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Resting-state functional magnetic resonance imaging in patients with leukoaraiosis-associated subcortical vascular cognitive impairment: a cross-sectional study

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Objectives: The aim of the study was to investigate the difference of resting-state default-mode network (DMN) between patients with leukoaraiosis (LA)-associated subcortical vascular cognitive impairment (SVCI) and control subjects, and to provide functional imaging evidence of SVCI.

Methods: All subjects (n = 58) were divided into two groups based on their clinical diagnosis: a LA-associated SVCI group (n = 31, 14 males) and a control group (n = 27, 14 males). Demographic information and resting-state functional MRI (rs-fMRI) data were obtained. These subjects were assessed using the Hamilton Anxiety Depression Scale, Clinical Dementia Rating, Mini Mental State Exam, and Montreal Cognitive Assessment. Experimental data and confounding factors were described with a General Liner Model. Independent components of fMRI data were analyzed with an fMRI toolbox.

Results: The active areas involved in DMN of LA-associated SVCI group were similar to those of the control group. However, several active areas of LA-associated SVCI group, especially the left anterior cingulate cortex and the right parahippocampal gyrus, showed significantly lower blood oxygen level-dependent (BOLD) signals compared with the control group ($p \leq 0.05$); whereas the left caudate nucleus ($p = 0.015$), the right frontal lobe ($p = 0.004$), and the superior temporal gyrus/inferior parietal gyrus ($p = 0.001$) exhibited significantly higher BOLD signals compared with the control group.

Discussion: The present study provides neuroimaging evidence for the recognition of LA-associated SVCI. Moreover, the differences in the functional alterations of the resting-state DMN might be a distinguishing feature between SVCI and amnestic mild cognitive impairment patients.

Keywords: Subcortical vascular cognitive impairment, Leukoaraiosis, Default-mode network, Dementia

Introduction

Leukoaraiosis (LA) is a radiological term that was created by Hachinski in 1987.[1] Patients with LA show mottled or patchy changes in the periventricular or subcortical white matter on MRI. LA can be found in patients with Alzheimer's disease (AD), Binswanger's disease, vascular cognitive impairment, and carbon monoxide poisoned patients, as well as in a subset of normal elderly people. The morbidity of LA in the elderly people varies from 50 to 98%.[2] This wide range can be attributed to differences in the age of the populations being examined and to the imaging techniques applied to them. Cognitive impairment, the most common clinical feature associated with LA, manifests in memory loss, lack of attention, slow thinking process, and executive function impairment.[3,4] Radiological studies have shown that normal elderly people with LA are at risk of further cognitive deterioration.[5] The magnitude of LA is positively correlated with the severity of

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cognitive impairment. Vascular dementia often happens in conjunction with LA, and a large number of LA patients finally develop into vascular dementia.[6] Therefore, early identification of patients with cognitive impairment due to LA is as important as finding strategies to prevent the further development of cognitive impairment.

Functional magnetic resonance imaging (fMRI) can be used to measure oxygen saturation and blood flow in the brain. For example, the blood oxygen level-dependent (BOLD) fMRI method is widely used to observe different active areas of the brain at any given time. Resting-state fMRI (rs-fMRI) is performed on patients in a relaxed state with eyes closed, movement restrained, and structural thinking prohibited.[7] It has been demonstrated that waves of BOLD signaling occur in the resting state. Each type of the spontaneous signal waves can be attributed to a specific functional connectivity that exists in the motor, auditory, or the visual system and corresponds to a brain activity in the resting state.[8]

Default-mode network (DMN) is a distinct network in human brain shown to be active at resting state while deactivated in goal-oriented tasks, which supposes to contribute to basic introverted thinking patterns, such as insight and environmental sensation.[9] Previous studies have indicated that brain regions getting involved in the DMN include the medial prefrontal, anterior cingulate, inferior temporal, posterior cingulate/precuneus, the posterior parietal cortices,[10,11] and the medial temporal lobe.[12,13] fMRI studies based on cognitive tasks revealed that compared with young and normal older adults, patients with cognitive impairment showed significantly disrupted DMN,[9,14] which provided evidences supporting the contribution of DMN to cognitive function; and the different patterns of alteration in different diseases induced cognitive impairment [details in Discussion, e.g. subcortical vascular cognitive impairment (SVCI) vs. amnestic mild cognitive impairment (aMCI)] indicated DMN as a potential marker for differential diagnosis.[15,16]

Current medical workup for mild cognitive impairment includes medical history inquiry, independent function and daily activities assessment, input from relatives and caregivers, mental status assessment, in-office neurological examination, mood evaluation and laboratory tests, which largely relies on a physician's experience and judgment. Though the role of the DMN in human brain remains controversial, based on the studies mentioned above, it seems that the rs-fMRI signal changes could serve as a relatively objective marker for detecting significant functional alteration in patients at the early stage of dementia, such as SVCI and aMCI.[17] However, in LA patients with SVCI, no rs-fMRI data are available. The present study aimed to investigate the differences in the resting-state DMN between patients with LA-associated SVCI and control subjects, and to provide the functional neuroimaging evidence for the recognition of LA-associated SVCI.

Subjects and Methods

Subjects

From March 2012 to March 2015, subjects (n = 58) were recruited from the outpatients and inpatients of the Department of Neurology of Beijing Tiantan Hospital. Demographic information including age, gender, education, position, address, contact information, and past medical history (hypertension, diabetes, coronary atherosclerotic heart disease, lipid disorder, smoking and drinking, etc.) was obtained during their visits. The present study was approved by the Human Ethical Committee of Tiantan Hospital, and a written informed consent was given by the participants or their legal proxies.

Patients with LA-associated SVCI (n = 31) were diagnosed according to the criteria[16] as follows: (1) subjective cognitive complaints reported by the subjects or their caregivers; (2) objective cognitive impairments, but not meeting the Diagnostic and Statstical Manual of Mental Disorders, fourth edition (DSM-IV) criteria for dementia; (3) normal or nearly normal Activity of Daily Living score; (4) Clinical Dementia Rating (CDR) score = 0.5 and Mini Mental State Exam (MMSE) score ≥ 24; (5) significant evidence of subcortical vascular features on structural MRI was found by experienced radiologist according to Fazekas scale[18]; (6) patients with pseudo-cognitive impairment due to anxiety/depression were excluded using Hamilton Anxiety Depression Scale. Patients who met the diagnostic criteria for Parkinson's disease, fronto temporal dementia, Huntington disease or dementia due to other diseases (e.g. traumatic disease in central nervous system, intracerebral space-occupying lesions, infectious or metabolic disease, etc.) were excluded.

The healthy control subjects (n = 27) with normal cognitive function [CDR = 0, MMSE ≥ 27, Montreal Cognitive Assessment (MoCA) ≥ 26] had no previous history of neurological or psychiatric disorders, substance abuse, or severe internal organ involvement; and were confirmed with no LA, cerebral infarction, intracerebral space-occupying lesions, or demyelination by structural brain MRI.

Cognitive function evaluation

The anxiety/depressive state of each subject was assessed using the Hamilton Anxiety Depression Scale, and their cognitive state was determined using the CDR, MMSE, and MoCA. All tests were administered by neuropsychologists in a quiet room. The characteristics of the brain MRI of the LA patients were assessed using the Fazekas scale.

A total of 31 LA-associated SVCI and right-handed patients (14 males) with a CDR of 0.5 and 27 right-handed healthy control subjects (14 males) with a CDR of 0 were selected for this study. The demographic characteristics of all subjects are summarized in Table 1.

Table 1 Comparison of background information between LA[a]-associated SVCI[b] patients and controls

Variables	LA[a]-associated SVCI[b] group	Control group	*p*-value
Age (years)	63.39 ± 10.04	57.7 ± 12.62	0.061
Gender (M/F)	14/17	14/13	0.611
Education (years)	10.19 ± 2.24	11.93 ± 4.45	0.061
MMSE[c] (score)	27.06 ± 2.03	28.59 ± 1.05	0.001
MoCA[d] (score)	22.38 ± 2.72	28.26 ± 1.38	0.000
CDR[e]	0.5	0	
History of hypertension (Y/N)	16/15	14/13	0.586
History of diabetes (Y/N)	7/24	5/22	0.703
Dyslipidemia (Y/N)	7/24	7/20	0.766
History of smoking (Y/N)	10/21	12/15	0.663
History of drinking (Y/N)	5/26	5/12	0.436

Significant differences were found in MMSE[c] and MoCA[d] scores between LA[a] associated SVCI[b] and the control groups.
[a]leukoaraiosis.
[b]subcortical vascular cognitive impairment.
[c]Mini Mental State Exam.
[d]Montreal Cognitive Assessment.
[e]Clinical Dementia Rating

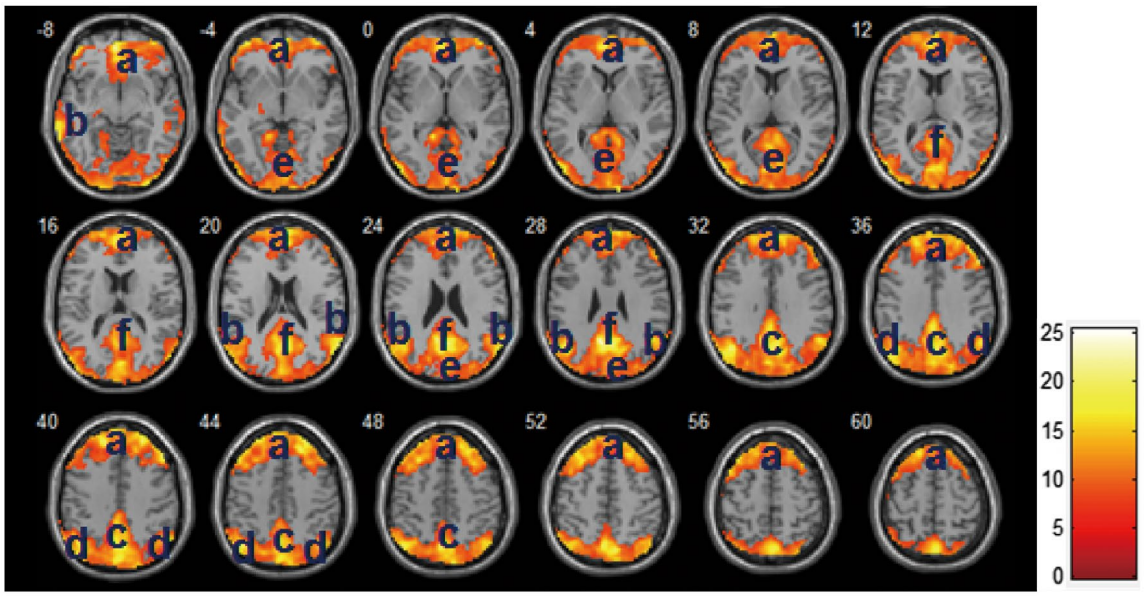

Figure 1 Activated brain areas of the control subjects in the resting state. (a) The bilateral medial frontal gyrus, (b) the bilateral medial temporal gyrus, (c) the bilateral superior parietal lobe, (d) the bilateral angular gyrus, (e) the bilateral occipital lobe, and (f) the posterior cingulate cortex/precuneus

rs-fMRI

All imaging data were acquired using a scanner (SIEMENS 3.0T) at Tiantan hospital. Subjects were lucid with their eyes closed and their heads fixed in place. They were asked to avoid cognitive processes and body movements during the data collection process. Berth calibration and shimming of the normal MRI machine were performed. T1 weighted imaging of the sagittal view was performed initially with a Spin echo (SE) sequence, followed by the transverse scan. After the sagittal T1 weighted and T2 axial scans, the T2 FLAIR axial scan was performed. Finally, resting-state neuroimaging data were collected. The whole brain was scanned with all layers parallel to the anterior-posterior commissural line (AC-PC). The rs-fMRI data were then processed using the Statistical Parametric Mapping 5 software and a parameter statistics model was generated after transferring all pixels.

Statistical analysis

Two independent-sample *t*-tests were used to compare the demographic information (such as age, education level, MMSE score, and MoCA score) of LA-associated SVCI subjects with that of the control subjects. Data of past medical history (e.g. hypertension, diabetes, dyslipidemia, smoking, and drinking) were analyzed using the Fisher algorithm. The results were considered significant if the *p* value was less than 0.05. Experimental data and confounding factors were analyzed using a General Linear Model (GLM). Parameters obtained from the GLM underwent statistical inference using a statistical parameter chart to obtain the active regions of all subjects in the resting state ($p < 0.05$). Independent component analysis (ICA) data from the LA and control subjects were analyzed using the fMRI toolbox.

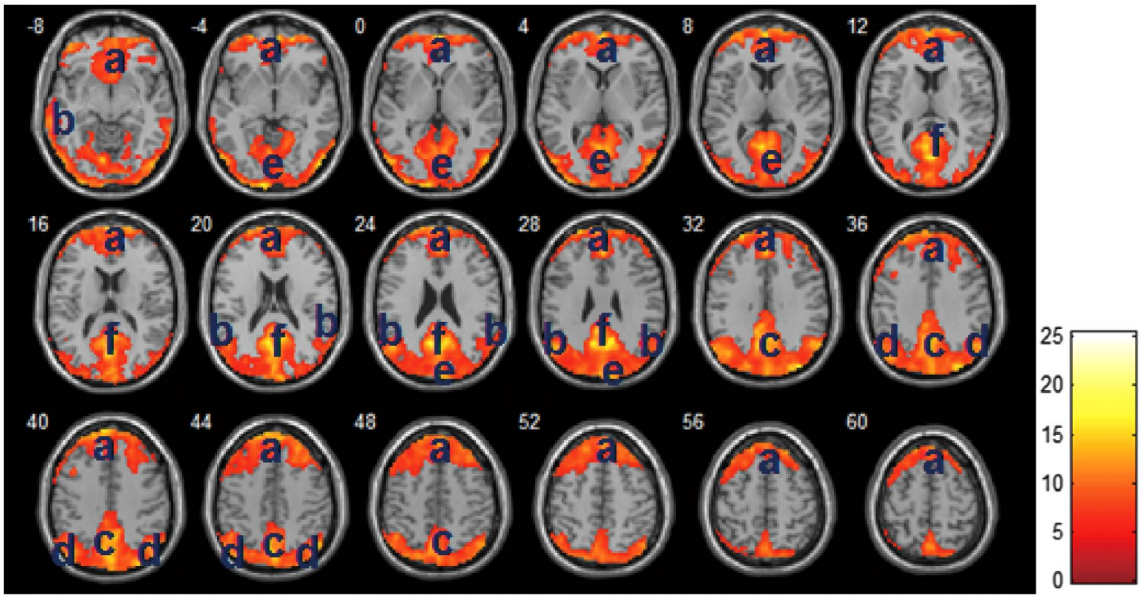

Figure 2 Activated brain areas of the leukoaraiosis-associated SVCI subjects in the resting state. (a) The bilateral medial frontal gyrus, (b) the bilateral medial temporal gyrus, (c) the bilateral superior parietal lobe, (d) the bilateral angular gyrus, (e) the bilateral occipital lobes, and (f) the posterior cingulate ortex/precuneus

Table 2 Areas with lower activity in the leukoaraiosis-associated SVCI group than in the control group

Position	Hemisphere	MNI[a] coordinates (mm)			T	*p*
		X	Y	Z		
Occipital lobe	right	45	–66	–39	4.07	0.051
Anterior cingulate cortex/medial frontal	right	–3	27	30	4.04	0.008
Parahippocampal gyrus/uncinate gyrus	right	36	–15	–27	3.75	0.009
Inferior temporal gyrus	right	30	–42	3	3.72	0.023
Middle frontal gyrus white matter/anterior caudate nucleus	left	–42	6	36	3.71	0.045
Basal ganglia region	right	33	–12	9	3.73	0.170
Posterior cingulate cortex	left	0	–57	6	3.59	0.077

[a]Montreal Neurological Institute.

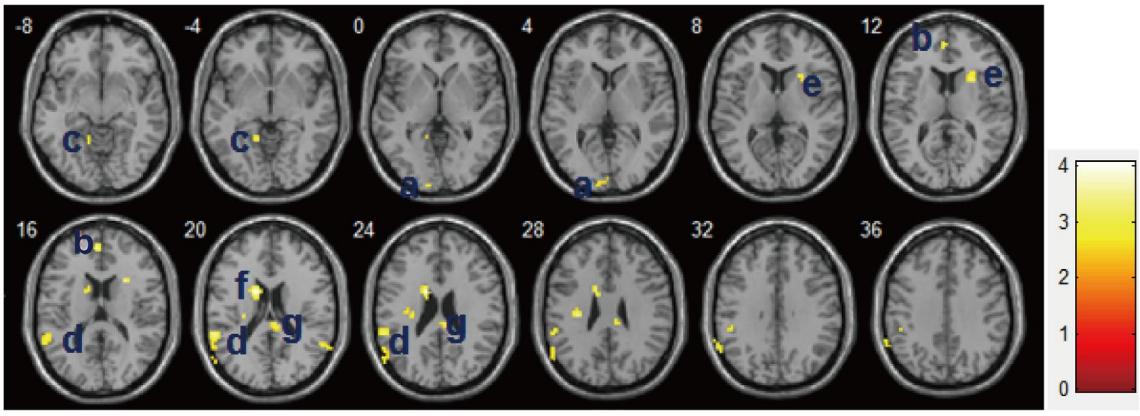

Figure 3 Regions with lower activity in the leukoaraiosis-associated SVCI subjects compared to control subjects. (a) The right occipital lobe, (b) the anterior cingulate cortex/the right medial frontal lobe, (c) the right parahippocampal gyrus/the uncinate gyrus, (d) the right inferior temporal gyrus, (e) the left middle frontal gyrus white matter/the caudate nucleus, (f) the right basal ganglia region, (g) the posterior cingulate cortex

Results

The active areas of resting-state DMN

The active areas involved in the resting-state DMN of the control group are shown in Fig. 1. The active areas included the bilateral medial frontal gyrus (a), the bilateral medial temporal gyrus (b), the bilateral superior parietal lobe (c), the bilateral angular gyrus (d), the bilateral occipital lobe (e), and the posterior cingulate cortex/precuneus (f).

The active areas of resting-state DMN of LA-associated SVCI group are shown in Fig. 2. They were similar to

Table 3 Areas with higher activity in the leukoaraiosis-associated SVCI group than in the control group

Position	Hemisphere	MNI[a] coordinates (mm)			T	*p*
		X	Y	Z		
Caudate nucleus	left	–15	3	21	4.45	0.015
Frontal lobe	right	33	–30	63	4.18	0.004
Superior temporal gyrus/inferior parietal gyrus	left	–57	–42	21	3.93	0.001
Posterior cingulate cortex/precuneus	left	6	–30	24	3.32	0.138

[a]Montreal Neurological Institute.

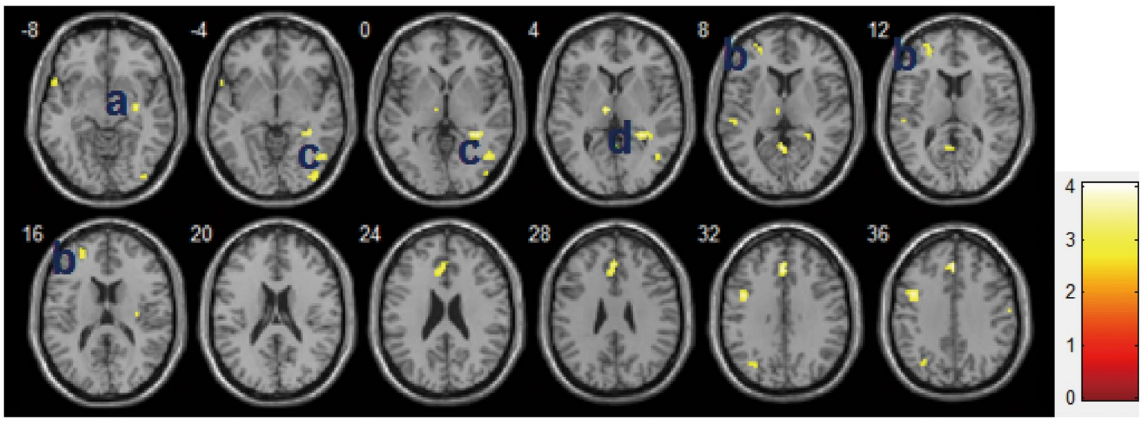

Figure 4 Regions with higher activity in the leukoaraiosis-associated SVCI subjects compared to control subjects. (a) The left caudate nucleus, (b) the right frontal lobe, (c) the left superior temporal gyrus/the inferior parietal gyrus, (d) the left posterior cingulate cortex/the precuneus

those of the control group, including the bilateral medial frontal gyrus (a), the bilateral medial temporal gyrus (b), the bilateral superior parietal lobe (c), the bilateral angular gyrus (d), the bilateral occipital lobes (e), and the posterior cingulate cortex/precuneus (f).

Differences in neuroimaging signal intensity of the resting-state DMN

The LA-associated SVCI group exhibited several areas with lower BOLD signals in the resting state compared with the control group (Table 2 and Fig. 3). The anterior cingulate cortex/right medial frontal lobe (b, $p = 0.008$), the right parahippocampal gyrus (c, $p = 0.009$), the right inferior temporal gyrus (d, $p = 0.023$), and the left middle frontal gyrus white matter/the anterior caudate nucleus (e, $p = 0.045$) showed the most significant differences between these two groups.

There were a few areas with higher BOLD signals in the resting state in the LA-associated SVCI group compared with the control group (Table 3 and Fig. 4). These areas included the left caudate nucleus (a, $p = 0.015$), the right frontal lobe (b, $p = 0.004$), and the left superior temporal gyrus/inferior parietal gyrus (c, $p = 0.001$). No significant difference was observed in the left posterior cingulate cortex/precuneus (d, $p = 0.138$).

Discussion

The present study collected rs-fMRI data from LA-associated SVCI patients and controls in the resting state. Active brain areas of the controls in the resting state included the bilateral medial prefrontal cortex, bilateral medial temporal gyrus, bilateral inferior parietal lobule, angular gyrus, bilateral occipital lobe, and posterior cingulate cortex/precuneus, which were consistent with the findings of previous studies.[10,12,13,19] Furthermore, active brain areas of the LA-associated SVCI patients in the resting state were found to be consistent with those of the controls. However, the neuroimaging signal intensity of the resting-state DMN was different between groups; and the areas with decreased activity in LA associated SVCI patients were different form previous studies in aMCI population.

Given that the areas involved in the DMN are associated with memory processing (especially the hippocampus), and that many studies have indicated the decreased activity in DMN areas during executing cognitive tasks,[9,14] it is proposed that the DMN is associated with cognitive processing[20,21] and it could be used to explore the mechanism of cognitive deficits, especially in patients with aMCI.

Studies of aMCI patients have revealed that the BOLD signaling activity of the brain decreases mostly in the medial and lateral parietal cortex.[22–24] A study combining rs-fMRI and cognitive tasks found that the activity decreased in the left medial temporal lobe, left medial temporal gyrus, posterior cingulate cortex/cingulate, lower precuneus and the right angular convolution apart from the lateral prefrontal cortex, and memory impairment was positively correlated with the activity of the left lateral prefrontal lobe and the right angular convolution (Table 4).[15]

Table 4 Alteration of DMN[a] in SVCI[b] [16], LA associated SVCI, aMCI[c] patients[15] (results from previous studies)

	Activity Increased Regions	Activity Decreased Regions
SVCI[b]	Right posterior cingulate/precuneus, right hippocampus/ thalamus	Bilateral medial frontal cortex
aMCI[c]	Middle cingulate cortex, medial prefrontal cortex and left inferior parietal cortex	Lateral prefrontal cortex, left medial temporal lobe, left medial temporal gyrus, posterior cingulate cortex/retrosplenial cortex/precuneus and right angular gyrus

[a]default mode network.
[b]subcortical vascular cognitive impairment.
[c]amnestic mild cognitive impairment.

Rombouts and colleagues[24] observed a decreased activity of the DMN in normal subjects and aMCI patients during completing visual coding tasks and spatial working memory tasks, finding that activity of the DMN in aMCI patients decreased more than that of normal subjects. One study exploring the connections between DMN regions in patients with aMCI indicated that the connections between the medial temporal gyrus and the hippocampus, and between the precuneus/posterior cingulate cortex and the hippocampus decreased.[25] Dysfunction in these connections was correlated with deficits in the semantic memory and learning. This finding highlights the importance of changes in DMN connectivity in aMCI pathogenesis.[26]

A recent study[16] combining structural MRI and rs-fMRI on 26 SVCI patients and 28 healthy controls showed decreased low-frequency oscillation amplitudes in the anterior part of the resting-state DMN (e.g. the media prefromtal cortex) and decreased functional connectivity of the DMN regions in SVCI patients compared with healthy controls. However, some of the resting-state DMN regions, including the posterior part of the DMN (e.g. the right posterior cingulate/adjacent precuneus), the right hippocampus, and the right thalamus, exhibited increased low-frequency oscillation amplitudes in SVCI patients compared with healthy controls (Table 4). This finding was quite different from previous studies in aMCI population.[22–24] In the resting-state fMRI study in SVCI population mentioned above, it was shown that the overall pattern of functional alterations remained unchanged after calibrating the volume loss of the structural gray matter.[16] This suggests that functional alterations can only be partially explained by the volume change of the gray matter. These findings imply that the difference of the functional alterations of the resting-state DMN might be a distinguishing feature between SVCI and aMCI patients, which still needs further investigation.

In the present study, activity of the resting-state DMN in LA-associated SVCI patients significantly decreased in the anterior cingulate gyrus/the right medial frontal gyrus, the right parahippocampal gyrus/the uncinate gyrus, the right inferior temporal gyrus and the left middle frontal gyrus white matter/the anterior caudate nucleus and significantly increased in the left caudate nucleus/ the cingulate gyrus, the right frontal and the left superior temporal/the inferior parietal gyrus compared with that of the control subjects. The areas with decreased activity in LA-associated SVCI patients were different form previous studies in aMCI population.[22–24] The majority of areas that showed decreased activity were associated with cognitive processing (medial prefrontal cortex, hippocampus, and inferior temporal gyrus). We, therefore, believe that the cognitive impairment of LA-associated SVCI patients was associated not only with the damage in the Papez circuit which is involved in memory, but also with the decreased activity in the above-mentioned areas.[27] However, this finding needs to be further verified in a larger sample size study.

Possible explanations for the differences in rs-fMRI patterns between LA-associated SVCI patients and aMCI patients are discussed below:

(1) The population in the present study were different from those of other studies. Many studies examined aMCI patients but did not specifically analyze rs-fMRI in LA-associated SVCI patients. This difference might explain why the findings of the present study were inconsistent with those of other studies.
(2) The age of the subjects in the present study was different from that of other studies. Greicius *et al.* demonstrated that the scope of the resting-state DMN was larger in elder population than that of the younger ones. In elder subjects, the area of the resting-state DMN included the inferior frontal lobe, the middle orbital cortex, the medial and lateral temporal cortex, as well as the same areas of the resting-state DMN that was activated in younger subjects.[28] These findings indicate that the resting-state DMN is associated with aging. The present study focused on middle-aged and elderly subjects, whereas some other studies have focused on middle-aged and younger subjects. The difference of age is likely to influence the areas of the resting-state DMN.

The present study has a few limitations, which should be acknowledged. 1) The sample size of the present study was small. As a result, it was impossible to perform correlation analysis between the types of cognitive impairment and the active areas in the resting state. 2) The present study focused solely on patients with LA-associated SVCI. Therefore, the relationship between the severity of cognitive deficits and the impaired resting-state DMN was not included in the correlation analysis. 3) For the same reason as point 2, the differences in the areas and the neuroimaging signal intensity of the resting-state DMN between different caused cognitive impairment were not studied.

Subsequent studies should increase the sample size and investigate the nature of the resting-state DMN in patients with cognitive deficits that are due to other causes (e.g. MCI that is the preclinical state of AD).

In conclusion, the present study provides neuroimaging evidence for the detection of LA-associated SVCI. Moreover, the differences in the functional alterations of the DMN might be a distinguishing feature between SVCI and aMCI patients, which still needs further investigation.

Abbreviations

AD = Alzheimer's disease
aMCI = amnestic mild cognitive impairment
BOLD = blood oxygen level-dependent
CDR = Clinical Dementia Rating
DMN = default-mode network
fMRI = functional magnetic resonance imaging
GLM = General Linear Model
ICA = independent component analysis
LA = leukoaraiosis
MMSE = Mini Mental State Exam
MoCA = Montreal Cognitive Assessment
rs-fMRI = resting-state functional magnetic resonance imaging
SVCI = subcortical vascular cognitice impairment

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References

1 Hachinski VC, Potter P, Merskey H. Leuko-Araiosis. Arch Neurol. 1987;44:21–23.
2 Wen W, Sachdev PS, Li JJ, Chen X, Anstey KJ. White matter hyperintensities in the forties: their prevalence and topography in an epidemiological sample aged 44–48. Hum Brain Mapp. 2009;30:1155–1167.
3 Lamar M, Dannhauser TM, Walker Z, Rodda JE, Cutinha DJ, Shergill SS. Memory complaints with and without memory impairment: the impact of leukoaraiosis on cognition. J Int Neuropsychol Soc. 2011;17:1104–1112.
4 Price CC, Jefferson AL, Merino JG, Heilman KM, Libon DJ. Subcortical vascular dementia: Integrating neuropsychological and neuroradiologic data. Neurology. 2005;65:376–382.
5 Ross ED, Hansel SL, Orbelo DM, Monnot M. Relationship of leukoaraiosis to cognitive decline and cognitive aging. Cogn Behav Neurol. 2005;18:89–97.
6 Te M, Zhao E, Zheng X, Sun Q, Qu C. Leukoaraiosis with mild cognitive impairment. Neurol Res. 2015;37:410–414.
7 Mazoyer B, Zago L, Mellet E, Bricogne S, Etard O, Houde O, *et al*. Cortical networks for working memory and executive functions sustain the conscious resting state in man. Brain Res Bull. 2001;54:287–298.
8 Biswal B, Yetkin FZ, Haughton VM, Hyde JS. Functional connectivity in the motor cortex of resting human brain using echo-planar mri. Magn Reson Med. 1995;34:537–541.
9 Buckner RL, Andrews-Hanna JR, Schacter DL. The brain's default network: anatomy, function, and relevance to disease. Ann NY Acad Sci. 2008;1124:1–38.
10 Raichle ME, MacLeod AM, Snyder AZ, Powers WJ, Gusnard DA, Shulman GL. A default mode of brain function. Proc Nat Acad Sci USA. 2001;98:676–682.
11 Shulman GL, Fiez JA, Corbetta M, Buckner RL, Miezin FM, Raichle ME, *et al*. Common blood flow changes across visual tasks: II. Decreases in cerebral cortex. J Cogn Neurosci. 1997;9:648–663.
12 Esposito F, Bertolino A, Scarabino T, Latorre V, Blasi G, Popolizio T, *et al*. Independent component model of the default-mode brain function: ass essing the impact of active thinking. Brain Res Bull. 2006;70:263–269.
13 Greicius MD, Menon V. Default-mode activity during a passive sensory task: uncoupled from deactivation but impacting activation. J Cogn Neurosci. 2004;16:1484–1492.
14 Buckner RL, Snyder AZ, Shannon BJ, LaRossa G, Sachs R, Fotenos AF, *et al*. Molecular, structural, and functional characterization of alzheimer's disease: evidence for a relationship between default activity, amyloid, and memory. J. Neurosci: Official J Soc Neurosci. 2005;25:7709–7717.
15 Jin M, Pelak VS, Cordes D. Aberrant default mode network in subjects with amnestic mild cognitive impairment using resting-state functional MRI. Magn Reson Imaging . 2012;30:48–61.
16 Yi L, Wang J, Jia L, Zhao Z, Lu J, Li K, *et al*. Structural and functional changes in subcortical vascular mild cognitive impairment: a combined voxel-based morphometry and resting-state fMRI study. PLoS One. 2012;7:e44758.
17 Oghabian MA, Batouli SA, Norouzian M, Ziaei M, Sikaroodi H. Using functional magnetic resonance imaging to differentiate between healthy aging subjects, mild cognitive impairment, and Alzheimer's patients. J Res Med Sci. 2010;15:84–93.
18 Fazekas F, Chawluk JB, Alavi A, Hurtig HI, Zimmerman RA. Mr. signal abnormalities at 1.5 t in Alzheimer's dementia and normal aging. AJR. Am J Roentgenol. 1987;149:351–356.
19 Damoiseaux JS, Rombouts SA, Barkhof F, Scheltens P, Stam CJ, Smith SM, *et al*. Consistent resting-state networks across healthy subjects. Proc Nat Acad Sci USA. 2006;103:13848–13853.
20 Morcom AM, Fletcher PC. Does the brain have a baseline? Why we should be resisting a rest. NeuroImage. 2007;37:1073–1082.
21 Morcom AM, Fletcher PC. Cognitive neuroscience: the case for design rather than default. NeuroImage. 2007;37:1097–1099.
22 Celone KA, Calhoun VD, Dickerson BC, Atri A, Chua EF, Miller SL, *et al*. Alterations in memory networks in mild cognitive impairment and Alzheimer's disease: an independent component analysis. J Neurosci. 2006;26:10222–10231.
23 Petrella JR, Wang L, Krishnan S, Slavin MJ, Prince SE, Tran TT, *et al*. Cortical deactivation in mild cognitive impairment: high-field-strength functional mr imaging. Radiology. 2007;245:224–235.
24 Rombouts SA, Barkhof F, Goekoop R, Stam CJ, Scheltens P. Altered resting state networks in mild cognitive impairment and mild Alzheimer's disease: an fMRI study. Hum Brain Mapp. 2005;26:231–239.
25 Bai F, Watson DR, Yu H, Shi Y, Yuan Y, Zhang Z. Abnormal resting-state functional connectivity of posterior cingulate cortex in amnestic type mild cognitive impairment. Brain Res. 2009;1302:167–174.
26 Yan H, Zhang Y, Chen H, Wang Y, Liu Y. Altered effective connectivity of the default mode network in resting-state amnestic type mild cognitive impairment. J Int Neuropsychol Soc. 2013;19:400–409.
27 Barber R, Gholkar A, Scheltens P, Ballard C, McKeith IG, O'Brien JT. MRI volumetric correlates of white matter lesions in dementia with lewy bodies and Alzheimer's disease. Int J Geriatr Psychiatry. 2000;15:911–916.
28 Greicius MD, Srivastava G, Reiss AL, Menon V. Default-mode network activity distinguishes Alzheimer's disease from healthy aging: evidence from functional MRI. Proc Nat Acad Sci USA. 2004;101:4637–4642.