia is even more prevalent in post-stroke patients, with a reported rate of 47.7% [3]. That is because post-stroke cognitive impairment (PSCI) is characterized by early impairments in executive function and preserved memory [4], but usual definitions of dementia emphasize the presence of memory deficits. Therefore, it might be useful to focus on “cognitive impairment” rather than “dementia”, because cognitive impairment includes all cognitive consequences of stroke, even if they are not severe enough to meet the criteria for dementia [5].

The prevalence of PSCI varies depending on the setting, the population, the exclusion criteria, the diagnostic criteria and the time interval since stroke [6]. A recent systematic review indicates that the prevalence of PSD in the first year after stroke ranges from 7% in population-based studies of first-ever stroke to 41% in hospital-based studies including recurrent stroke [6]. Despite no accepted consensus on the timing of cognitive assessment, many reports conduct neuropsychological assessments from 1 week to 3 years [1]. PSCI assessed at 3 months post-stroke, particularly in executive and visuospatial functions, was related to poor survival [7] and PSCI assessed within 3 weeks post-stroke is found to be a

predictor of long-term cognitive and functional outcome [8]. Therefore, early detection of PSCI with brief screening is necessary to identify high-risk groups and improve prognosis [9].

It is unclear which screening tool is most effective for assessing cognitive function in early phases after stroke injury. Post-stroke patients can rarely tolerate extensive neuropsychological batteries. The Mini-Mental State Examination (MMSE) [10] is one of the most widely used cognitive screening instruments. However, it has been criticized for inadequacy especially in detecting PSCI due to lack of prefrontal-executive tasks [11]. The Montreal Cognitive Assessment (MoCA) [12] is a relatively new screening instrument developed to detect mild cognitive impairment. Unlike MMSE, MoCA includes executive, attention and abstraction tasks, and thus might be expected to be more sensitive to PSCI in which prefrontal rather than memory deficits tend to predominate [13, 14]. MoCA was proposed as one of the instruments for brief evaluation in the Vascular Cognitive Impairment Harmonization Standards from the National Institute for Neurological Disorders and Stroke-Canadian Stroke Network [14]. Furthermore, MoCA administered in the subacute stroke phase is predictive of subsequent PSCI [15].

In this study, we investigated whether regional cerebral blood flow (rCBF) in the subacute phase post-stroke correlates with cognitive function scores assessed with MoCA and MMSE, which may contribute to the understanding of the clinico-anatomical relations of PSCI. This is

the first study that assessed a correlation of neuropsychological test scores with rCBF in the subacute phase after stroke. Regional CBF was assessed with single photon emission computed tomography (SPECT), which reflects neuronal activity in each brain region and allows speculations on functional connectivity among distant areas [16]. Brain perfusion SPECT has been a sensitive tool to assess the functional deficit in the early stages of cognitive impairment and is thus helpful in investigating the causes of cognitive impairment. In recent years, functional network disruption has been reported to be important not only in degenerative dementias but also in PSCI [17]. In addition to the comprehensive analyses using statistical parametric mapping (SPM), we have also analyzed and focused on rCBF in the prefrontal area which is often disrupted in PSCI [18] with a volumes-of-interest (VOI) approach.

2. Patients and Methods

2.1 Participants

During the study period of five months from November 2012 to March 2013, a total of 105 patients were admitted to the Red Cross Otsu Hospital with symptomatic acute cerebral infarction. Acute cerebral infarction was diagnosed by 1) the presence of neurological deficits lasting more than 24 hours and 2) acute ischemic lesion confirmed by MRI. Patients were enrolled if they underwent cognitive assessment and SPECT imaging within 3 weeks

post-stroke [8] because the time window of subacute stroke phase was defined as within 3 weeks after stroke. SPECT scanning was conducted at the discretion of attending physicians to aid in the differentiation of dementia subtypes. Recent research suggests that even a single lacunar infarct adversely affects cognition, particularly in the presence of concurrent leukoaraiosis [19]. Exclusion criteria were 1) infratentorial lesion or 2) inability to be examined due to severe disturbances in consciousness or inability to comprehend task instructions [8]. Based on the above inclusion/exclusion criteria, 28 patients with acute cerebral infarction were included. The cognitive assessment was conducted on 14.7 ± 4.7 hospital days and SPECT imaging on 12.4 ± 4.1 hospital days. MRI was performed on 1.6 ± 0.8 hospital days. Demographic details of the subjects, their vascular risk factors and stroke features are provided in Table 1 and 2. The study was approved by the ethics committee of our hospital. Informed consent of this retrospective study was also obtained through an opt-out approach.

2.2. Neuropsychological evaluation

Patients underwent a general physical and neurologic examination and neuropsychological assessment, including the Japanese version of MoCA [20] followed by MMSE on 14.7 ± 4.7 hospital days. To avoid effects of habituation, items redundant between

MoCA and MMSE (orientation and serial 7s) were performed only once and the scores shared between the two screening tests.

MoCA (available at www.mocatest.org) is a 30-point test administered in 10 minutes.

Details on the specific MoCA items are as follows. It consists of seven subtests [21].

Visuoexecutive functions are assessed using a clock-drawing task (3 points), a three-dimensional cube copy (1 point) and the Trail Making B task (1 point). Naming is assessed using a three-item confrontation naming task with low-familiarity animals (lion, camel, rhinoceros; 3 points). Attention is evaluated using a sustained attention task (target detection using tapping; 1 point), a serial subtraction task (3 points) and digits forward and backward (1 point each). Language is assessed using repetition of two syntactically complex sentences (2 points) and a phonemic fluency task (1 point). Abstraction is assessed using a two-item verbal abstraction task (2 points). The short-term memory recall task (5 points) involves two learning trials of five nouns and delayed recall after approximately 5 minutes. Finally, orientation to time and place is evaluated (6 points). Patients with the highest education level of primary school or below would award 1-point as education adjustment in MoCA scores.

2.3. Magnetic Resonance Imaging (MRI)

All patients had MRI scans (1.5-Tesla Achieva; Philips, Netherlands) within three days after the onset. T1-weighted axial images were obtained with a spin-echo pulse sequence with a repetition time of 422 ms and an echo time of 12 ms. Axial T2-weighted images were also obtained (repetition time, 3838 ms; echo time, 100 ms). Axial diffusion weighted images were also obtained (repetition time, 3000 ms; echo time, 75 ms). The corresponding parameters for the FLAIR images were 6000/140ms, respectively. The inversion time of FLAIR images was 2000 ms. Axial images were obtained in parallel to the orbitomeatal line. Slice thickness was 6 mm, with an interslice gap of 1 mm in the axial plane. The stroke subtype was classified into categories using the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria: (1) large-artery atherosclerosis, (2) small-vessel occlusion (lacune) and (3) cardioembolism (CE) [22]. The distribution of the lesions detected by MRI is provided in Table 1. Arterial distribution was determined according to the established arterial territories of the human brain [23].

2.4. Single photon emission computed tomography

The patients underwent measurement of rCBF by SPECT using ^{123}I -IMP (Nihon Medi-Physics Co., Ltd. Takarazuka, Japan) on 12.4 ± 4.1 hospital days. The SPECT scanner was a PRISM-IRIX (Philips, Netherlands) fitted with low energy, high resolution collimators.

SPECT scanning was carried out 20 minutes after intravenous bolus injection of 167 MBq ^{123}I -IMP while the patients were supine position with their eyes closed in a quiet room. The data were acquired in a 128×128 matrix through a 360° rotation with a voxel size of 1.8×1.8×5.4 mm. The projection data were prefiltered through a Butterworth filter, and then reconstructed using a Ramp backprojection filter.

2.5. Statistical analysis with statistical parametric mapping

The SPECT images were spatially normalized into the Montreal Neurological Institute (MNI) standard template. To minimize individual anatomical variability, the normalized images were smoothed using a 12 mm full-width at half-maximum isotropic Gaussian kernel in accordance with the prior research [24]. Relative rCBF values were normalized to the mean count in the ipsilateral cerebellar hemisphere [25]. It is known that in post-stroke patients crossed cerebellar diaschisis (CCD) occurs. This phenomenon (CCD) is matched to hypoperfusion in the contralateral cerebellum due to the remote effect of contralateral supratentorial lesion [26]. Statistical analysis was performed with SPM version 8 software package (<http://www.fil.ion.ucl.ac.uk/spm/software/spm8>), allowing correlation analyses of relative rCBF values with the total scores of MoCA and MMSE. If the total score has significant correlations, the subtest scores are also analyzed. In SPM, a statistic is calculated

at every voxel of whole brain using the general linear model. As for each test, the resultant set of voxel values constituted a statistical parametric map of the t statistic SPM (t). SPM maps were obtained at a height threshold of uncorrected $p < 0.001$, but only those correlations significant at $p < 0.05$, cluster-level corrected for multiple comparisons, were retained [27-29]. This cluster-based correlation implies a two-stage thresholding: first, creating a statistical image at uncorrected $p < 0.001$, and second, assessing the chances that the identified regions of contiguous voxels reach to be considered significant using cluster-level corrected $p < 0.05$. This cluster-based correction for multiple comparisons is regarded as more powerful and commonly used than voxel-based correction [30]. The statistical maps were rendered by the BrainNet Viewer (<http://www.nitrc.org/projects/bnv/>). The statistical maps were displayed in correlation coefficient maps which were converted from the t statistic SPM (t). To identify precise anatomical location of the results, we entered the values of x, y, z of the cluster of a statistical significance into the SPM anatomy toolbox program, and finally obtained anatomical locations and Brodmann areas of the results.

2.6. Statistical analysis with volume-of-interest

In PSCI, rCBF reduction has been reported especially in the prefrontal cortex of all the cortices [31]. We have focused on the prefrontal area and analyzed with VOI-approach. We

selected the prefrontal area because the prefrontal cortex is disrupted in patients with PSCI [18] and MoCA places great emphasis on prefrontal-executive function [13]. The relative rCBF was extracted from the normalized images using the ipsilateral cerebellar hemisphere as reference, which is the same as the SPM analysis. The Pearson's correlation analyses were performed between total scores of MoCA/MMSE and rCBF of the prefrontal areas with Bonferroni correction for two comparisons. Because of the multiple comparisons in two cognitive tests, differences between the groups were considered significant at a level of $p < 0.025$ ($=0.05/2$). If the total score has significant correlations, the subtest scores are also analyzed. These statistical analyses were performed using SPSS Statistics software program.

3. Results

3.1. Baseline characteristics

All 28 patients (average 72.6 ± 9.6 years old) had at least one risk factor for ischemic cerebrovascular disease, including hypertension and diabetes mellitus (Table 1). The mean MoCA score in the patients was determined to be 20.7 ± 6.4 and that of MMSE was 24.8 ± 5.4 (Tables 1 and 2). There is no difference of these cognitive scores (MoCA and MMSE) between the right and left hemispheric strokes (Table 2). The etiologies of the infarcts were atherosclerosis in 14 cases, cardioembolism in 7 cases and lacunar stroke in 7 cases (Tables 1

and 2). The stroke lesion was localized in the anterior circulation territory in 25 cases, the posterior circulation territory in 4 cases, and both territories in 1 case (Table 2).

3.2. Correlation analysis with Statistical parametric mapping

Voxel-based analyses demonstrated clusters having a significant positive correlation of the total MoCA score with rCBF (Fig. 1). By contrast, there were no significant correlations of the total MMSE score with rCBF in those areas. The total MoCA score demonstrated a significant positive correlation with rCBF in the bilateral prefrontal cortex, the bilateral cingulate cortex, the right caudate nucleus and the right thalamus (Fig. 1, Table 3). As the total MoCA score has good correlations with rCBF, we will scrutinize the subtest scores of MoCA. Among the subtest scores of MoCA, visuoexecutive function positively correlated with rCBF in the right prefrontal cortex, the right superior temporal cortex and the right insula (Fig. 2a). Language function positively correlated with rCBF in the left anterior cingulate cortex, the bilateral caudate nucleus and the right thalamus (Fig. 2b). Delayed recall positively correlated with rCBF in the right prefrontal cortex, the right superior temporal gyrus and the right insula (Fig. 2c). The prefrontal cortex was the area with which both visuoexecutive function and delayed recall were positively correlated.

3.3. Correlation analysis with volume-of-interest

Figure 3 shows the results of VOI-based correlation analyses. The rCBF of the prefrontal cortex was significantly correlated with the total MoCA score (Fig. 3a; $p=0.003$, $r=0.534$) but only weakly with the total MMSE score (Fig. 3b; $p=0.028$, $r=0.416$). In addition, the rCBF of the prefrontal cortex had a trend of correlation with the subtest scores of MoCA, including attention (Fig. 3c; $p=0.023$, $r=0.427$), visuoexecutive function (Fig. 3d, $p=0.022$, $r=0.432$), language (Fig. 3e, $p=0.031$, $r=0.408$) and delayed recall (Fig. 3f, $p=0.010$, $r=0.478$) but not with naming ($p=0.285$, $r=0.209$), abstraction ($p=0.191$, $r=0.255$) or orientation ($p=0.056$, $r=0.365$).

These results of VOI-based correlation analyses of the rCBF of the prefrontal cortex with the MoCA/MMSE scores are compatible with those of the voxel-based analyses.

4. Discussion

In this study, voxel-based analyses demonstrated a significant positive correlation of the total MoCA score with rCBF in the bilateral prefrontal cortex, the bilateral cingulate cortex, the right caudate nucleus and the right thalamus, which corresponded to essential components of the prefrontal-subcortical circuits [32]. The prefrontal-subcortical circuits originate in the prefrontal cortex and then proceed to the striatum, globus pallidus, and thalamus, returning

through a final loop to the prefrontal cortex. VOI-based correlation analyses demonstrated a significant positive correlation of the total MoCA score with rCBF in the prefrontal cortex. These results validated those of the voxel-based analyses. In a previous report, CBF deficits of PSCI have been reported in the frontal lobes and the basal ganglia [31]. Another study using arterial spin labeling has shown that PSCI due to subcortical infarction is accompanied by marked CBF reductions in the frontal and parietal cortices [33]. Our results are consistent with these previous two reports showing that frontal lobe CBF is reduced in PSCI.

What is the characteristic neuropsychological profile of PSCI? Beyond focal hypoperfusion or infarction and resulting cognitive impairment, global cognitive dysfunction has been reported after stroke [34]. Global cognitive dysfunction can involve impairment in prefrontal-executive tasks as well as memory [4]. It is important to note that visuoexecutive function positively correlated with rCBF in the prefrontal cortex. In the Leukoaraiosis and Disability (LADIS) study, the number of lacunes was significantly correlated with impairment of executive function [35]. Other studies have shown that post-stroke patients demonstrate poor executive function which is characterized by disturbance of prefrontal functions [36]. Kandiah reported that patients with lacunar infarcts in the frontal subcortical region have a substantially higher risk of PSCI than infarcts in other brain regions [37]. These studies, however, have not shown functional abnormalities of the prefrontal cortex by directly using

functional modalities such as SPECT or positron emission tomography. Therefore, the current study is the first report that evaluated a direct correlation of the neuropsychological MoCA test scores with rCBF in the subacute post-stroke phase. It remains unknown why infarctions in the prefrontal area cause more dementia than other brain regions. One of the plausible reasons is that the prefrontal cortex is highly interconnected with many cortical regions, basal ganglia and thalamus than any other cortices. These extensive connections allow the prefrontal cortex to play essential roles in executive functions [38].

Three prefrontal-subcortical circuits appear involved in behavioral and cognitive changes; the dorsolateral prefrontal circuits, the orbitofrontal circuits and the anterior cingulate circuits [39]. In addition to these closed frontal-subcortical loops, there are open connections of the circuits that integrate information from anatomically distant but functionally related brain areas, e.g. the superior temporal area, the parietal area and the entorhinal region [40]. The ischemic stroke lesions related to PSCI often disturb the prefrontal-subcortical circuits including the bundles of white matter (corona radiata or centrum semiovale) [41, 42], leading to executive deficits associated with prefrontal hypoperfusion [43]. SPECT demonstrates that the disconnective syndrome can be caused by regions of hypoperfusion remote from the stroke lesions [44]. Given that strictly gray matter infarction was observed only in 21.4% of the current cases (Table 1), our study suggests that the white matter was more likely

responsible for developing subacute PSCI. Recently, the white matter of the brain is increasingly recognized as equally critical for cognition, whereas the gray matter has long been regarded as the major locus of cognitive function [45].

Voxel-based and VOI-based analyses demonstrated a significant positive correlation of rCBF with total score of MoCA rather than MMSE. This is consistent with previous reports: MoCA has been proposed as a promising screening tool of PSCI compared to MMSE [14]. The profile of PSCI differs from the memory-focused decline of Alzheimer's disease [46, 47]. The most frequent impairments of PSCI is prefrontal-executive deficits [48]. MoCA identified substantially more cognitive deficits that were not detected by MMSE, including visuoexecutive function and attention (not sufficiently tested with MMSE) and delayed recall and language (items too easy in MMSE).

There were several limitations to this study. First, the sample was small in size and inherently heterogeneous. The required sample size would be $n=28.2$, which means that this study nearly met the required sample size, if we assume a two-sided test with a moderate correlation ($r=0.5$), $\beta = 0.20$ and $\alpha = 0.05$. However, if we assume a two-sided test with $r=0.5$, $\beta = 0.20$, and $\alpha = 0.01$ ($= 0.05/5$) or 0.005 ($= 0.05/10$) for multiple comparisons, the required sample sizes would be 42 or 47, respectively, and therefore this study was considered not to reach the required sample size. Therefore, this study should be regarded as a

hypothesis-generating pilot study, although complementary findings of voxel-based and VOI-based analyses consolidated the results. A subsequent study with a larger cohort will be required to elucidate the specific correlations between rCBF and MoCA in PSCI, and possibly to compare the current results with those of other screening tests, which focus more on executive function [49]. Second, pre-stroke cognitive status was not available. Third, for relative quantification of SPECT measures, we used the ipsilateral cerebellar hemisphere as reference [25]. This normalization assumes that the ipsilateral cerebellar hemisphere is unaffected by the ischemic insult. But, there is no region perfectly ensured to be escaped from vascular injury.

5. Conclusions

In conclusion, MoCA reflects post-stroke CBF reductions in brain regions mainly comprising the prefrontal-subcortical circuits. The findings of this hypothesis-generating study support the notion that MoCA is useful for early detection of PSCI.

Conflicts of interests: none

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Table 1 Baseline characteristics of patients

Characteristic	Values or Frequency
Baseline characteristics	
Age, years	72.6 ± 9.6
Sex F/M	5/23
Education, years	13.4 ± 2.8
Hypertension	18 (64%)
Diabetes mellitus	5 (18%)
Cigarette smoking	15 (54%)
Atrial fibrillation	3 (11%)
Previous cerebrovascular disease	4 (14%)
Statin use	3 (11%)
Antiplatelet use	9 (32%)
LDL cholesterol, mg/dL	108 ± 41
Triglyceride, mg/dL	128 ± 87
Hematocrit, %	40 ± 6
Fibrinogen, mg/dL	291 ± 53
Stroke features	

Gait disturbance	11 (39%)
Dysarthria	11 (39%)
MoCA-J score†	20.7 ± 6.4
MMSE score†	24.8 ± 5.4
modified Rankin Scale	1.29 ± 1.24
Imaging characteristics	
Lesion side R/L	14/14
Lesion locus	
strictly white matter	13 (46.4%)
strictly gray matter	6 (21.4%)
both white/gray matter	9 (32.1%)
Old lacunas in the basal ganglia/ thalamus	19 (68%)
Etiologies of the ischemic stroke	
Atherosclerosis	14 (50%)
Cardioembolism	7 (25%)
Lacunar stroke	7 (25%)

Values are shown with mean $\pm$ standard deviation. Numbers are shown with frequency (%).†, conducted at 14.7 ± 4.7 days after admission. Abbreviations: F, female; M, male; LDL, low-density lipoprotein; MoCA-J, the Japanese version of the Montreal Cognitive Assessment; MMSE, the Mini-Mental State Examination; R, right; L, left.

Table 2 Baseline and imaging characteristics of patients

Patient (no.)	Age (y)	Sex	MMSE score	MoCA score	Lesion side	Arterial distribution	Etiologies
1	78	M	29	22	L	MCA	C
2	69	F	17	12	L	MCA	C
3	84	F	15	7	L	MCA	C
4	71	M	29	24	L	MCA	A
5	63	M	22	15	L	MCA	A
6	66	M	30	28	L	MCA	La
7	55	M	30	28	L	PCA	La
8	79	M	30	28	L	MCA	La
9	64	M	27	19	R	MCA	A
10	88	F	24	18	R	MCA and PCA	C
11	70	M	30	29	R	MCA	A

12	69	M	28	23	L	AchA	A
13	66	F	28	30	R	MCA	A
14	68	M	27	25	R	MCA	La
15	84	M	12	8	R	ACA and MCA	A
16	72	M	26	24	L	AchA	La
17	78	M	30	25	L	MCA	A
18	61	M	27	21	R	PCA	C
19	74	M	30	25	R	MCA	C
20	73	M	22	16	L	ACA	A
21	79	M	14	10	R	MCA	A
22	80	M	22	22	R	MCA	A
23	83	M	28	24	L	ACA and MCA	A
24	88	F	27	17	R	MCA	A
25	79	M	22	20	R	MCA	C
26	52	M	28	27	L	MCA	A
27	80	M	17	14	R	AchA	La
28	60	M	23	19	R	PCA	La

Abbreviations: M, male; F, female; MMSE, the Mini-Mental State Examination;

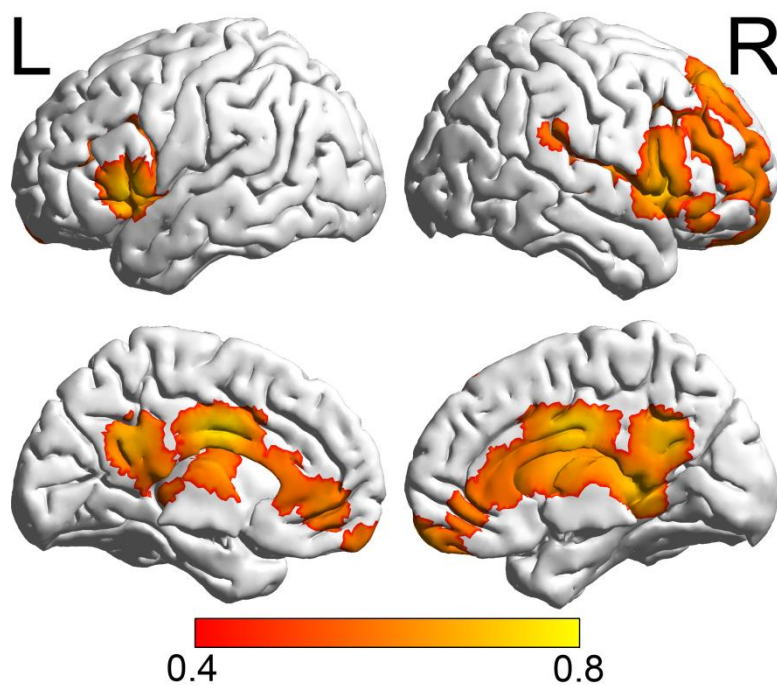
MoCA, the Montreal Cognitive Assessment; R, right; L, left; ACA, anterior cerebral artery; MCA, middle cerebral artery; PCA, posterior cerebral artery; AchA, anterior choroidal artery; A, atherosclerosis; C, cardioembolism; La, lacunar stroke

Table 3 Brain regions with significant positive correlation of rCBF with the total score of MoCA (Voxel-based correlation analysis)

Region (Brodmann's area)	MNI coordinates			z score
	x	y	z	
L anterior cingulate gyrus (24)	-4	-6	34	4.48
L inferior frontal gyrus (44, 45)	-52	18	-2	4.32
R posterior cingulate gyrus (23)	8	-50	30	4.20
R insula gyrus (13)	46	18	2	4.09
R thalamus	10	-36	6	4.08
R inferior frontal gyrus (44, 45)	62	18	-2	4.01
R caudate	6	-2	18	3.86
R rolandic operculum	50	0	6	3.81
R superior frontal gyrus (8)	24	42	52	3.78

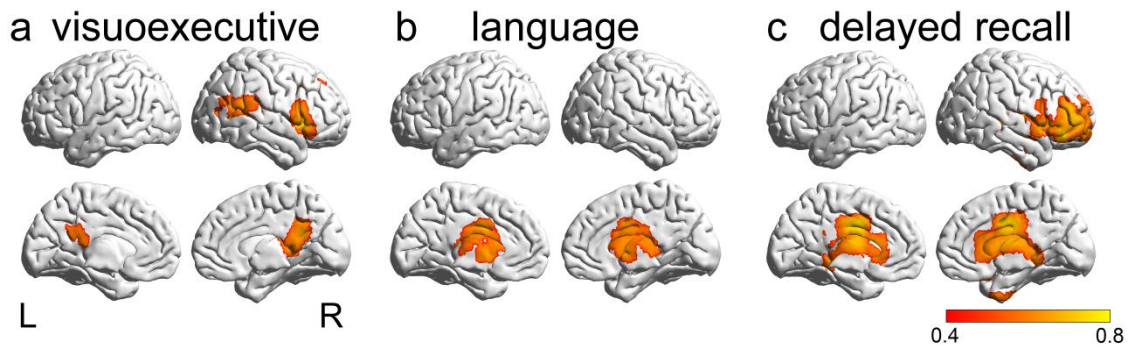
The MNI coordinates: a standard coordinate system of the brain in SPM, used to index voxels in the space of the MRI volume.

Fig. 1. Statistical parametric mapping showing a significant positive correlation of total score of MoCA with rCBF.



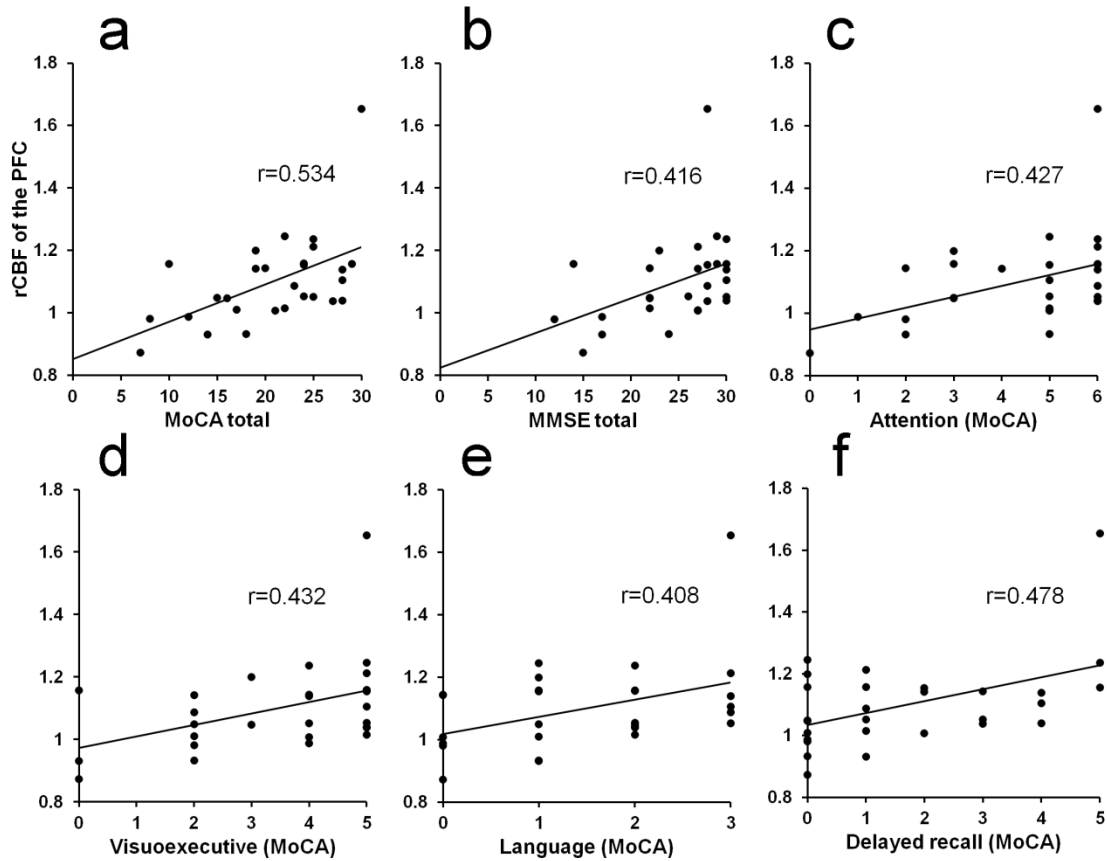
Voxel-based analyses demonstrated a significant positive correlation of total score of MoCA with rCBF in the prefrontal cortex, the cingulate cortex, the caudate nucleus and the thalamus. On the other hand, total score of MMSE has no significant correlations.

Fig. 2. Statistical parametric mapping showing a significant positive correlation of subtest scores of MoCA with rCBF.



(a) Visuoexecutive function positively correlated with rCBF in the right prefrontal cortex, the right superior temporal cortex and the right insula. (b) Language function positively correlated with rCBF in the left anterior cingulate cortex, the bilateral caudate nucleus and the right thalamus. (c) Delayed recall positively correlated with rCBF in the right prefrontal cortex, the right superior temporal gyrus and the right insula.

Fig. 3. Scatterplot showing the positive correlations of scores of MoCA and MMSE with rCBF in the prefrontal cortex.



(a-b) The rCBF of the prefrontal cortex was significantly correlated with the total MoCA score (a; $p=0.003$, $r=0.534$) but only weakly with the total MMSE score (b; $p=0.028$, $r=0.416$).

(c-f) The rCBF of the prefrontal cortex had a trend of correlation with the subtest scores of MoCA, including attention (c; $p=0.023$, $r=0.427$), visuoexecutive function (d; $p=0.022$, $r=0.432$), language (e; $p=0.031$, $r=0.408$) and delayed recall (f; $p=0.010$, $r=0.478$).