

# Hemispheric difference of regional brain function exists in patients with acute stroke in different cerebral hemispheres—a resting-state fMRI study

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## Research

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# Abstract

**Objective:** To explore the different compensatory mechanisms of brain function between the patients with brain dysfunction after acute ischemic stroke (AIS) in dominant hemisphere and the non-dominant hemisphere, based on Resting-state Functional Magnetic Resonance

Imaging (Rs-fMRI).

**Methods:** In this trial, 15 healthy subjects(HS) were used as blank controls. 30 hemiplegic patients with middle cerebral artery acute infarction of the different dominant hemisphere were divided into the dominant hemisphere group (DH) and the non-dominant hemisphere group (NDH), scanned by a 3.0 T MRI scanner, to obtain the amplitude of low frequency fluctuations (ALFF) and regional homogeneity (ReHo) and compare the differences.

**Results:** Compared with the HS, increased ALFF values in the brain areas such as bilateral midbrain were observed in DH. While decreased ReHo values in the brain areas such as right postcentral gyrus (BA3) were also observed. Enhanced ALFF values in the brain areas such as left BA6, and enhanced ReHo values in the brain areas such as left precuneus were observed in NDH. And the ALFF and ReHo values of right BA9 and precentral gyrus were both increased. Compared with DH, NDH have lower ALFF values in left supplementary motor area and lower ReHo values in right BA10.

**Conclusion:** After acute infarction in the middle cerebral artery of the dominant hemisphere, a compensation mechanism is triggered in brain areas of the ipsilateral cortex regulating motor-related pathways, while some brain areas related to cognition, sensation and motor in the contralateral cortex are suppressed, and the connection with the peripheral brain regions is weakened. After acute infarction in the middle cerebral artery of the non-dominant hemisphere, compensatory activation appears in motor control-related brain areas of the dominant hemisphere. After acute middle cerebral artery infarction in the dominant hemisphere, compared with the non-dominant hemisphere, functional specificity in bilateral supplementary motor area weakens. After acute middle cerebral artery infarction in different hemispheres, there are hemispheric differences in the compensatory mechanism of brain function.

**Trial registration:** Ethics Committee of the China-Japan Union Hospital at Jilin University approval. Trial Registration Number:Chinese Clinical Trial Registry ChiCTR-IOR-15007672. Registered July 18, 2016 (No. 2016ks043).

## 1. Introduction

The brain is the most complex organ of human and research on it is the most advanced and popular field in life science. With the implementation of " Brain Plan ", more researchers nowadays are exploring cerebral functional changes with an aim to study various cerebral diseases.

As one of the cerebral diseases in the "brain program ", stroke is listed the primary cause of disability and death [1, 2] due to its characteristics of high incidence, high disability rate, and high mortality rate. The existing basic researches mainly concentrate on proteomics, genomics, and metabolomics<sup>[3-5]</sup>. Neuroimaging technology is a research focus in the field of in-vivo research on post-stroke injury. With the continuous development of neuroimaging technology, neuroimaging diagnosis is no longer limited to observing the changes in brain

histomorphology, but has entered the stage of comprehensive diagnosis by combining brain morphology with function<sup>[6]</sup>. Particularly, understanding of cerebral reorganization after the injury in the central nervous system has been increased significantly through the non-invasive examination of functional MRI.

Functional magnetic resonance imaging (fMRI) is one of the representative neuroimaging techniques and can be divided into task state fMRI technology and resting state fMRI technology (resting-state fMRI, rs-fMRI). Under rest state, Rs-fMRI<sup>[7, 8]</sup> receives feedback on neuronal activity by detecting the change of the hemodynamics in the local brain area after the spontaneous cerebral function activity and measuring the change of deoxyhemoglobin content. It can also reflect the pathophysiological changes of cerebral functions in resting state and directly display the location, range, and size of the activated area of cerebral functions with accurate positioning. This is beneficial to compare the rs-fMRI results of acute ischemic stroke in different lesions and is more meaningful for stroke patients with dysfunction in clinical diagnosis and treatment evaluation<sup>[9]</sup>.

At present, clinical researchers have utilized different analytical methods of rs-fMRI to study a variety of brain diseases. However, most studies only use a single parameter (ALFF/fALFF/ReHo/FC) of rs-fMRI to observe local or overall functional changes in the brain after stroke<sup>[10, 11]</sup>. Moreover, functional disorders in patients with acute stroke in the dominant hemisphere (left hemisphere) differ significantly from those in non-dominant hemisphere (right hemisphere) clinically. Physiologically, there are hemispheric differences between dominant hemisphere and non-dominant hemisphere in neuroanatomy, physiology, neurotransmitter, and control of sympathetic nerves<sup>[12]</sup>.

However, specific effects of dominant hemispheric and non-dominant hemispheric infarctions on brain function reorganization have not been reported in human trials, and there is a lack of rs-MRI studies on hemispheric differences of brain function after acute stroke.

Therefore, this study aims to explore the difference of brain function between dominant hemisphere and non-dominant hemisphere after acute middle cerebral artery infarction using two parameters of rs-fMRI - amplitude of low-frequency fluctuation (ALFF) and regional homogeneity (ReHo) .

## 2. Methods

### 2.1 Study design

Exploratory case-control study

### 2.2 Participants

Ethical approval was obtained from the Ethics Committee of China-Japan Union Hospital of Jilin University on July 18, 2016 (No: 2016ks043). Participants aged 40–70 years old were recruited from January to December 2017 in this hospital. And written informed consent was obtained from each participant.

#### 2.2.1 Health subjects

15 healthy subjects were recruited into the normal group(HS). The inclusion criteria include:(1)moderate figure, regardless of gender; (2)regular diet and normal sleep, no addiction to smoking or alcohol, no tea or coffee for

24 hours; (3) no head acupuncture and physiotherapy performed in the last one month; (4) right hand; Must meet all the above conditions. The exclusion criteria include: (1) having history of stroke; (2) sensory aphasia/mixed aphasia/claustrophobia/dementia, or other factors affecting communication and operation during the experiment; (3) pregnant and lactating women; (4) having metallic substances in the body (e.g. heart stents); (5) cerebral vascular pathological variation; (6) cardiovascular, renal and liver diseases, tumors, or other diseases affecting the test results; (7) having underlying hypertension or diabetes or thyroid disease, and the recent disease control is not stable. Any of the above conditions shall be excluded.

## 2.2.2 Patients

1983 stroke patients with acute stroke were consecutively selected from the Department of Neurology. Based on the complexity and particularity of fMRI image acquisition and data statistics of stroke patients, this paper estimates the sample size of fMRI study. Referring to the systematic review<sup>[13]</sup> and statistical analyses<sup>[14]</sup> on estimating sample size in functional MRI, and considering 20% of shedding rate, 15 patients were included in the dominant hemisphere group (DH) and the non-dominant hemisphere group (NDH) respectively. The inclusion criteria include: (1) meet the diagnostic criteria of Chinese Guidelines for Diagnosis and Treatment of Acute Ischemic Stroke, 2014 by the Neurology Branch of Chinese Medical Association and the Cerebrovascular Disease Group of the Neurology Branch of Chinese Medical Association; (2) first-ever ischemic stroke, within 72 hours after symptoms appear; (3) limb motor and sensory deficits; (4) stroke lesions locate within the right or left middle cerebral artery (MCA) territory, as verified by magnetic resonance imaging (MRI) or computed tomography (CT); (5) in stable condition; (6) normal diet and sleep, no addiction to smoking, alcohol, tea or coffee; (7) right hand; Must meet all the above conditions. The exclusion criteria include: (1) hemorrhagic stroke, as verified by CT; (2) sensory aphasia/mixed aphasia/claustrophobia/dementia, or other factors affecting communication and operation during the experiment; (3) pregnant and lactating women; (4) having metallic substances in the body (e.g. heart stents); (5) cerebral vascular pathological variation; (6) cardiovascular, renal and liver diseases, tumors, or other diseases affecting the test results; (7) having underlying hypertension or diabetes or thyroid disease, and the recent disease control is not stable. Any of the above conditions shall be excluded.

## 2.3 MRI data acquisition

The MRI system (Siemens 3.0T, Siemens Healthineers, Germany) and the standard head coil were used to obtain data of T1MPRAGE and rs-fMRI (EPI sequence). The technician asked the participants to lie on the MRI scanning bed and fixed their heads in the coil with foam pads to keep their heads still. Participants were required to remain awake, keep calm breathing, cover their eyes with a black eye mask, plug their ears with sponge earplugs, and try not to engage in specific thinking activities during the scanning.

T1MPRAGE scanning parameters: 3 D TFE sequence cross section scan, a high-resolution anatomical image T1WI of the whole brain is obtained. Scanning parameters: repetition

time/echo time ratio = 2300 ms/2.45 ms, flip angle = 8°, field of view (FOV) = 250 × 250 mm, slice thickness = 1 mm, Voxel = 1.0 mm × 1.0 mm, Matrix = 256 × 256, number of slices = 192.

fMRI-BOLD scanning parameters: Single excitation echo plane imaging (EPI) technique was used for horizontal axis scanning. Pulse time (TR) = 2000 ms, echo time (TE) = 30 ms, flip Angle = 90°, slice thickness = 3.5 mm,

slice spacing = 0.7 mm, voxel = 3.5 mm × 3.5 mm × 3.5 mm, field of view (FOV) = 224 cm × 224 mm, phases per location = 240, matrix = 64 × 64, number of slices = 37, covering a total of 8 minutes.

## 2.4 Data processing

ALFF and ReHo values of the three groups were calculated, respectively, based on Matlab 2012a platform and by using the DPABI toolkit to launch statistical parameter maps (SPM 12) after removing time point, time correction, head movement correction, registration, de-linear drift, covariate removal, and image filtering, etc. Then, based on the two independent samples t test in rest 1.8 software package, the three sets of data were compared and analyzed, respectively, to get statistical parameters maps. We identified and corrected (AlphaSim correction, Cluster Size 27, rmm = 4,  $P < 0.005$ ) the statistical parameter maps to achieve the anatomical location and activation intensity of brain regions with significant changes in ALFF and ReHo. The maps were finally calibrated by an experienced neurologist with anatomical knowledge and clinical experience. When DH or NDH was compared with HS, sex, age, and head movements were used as covariates; When DH and the NDH were compared, sex, age, course of disease, systolic blood pressure, diastolic blood pressure and NHISS score were used as covariates.

In addition, data such as gender were measured by  $\chi^2$  test and other data like age were checked by t-test. Statistical analysis was completed with statistical software SPSS20.0.

## 3. Results

### 3.1 General information

According to the diagnostic inclusion and exclusion criteria, 30 patients were selected into patient groups from 1983 patients suspected of acute ischemic stroke. 5 cases in DH and 3 in NDH failed to complete fMRI-BOLD data collection as participants were unable to withstand long magnetic resonance scans. The EPI scanning parameters of 2 cases in NDH were different from the experimental design and the data were thus stripped out. Participants in 1 case of the noamal group fell asleep during the test, and 2 cases had different T1 MPRAGE scanning parameters from the experimental design and the data were all removed. Flowchart of participants is shown in Fig.1.

There were no significant differences among the three groups in their gender, course of disease, systolic and diastolic blood pressure, and NHISS scores ( $P > 0.05$ ) (Table 1). However, the age difference of the included subjects in the three groups was statistically significant ( $P < 0.05$ ) (Table 1).

Table 1: Demographic and clinical characteristics of all patients in three groups.

Group	Case (n)	Gender (case)		Age (year)	Course of disease	systolic pressure (mmHg)	diastolic pressure (mmHg)	NIHSS
		male	female					
HS	12	4	8	56.17±3.83	\	\	\	\
DH	10	7	3	63.70±6.00	2.15±0.94	147.80±13.14	84.90±10.07	5.30±4.99
NDH	10	8	2	59.40±7.65	2.10±0.88	152.90±12.34	90.40±10.74	3.80±1.03
S statistics		$\chi^2=5.728$		F=4.437	t=0.123	t=-0.895	t=-1.181	t=0.931
P Value		0.057		0.021	0.904	0.383	0.253	0.374

Notes: Values presented are mean ± SD (range) or median [IQR]. NIHSS= National Institutes of Health Stroke Scale.

### 3.2 fMRI results

#### 3.2.1 Normal Group VS Dominant hemisphere Group

Compared with HS, DH showed significantly increased ALFF values in right midbrain and lobus anterior cercbelli, extending to vermis including cerebellar lingual, and in left midbrain and mammillary body.

Increased ReHo values appeared mainly in the left caudate tai, extending to pulvinar in DH. On the contrary, the ReHo values decreased mainly in right inferior orbital gyrus (including BA47), triangular inferior frontal gyrus BA45, supra marginal and postcentral gyrus (mostly in BA3) extending to the precentral gyrus (BA4). (Table 2, Fig.2, and Fig. 3)

Table 2 Regions of DH showing significant changes in ALFF and ReHo values compared with HS

Parameter	Effect	Brain region	MNI coordinate			Intensity (T-value)
			X	Y	Z	
ALFF	Enhanced	Right midbrain, lobus anterior cercbelli and Vermis	9	-33	-18	5.6226
	Enhanced	Left Midbrain and Mammillary Body	-3	-12	-12	5.0006
ReHo	Enhanced	Left Caudate Tai and Pulvinar	-21	-36	15	5.3222
	Reduced	Right inferior orbital gyrus (including BA47)	27	33	-9	-5.1493
	Reduced	Right triangular inferior frontal gyrus BA45	48	30	24	-7.3696
	Reduced	Right supramarginal gyrus	66	-42	30	-4.876
	Reduced	Right postcentral gyrus (mostly in BA3) and precentral gyrus (BA4)	60	-15	30	-6.2719

Note: X Y Z represent the brain space position axis respectively in the MiNi standardized spatial coordinate system in the left and right, front and back and up and down position of the coordinate position.

### 3.2.2 Normal Group VS Non-dominant hemisphere Group

Compared with HS, ALFF values of NDH increased significantly mainly in left inferior orbital gyrus(including BA47) ,extending to left BA25, mainly in the left cerebellum anterior lobe (including cerebellar lingual) and Vermis, in left lentiform nuclei and globus pallidus, in medial dorsal nucleus, extending to left midbrain, in right caudate head, in left BA6 and paracentral lobule. On the contrary, the ALFF values decreased in right BA9 and precentral gyrus.

ReHo values were increased mainly in left Precuneus (BA7) and rectal gyrus, extending to orbital gyrus (including BA11), mainly in left parahippocampal gyrus, extending to BA47.

In contrast, the ReHo values decreased mainly in the left cerebellum posterior lobe , tubera valvulae, right BA9 and precentral gyrus. (Table 3, Fig.4, and Fig. 5)

Table 3 Regions of NDH showing significant changes in ALFF and ReHo values compared with HS

Parameter	Effect	Brain region	MNI coordinate			Intensity (T-value)
			X	Y	Z	
ALFF	Enhanced	Left inferior orbital gyrus (including BA47), BA25	-15	12	-24	6.8358
	Enhanced	Left cerebellum anterior lobe (including cerebellar lingual) and Vermis	0	-39	-28	4.633
	Enhanced	Left lentiform nuclei and globus pallidus	-9	3	3	7.4651
	Enhanced	Left medial dorsal nucleus and midbrain	-3	-12	3	5.3041
	Enhanced	Right caudate head	9	6	0	6.6047
	Enhanced	Left BA6 and paracentral lobule	-3	-15	66	5.0251
	Reduced	Right BA9 and precentral gyrus	57	9	36	-4.9502
ReHo	Enhanced	Left precuneus(BA7)	-9	-54	45	5.1723
	Enhanced	Left rectal gyrus and orbital gyrus (including BA11)	-6	33	-27	4.5542
	Enhanced	Left parahippocampal gyrus and BA47	-15	6	-24	4.386
	Reduced	Left cerebellum posterior lobe and tubera valvulae	-30	-75	-36	-5.4037
	Reduced	Right BA9 and precentral gyrus	54	12	36	-5.0544

Note: X|Y|Z represent the brain space position axis respectively in the MiNi standardized spatial coordinate system in the left and right, front and back and up and down position of the coordinate position.

### 3.2.3 Non-dominant hemisphere Group VS Dominant hemisphere Group

Compared with NDH, DH indicated significantly decreased ALFF values mainly in left supplementary motor area(including BA6). While decreased ReHo values appeared mainly in the right BA10. (Table 4, Fig.6 and Fig.7)

Table 4, Regions of DH showing significant changes in ALFF and ReHo values compared with NDH

Parameter	Effect	Brain region	MNI coordinate			Intensity (T-value)
			X	Y	Z	
ALFF	Reduced	Left supplementary motor area(including BA6)	-12	15	63	-4.9172
ReHo	Reduced	Right BA10	30	69	9	-5.6143

## 4. Discussion

In this study, changes of the brain function in patients after acute stroke were observed, and differences between the dominant hemisphere and the non-dominant hemisphere were explored through ReHo and ALFF. For now, this is the first rs-fMRI study to compare the hemispheric differences of brain functions after stroke, especially in acute period. Analyses of these differences are demonstrated as follows.

### 4.1 Normal Group (HS) VS Dominant hemisphere Group (DH)

Compared with HS, the ALFF values of changed brain regions in DH were mainly activated, which means the focal neuronal activities of these regions enhanced.

The midbrain, as the reflex center of vision and hearing, participates in the information feedback link of the closed-loop control system and can modify an executing movement in time. This is part of the typical theory of motion control<sup>[15]</sup>. The cerebellar vermis(including cerebellar lingual) belongs to the anterior cerebellum and plays an important role in the transmission and feedback of the brain-cerebellar sensorimotor network<sup>[16, 17]</sup>. The mammillary body related to the operation of emotions is a part of the limbic system of the brain. According to some literatures<sup>[18]</sup>, fierce emotions can affect the control of movement and produce significant behavioral responses to posture patterns or motor strategies.

Both the ALFF and ReHo values were enhanced in the left caudate tai and pulvinar. The pulvinar receives fibers from the inner and outer geniculate body and participates in the visual and auditory pathways<sup>[19-23]</sup>. Caudate tail is one of the important components of the extravertebral motor pathway that engages in the generation and regulation of motor planning.

As is well known, when the brain receives a specific action, command, signal sent by the cerebral cortex will pass through the outgoing fiber to the skeletal muscle motor endplate and finally complete the action. Motor planning generation, coordinated control of the action, and the feedback for correction are assisted by the cortex, basal ganglia, cerebellum, and midbrain. Therefore, it is speculated that due to the infarction of the middle cerebral artery in the dominant hemisphere, it is difficult for the motor cortex to send out accurate action task signals in contrast to healthy subjects. The signal and function of the brain areas involved in the regulation of movement are strengthened as compensation to ensure the integrity and accuracy of movement.

In addition, ReHo values of the right inferior orbital gyrus (including BA47), triangular inferior frontal gyrus (including BA45), postcentral gyrus (mostly BA3), central anterior gyrus (BA4), and supramarginal gyrus decreased. These brain areas are distributed in the blood supply area of the middle cerebral artery. Vincent has shown that there is a high correlation between bilateral hemispheric ipsilateral brain interval neural activity<sup>[24]</sup>. Therefore, after an acute stroke in the dominant hemisphere, the connection between the homologous brain regions of the non-dominant hemisphere and the peripheral brain regions weakens. Among these brain regions, BA45 is responsible for performing semantic tasks and text production<sup>[25]</sup>, BA47 is related to grammar processing of language<sup>[26]</sup>, the precentral gyrus (BA4) can control behavior and movement<sup>[27][26][26][25]</sup> the postcentral gyrus (BA3) manages somatosensory, and the upper marginal gyrus (BA40) is relevant with fine movement<sup>[28]</sup>. ALFF and ReHo values of some brain areas were not reduced in the dominant hemisphere, which may be related to the ischemic stroke classification (TOAST) and the compensation mechanism of cerebral collateral circulation<sup>[29]</sup>.

## 4.2 Normal Group VS Non-dominant hemisphere Group

Compared with HS, neuronal activities of the injured side and precentral gyrus in the non-dominant hemisphere weakened in NDH. The connection with peripheral brain regions was also reduced, which is consistent with the physiological changes caused by the responsible lesions. Precentral gyrus is the advanced motor control center, and BA9, BA6, and BA8 constitute the supplementary motor area. They serve as the main brain regions for motor sequence management and participate in the learning, planning, preparation, starting and production of movement<sup>[29]</sup>. Negative activation of these two brain regions matches the hemiplegic symptoms of patients.

Interestingly, brain regions with activated ALFF and ReHo values mainly locate in the dominant hemisphere. We believe this is due to the compensation of the uninjured hemisphere<sup>[32]</sup>. Paracentral lobule and the precentral gyrus constitute the primary motor cortex and participate in the stage of motor execution. BA6 belongs to part of the premotor cortex and mainly engages in the initial stage of motor preparation and planning<sup>[30, 31]</sup>. The supramarginal gyrus is related to fine motor<sup>[28]</sup>. Thalamus and lentiform nuclei are basal ganglia nuclei and play an important role in regulating complex and voluntary movement<sup>[33]</sup>. The lentiform nucleus, dorsomedial nucleus of the left thalamus, and the midbrain can control and purposefully perform active movement through two pathways: cortex-striatum (globus pallidus)-dorsal thalamus cortex and striatum midbrain (substantia nigra)-striatum. Precuneus are brain regions related to cerebrum's cognitive function<sup>[34]</sup>, which can analyze external stimuli and adjust the movement. As part of the cerebellum, the anterior lobe and superior vermis (including lingula of cerebellum) can coordinate the motor through the feedback path of cerebellum-thalamus-(pre) motor cortex. On the other hand, parahippocampal gyrus and cingulate cortex in BA25 are components of the limbic system and can make the cerebral cortex form higher cognitive connection and program movement to achieve ideal motor control effect<sup>[35]</sup>. According to the theory of motor control, sensation, cognition, and activity act together in the process of motor control. Based on the theory of neuroplasticity, activation of the upper brain areas indicates a new motor control network has established in the uninjured hemisphere soon after stroke, which can strengthen body movement coordination in many aspects and ensure active movement to the greatest extent.

In addition, orbital gyrus (including BA47), the orbital part of the left inferior frontal gyrus, and rectal gyrus (including BA11) were activated<sup>[36-39]</sup>. Related to human's emotion control, these are components of the

orbitofrontal cortex and regulate motor together with brain regions of the motor network mentioned above.

## **4.3 Dominant hemisphere Group VS Non-dominant hemisphere Group**

Compared with NDH, focal neuronal activities in BA6, the area responsible for motor guidance and sequence control, lessened in the left supplementary motor area in DH. BA10 is the brain area related to emotion control movement. After Stroke, the connection between BA10 and its peripheral brain areas also reduced at the uninjured-side hemisphere. This may be related to the specific influence on the functional impairment of the brain regions responsible for the sequential control of motor guidance in the motor brain network after the injury of the dominant hemisphere<sup>[40]</sup>.

## **4.4 Hemispheric differences in stroke can conduct the clinical application of transcranial direct current stimulation**

Early studies have found that when the cathode of tDCS (transcranial direct current stimulation) is close to the cell body or dendrite of nerve cells, the resting potential threshold increases and the discharge of neurons decreases, while the anode reduces the threshold of resting potential and increases the discharge of neurons<sup>[41]</sup>. Therefore, tDCS can regulate cortical excitability and has the function of nerve regulation. We believe that exploring the changes of brain function after acute stroke in different hemispheres is of great clinical significance for conducting the application of tDCS in the early phase. The cathode can be placed in the abnormal activation enhanced brain area to inhibit the local neuronal activity, while for the brain area with reduced function, the anode should be placed in the corresponding position to enhance the excitability of the neurons.

## **4.5 Limitations of the study**

This study also has some limitations. First of all, due to the high requirement of resting state functional magnetic resonance imaging on patients, although the sample size of this study was estimated according to the literature, but there was still a large drop-off rate, resulting in the study's sample size of only 10–12 cases. Secondly, this study only used ALFF and ReHo, the focal indicators of the rs-fMRI, to observe the changes in brain function of patients after acute stroke. And the results were not further discussed by the association between cerebral hemispheres after acute stroke, which needs to be verified in animal experiments.

## **5. Conclusion**

The findings of this study are as follows: 1) After acute infarction in the middle cerebral artery of the dominant hemisphere, a compensation mechanism is triggered in brain areas of the ipsilateral cortex regulating motor-related pathways, while some brain areas related to cognition, sensation and motor in the contralateral cortex are suppressed, and the connection with the peripheral brain regions is weakened. 2) After acute infarction in the middle cerebral artery of the non-dominant hemisphere, compensatory activation appears in motor control-related brain areas of the dominant hemisphere. 3) After acute middle cerebral artery infarction in the dominant hemisphere, compared with the non-dominant hemisphere, functional specificity in bilateral supplementary motor area weakens. After acute middle cerebral artery infarction in different hemispheres, there are hemispheric differences in the compensatory mechanism of brain function.

# Abbreviations

# Declarations

**Ethics approval and consent to participate** Trial Registration Number: Chinese Clinical Trial Registry ChiCTR-IOR-15007672. Approved No. of ethic committee: Ethics Committee of the China-Japan Union Hospital at Jilin University approval (No. 2016ks043). And written informed consent was obtained from each participant.

**Consent of publication:** Informed consent was obtained for publication of patient data.

**Availability of data and materials section:** All data generated or analysed during this study are included in this published article.

**Competing interests:** The authors declare that they have no conflict of interests or disclosures. And all the authors agree to publish this article.

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**Author contributions:** JQC and GL were the project holders and participants, also contributed to conception and study design. JCG, CHY and QXL were responsible for study follow-up; YJJ were responsible for fMRI acquisition. LPC and YJJ analysed the data. SYL and JZ was responsible for patients' recruitment, diagnosis and treatment. JCG and QXL wrote the manuscript. CHY and LPC revised the manuscript. JCG, CHY, and QXL's contributions to this article are tied for first place. All authors approved the final version of the paper.

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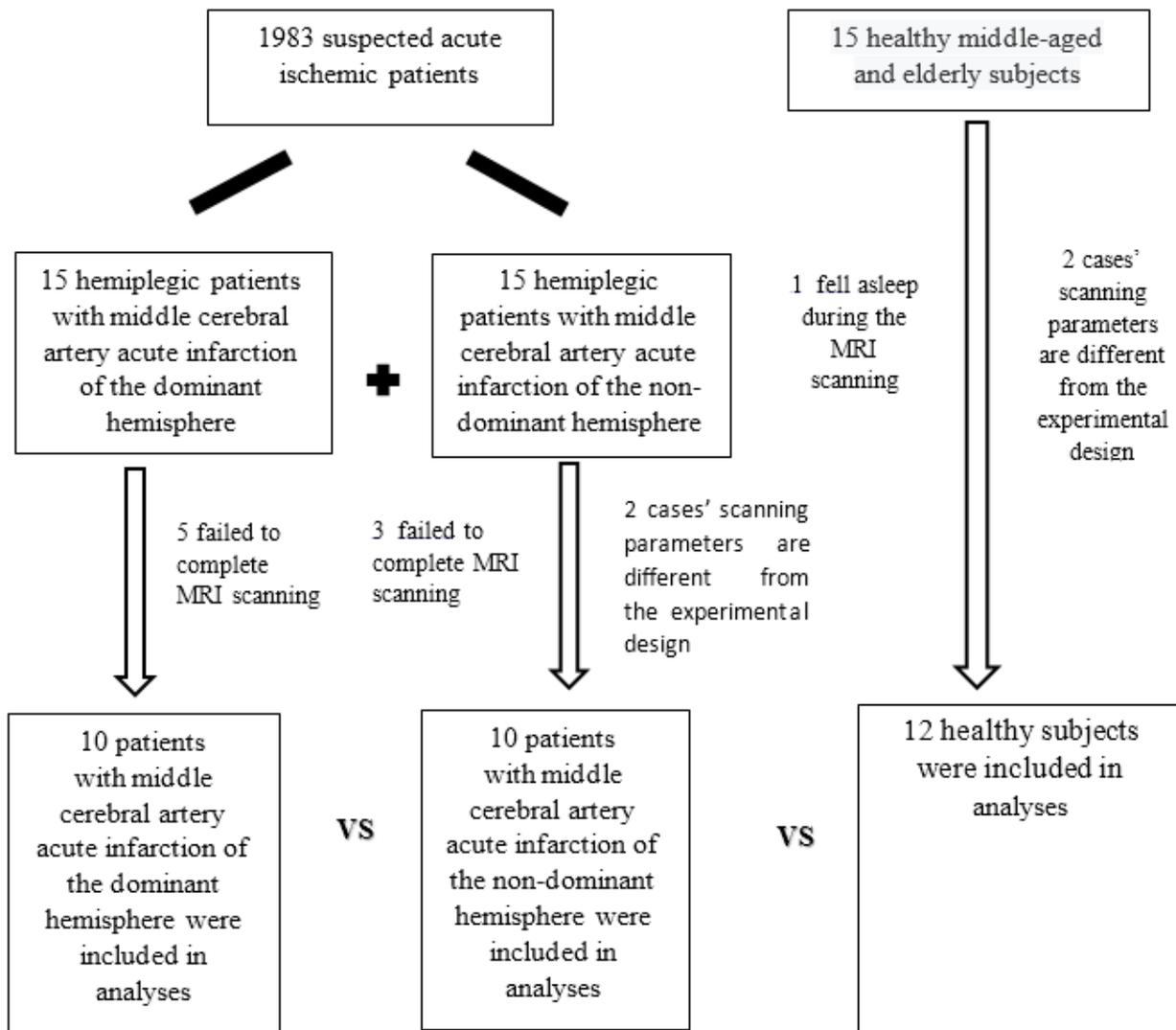
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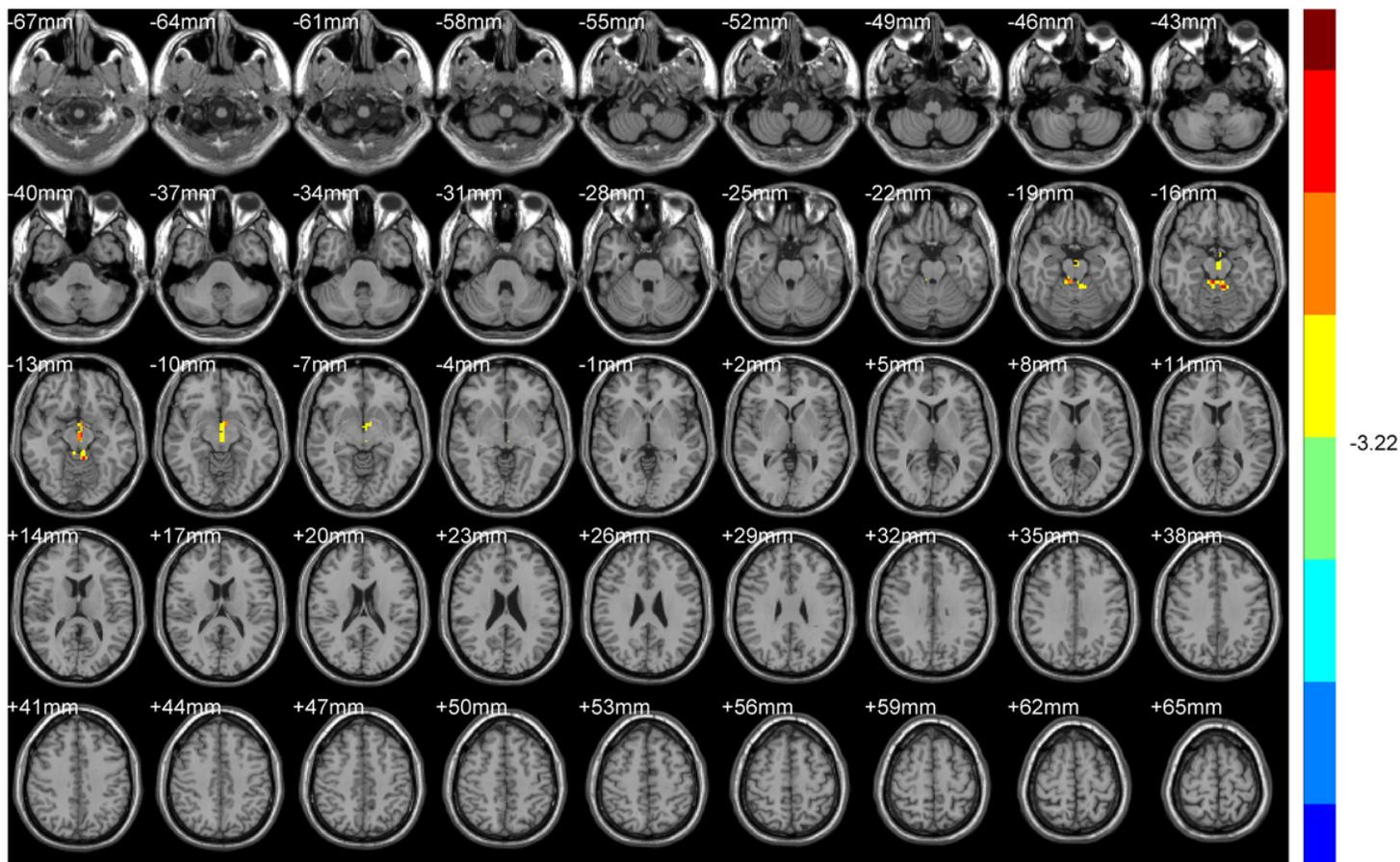
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## Figures



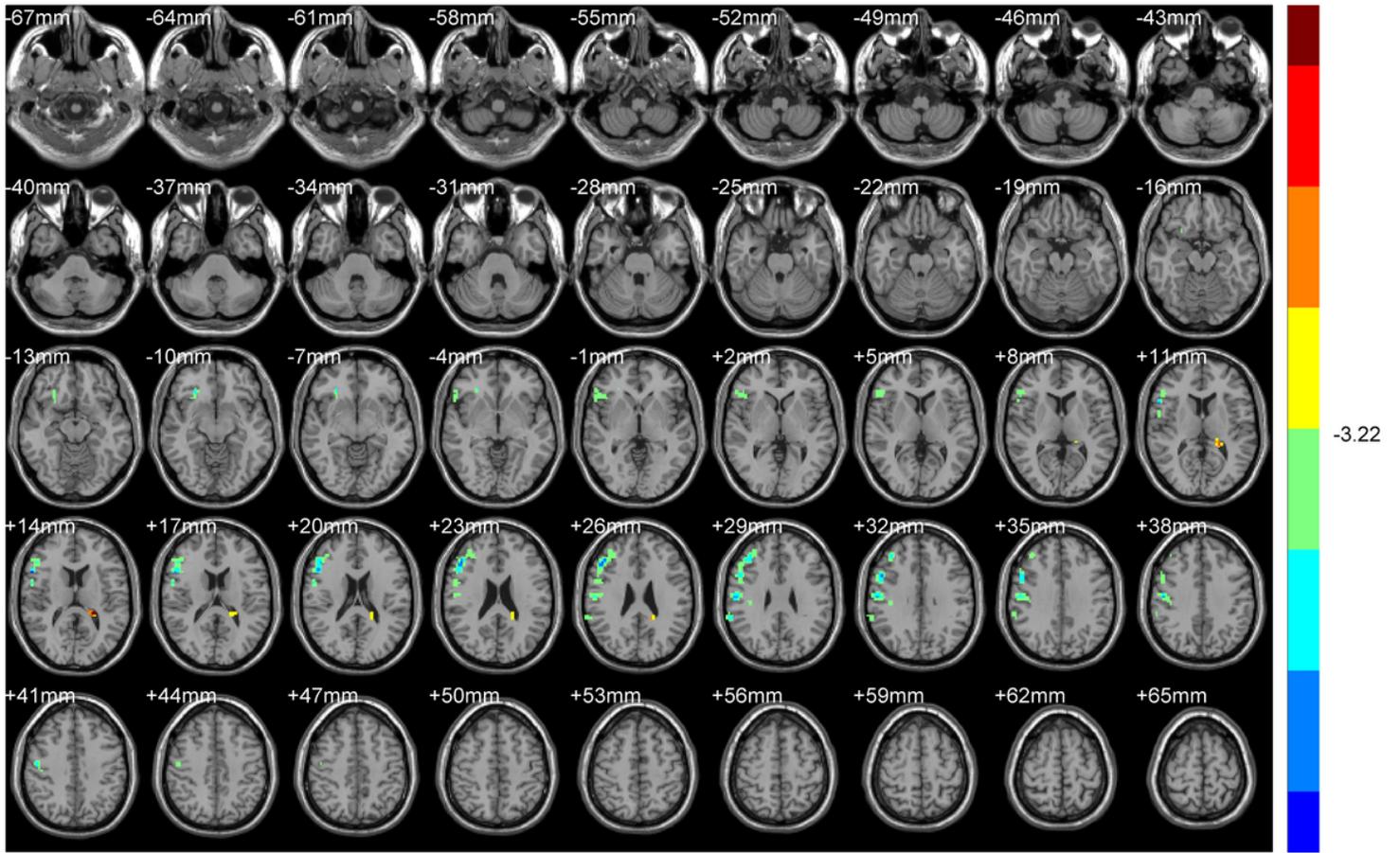
**Figure 1**

Integration of stroke patients and healthy subjects



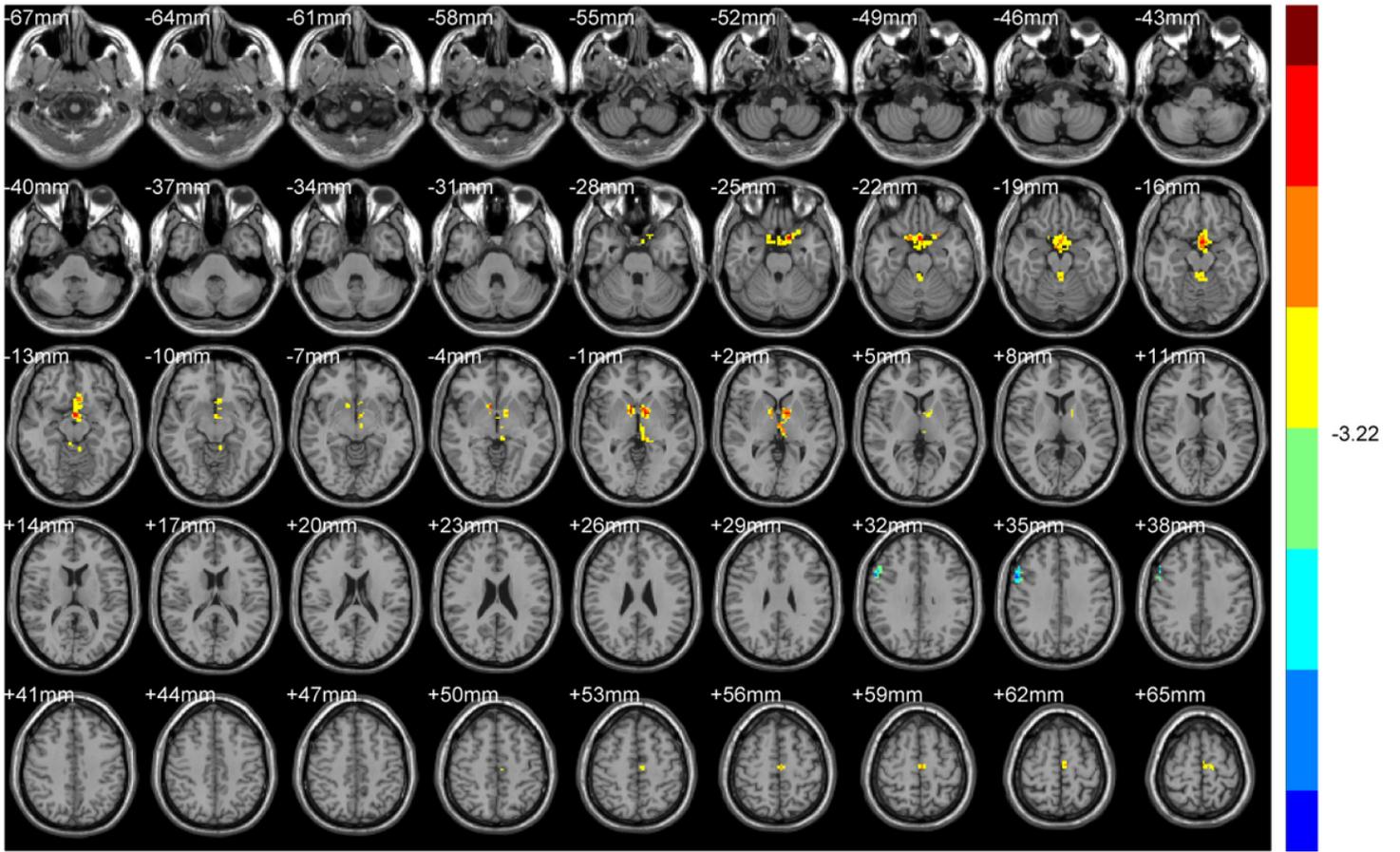
**Figure 2**

ALFF(Dominant hemisphere VS Normal)



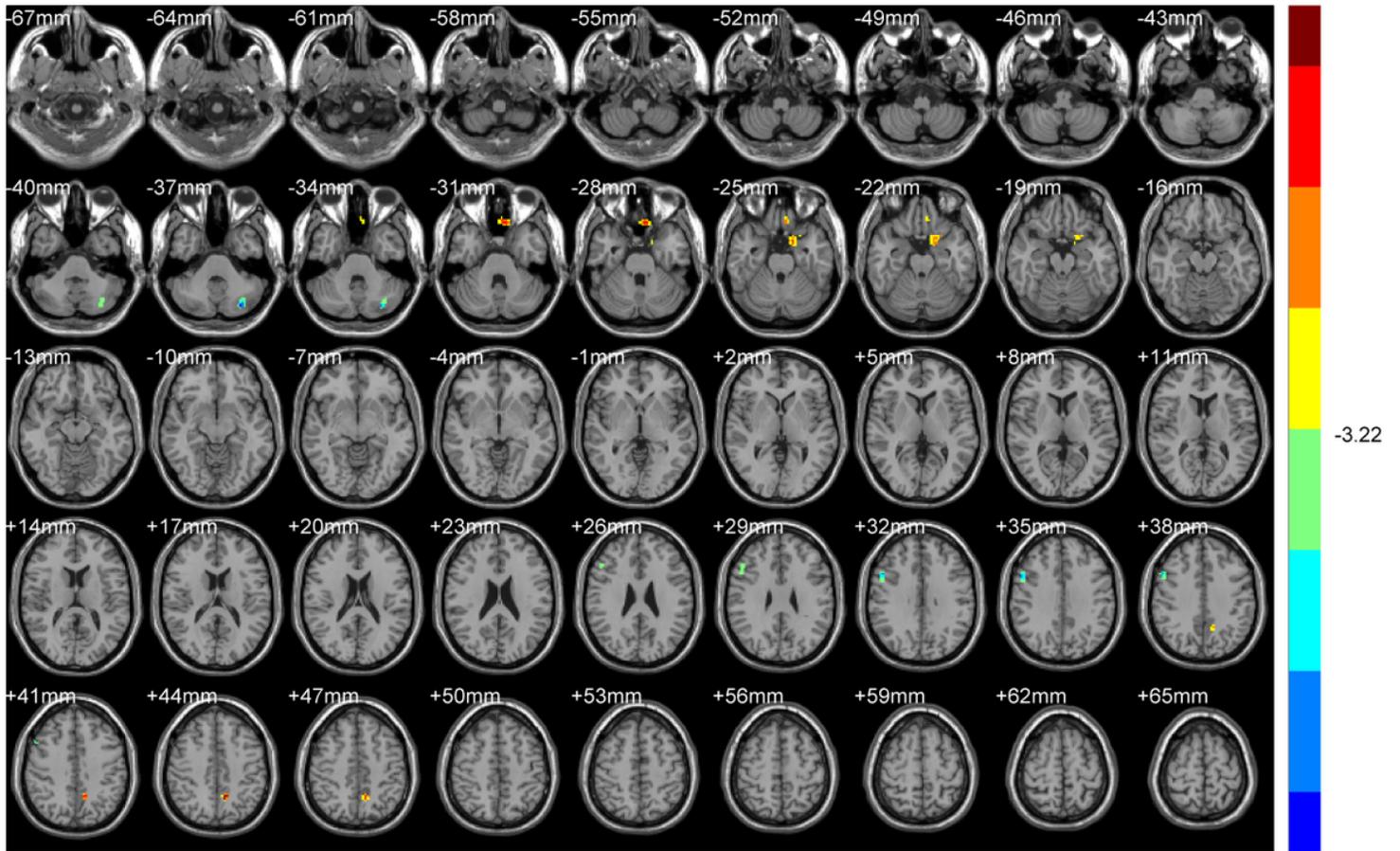
**Figure 3**

ReHo(Dominant hemisphere VS Normal)



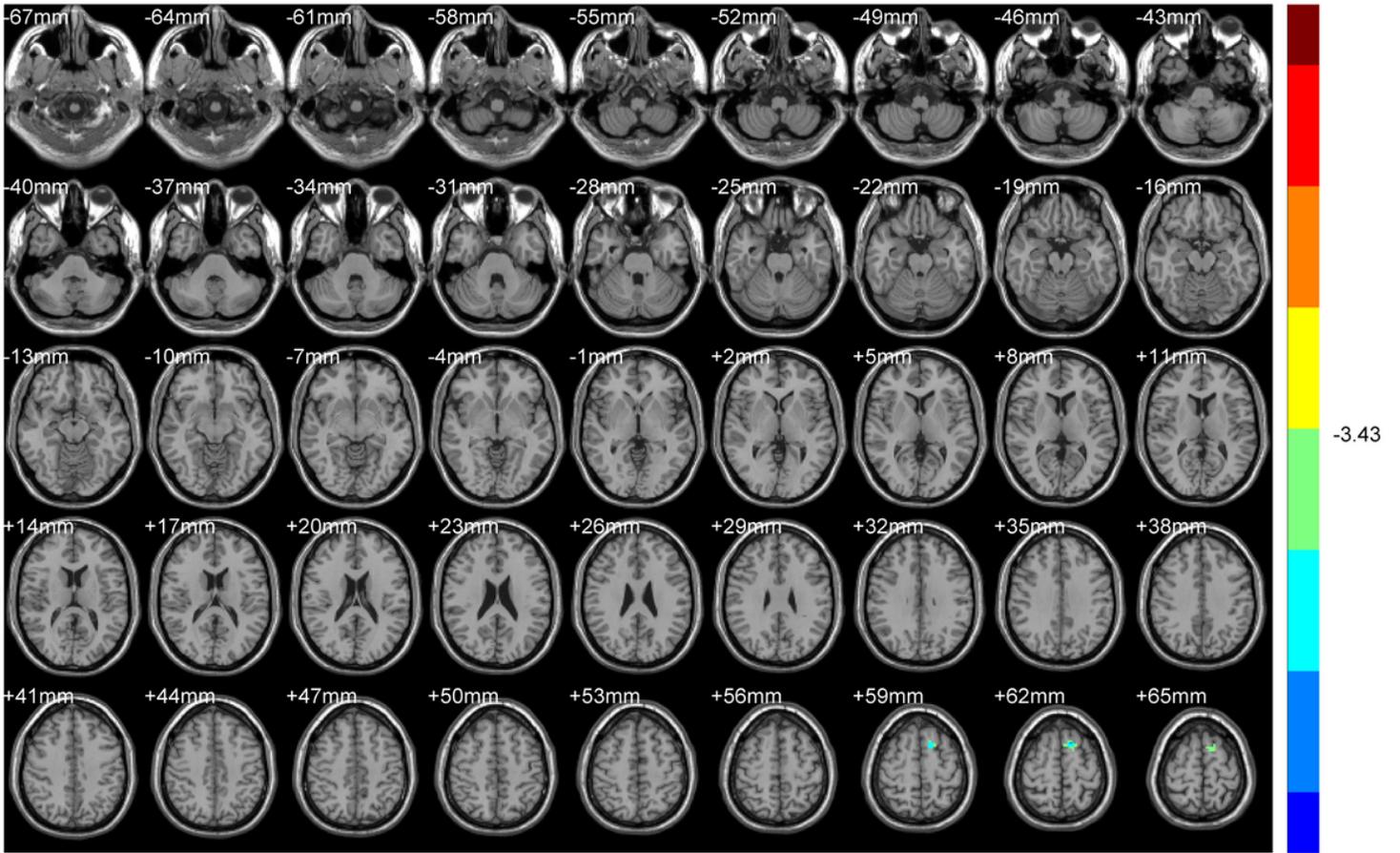
**Figure 4**

ALFF(Non dominant hemisphere VS Normal)



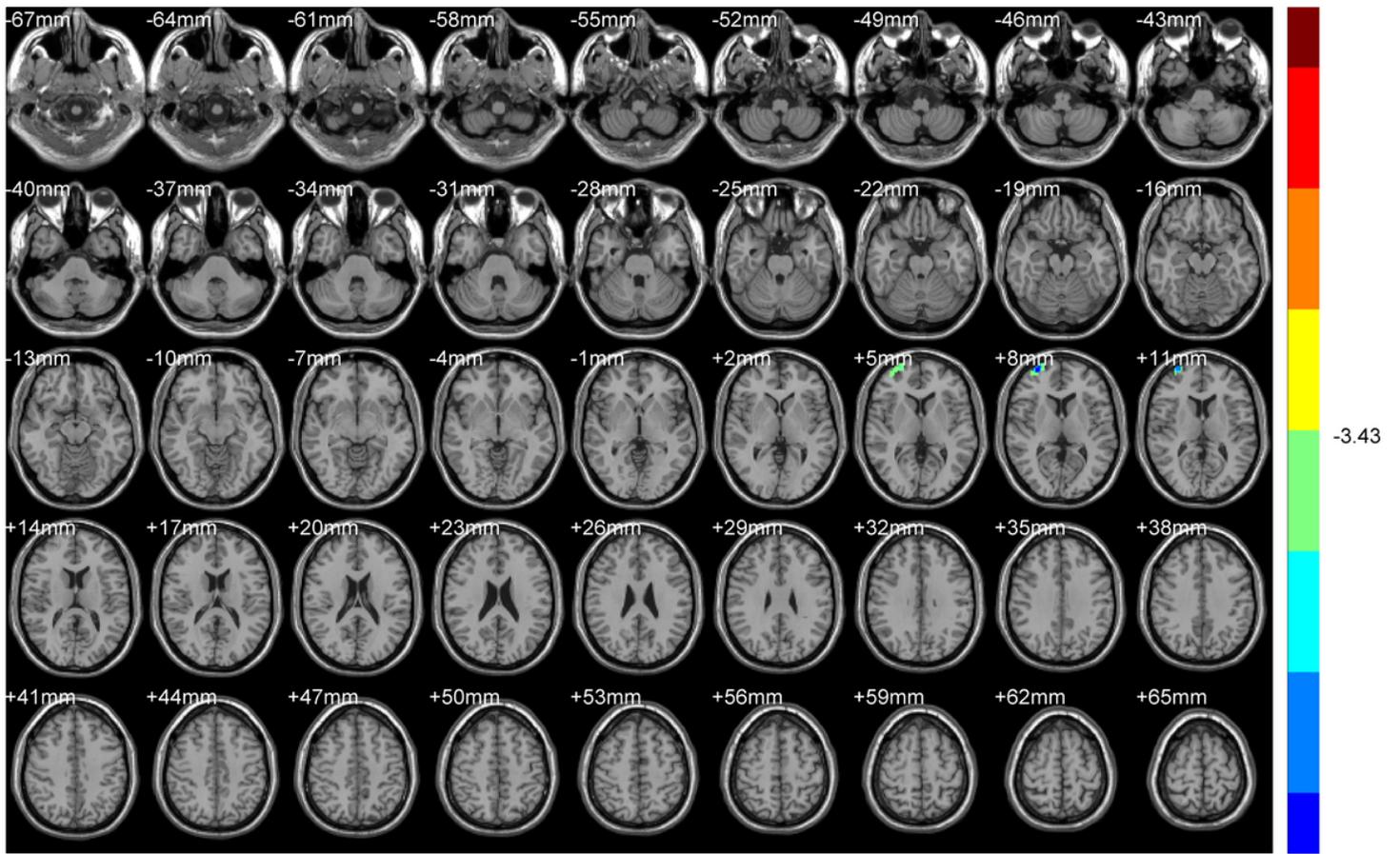
**Figure 5**

ReHo(Non dominant hemisphere VS Normal)



**Figure 6**

ALFF(Dominant hemisphere vs Non dominant hemisphere)



**Figure 7**

ReHo (Dominant hemisphere vs Non-dominant hemisphere)

<b>ALFF</b>	<b>amplitude of low frequency fluctuations</b>
ReHo	regional homogeneity
AIS	acute ischemic stroke
MRI	Magnetic Resonance Imaging
Rs-fMRI	Resting-state Functional Magnetic Resonance Imaging
BA	Brodmann area
fALFF	fractional amplitude of low frequency fluctuations
FC	Functional Connectivity
HS	healthy subjects
DH	the dominant hemisphere group
NDH	the non-dominant hemisphere group
NHSS	National Institute of Health stroke scale
tDCS	transcranial direct current stimulation