BMJ Open

Acupuncture for poststroke hemiplegia focusing on cerebral bilateral connections: study protocol for a randomised controlled neuroimaging trial

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To cite: Jiang L, Geng H, Lu M, *et al*. Acupuncture for poststroke hemiplegia focusing on cerebral bilateral connections: study protocol for a randomised controlled neuroimaging trial. *BMJ Open* 2020;**10**:e034548. doi:10.1136/bmjopen-2019-034548

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2019-034548).

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Received 25 September 2019
Revised 06 February 2020
Accepted 11 March 2020

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ABSTRACT

Introduction Acupuncture is safe and effective for improving the motor function of poststroke hemiplegic patients, but there still exists a certain gap between clinical practice and understanding its neural mechanisms. The cerebral functional reconstruction after unilateral motor pathway injury exhibits a bilateral tendency, however current studies seldom pay attention to it. Hence, based on cerebral bilateral connections, the underlying mechanism of acupuncture in stroke rehabilitation remains an area for further research. The results of this study will increase our understanding of acupuncture-induced motor recovery in patients who had suffered a stroke and demonstrate the differences in brain response and clinical assessments.

Methods and analysis This is a single-centre, randomised controlled, paralleled neuroimaging trial, with patients and outcome assessors blinded. Thirty patients who had a stroke with motor dysfunction meeting the inclusion criteria will be randomly assigned (2:1) to receive either 10 sessions true or sham acupoints treatments (five sessions per week for 2 weeks). All the participants will receive conventional standard medical care and rehabilitation. Motor function assessments and neuroimaging scanning will be conducted before and after the entire acupuncture treatment. The clinical and neuroimaging data will be analysed, respectively. The voxel-mirrored homotopic connectivity will be the primary outcome and the primary effect indicator. The secondary outcomes comprise clinical evaluations and neuroimaging assessments, which include Fugl-Meyer Assessment, the National Institutes of Health Stroke Scale, fractional anisotropy and gray matter volume. The Needle Sensation Assessment Scale is an additional outcome. The correlation analysis will be explored between the neuroimaging indicators, clinical motor assessments and needle sensation.

Ethics and dissemination The protocol has been approved by the ethics committee of Dongzhimen Hospital affiliated to Beijing University of Chinese Medicine (DZMEC-KY-2018-04). The results of the neuroimaging trial will be disseminated through peer-reviewed publications and conferences.

Trial registration number Chinese Clinical Trials Registry (ChiCTR 1800016263).

Strengths and limitations of this study

- The application of the randomised controlled neuroimaging trial will provide objective and valid evidence about how acupuncture treatment promotes the recovery of poststroke hemiplegia.
- A series of motor function scales, the Needle Sensation Assessment Scale and multimode neuroimaging scanning will be used to judge the effects of acupuncture treatment on poststroke hemiplegia.
- The research based on cerebral bilateral connections is better for understanding the mechanism of coordination and integration in the acupuncture-induced brain recovery.
- The 2-week treatment design is set up for the purpose to study the mechanism of acupuncture on poststroke motor impairment, which is not the recommended course for stroke hemiplegia recovery.

INTRODUCTION

In China, stroke often is the leading cause of death and disability, resulting in 70% of survivors living with motor function impairments.[1–3] Evidence-based medicine has shown that poststroke functional rehabilitation is the most primary method to decrease the disability rate and get functional recovery.[4 5] Acupuncture has always played an important role in hemiplegic recovery in long-term clinical practice, the use of which dates back thousands of years. Both WHO and National Institutes of Health recommend acupuncture treatment as an alternative or as part of a comprehensive programme in stroke rehabilitation,[6] and its positive effect has been confirmed by systematic reviews and multicentre clinical studies.[7 8] However, the

underlying mechanisms of acupuncture for hemiplegia remain unclear, which partly restricts its widespread application in stroke recovery.

Brain functional reorganisation and structural remodelling are closely related to the prognosis of stroke recovery. Cerebral bilateral modulation and cooperation have significant influences on motor recovery. Physiologically, every achievement of human activities is the process of resource allocation and execution controlled by the right and left hemispheres.[9] Increasing functional magnetic resonance imaging (fMRI) researches reported that, along with poststroke motor recovery, there existed a pathologically enhanced or decreased activation pattern between ipsilesional primary motor cortex (M1) and contralesional M1.[10–13] In our previous studies, patients who had a stroke with unilateral subcortical infarcts showed activations in multiple brain regions in both hemispheres.[14] All of the above proves that the bilateral issue is really important in the brain functional reorganisation.

To observe the changes in strength and location of cerebral bilateral connections, voxel-mirrored homotopic connectivity (VMHC) is an optimal neuroimaging indicator. It reflects functional connectivity between any pair of symmetry interhemispheric voxels, which is a fundamental characteristic of the intrinsic functional architecture of the brain.[15 16] During the stroke hemiplegia recovery, local infarct always affects the remote cerebral function, not only involving the sensorimotor networks but also the cognitive and executive networks.[17] VMHC, the whole-brain based functional connectivity method, will provide more global information than other data processing methods (ReHo, ALFF and so on).

In our previous studies, we found that instant acupuncture at Yanglingquan (GB34) will improve the decreased functional connectivity between bilateral M1 of right-hemispheric subcortical patients who had a stroke.[18 19] Whether long-term acupuncture intervention will facilitate the bilateral functional reorganisation and structural remodelling, is worthy to be explored.

Consequently, from the perspective of cerebral bilateral connections, figuring out the changes in brain function and structure after unilateral cerebral infarction via neuroimaging tools helps to illustrate the central mechanism of acupuncture treatment.

Based on the viewpoint of bilateral connections, this study aims to: (1) assess the differences of brain response, motor assessments and needle sensation between true acupoints treatment group (TATG) and sham acupoints treatment group (SATG); (2) characterise the influence of acupuncture treatment on cerebral functional activities and structural changes; (3) analyse the relationship between changes in brain activities and clinical assessments, in order to demonstrate the underlying mechanism of acupuncture treatment and its effects on clinical motor performances in hemiplegic patients.

METHODS

Study design

This is a single-centre, randomised controlled, paralleled neuroimaging study, with patients and assessors blinded to the group assignment. Patients who had a stroke with motor dysfunction meeting the inclusion criteria will be randomly divided into TATG and SATG by the ratio of 2:1. In addition to conventional standard medical care and rehabilitation, participants will receive 10 sessions of acupuncture treatment in 2 weeks (five sessions per week). Motor function scales and MRI scanning will be conducted before and after the entire acupuncture treatment. The Needle Sensation Assessment Scale (NSAS) will be assessed after each acupuncture treatment.

The study procedures are detailed in figure 1.

Patients population and recruitment strategy

Participants will be screened and recruited among the Department of Neurology, Rehabilitation and Acupuncture in Dongzhimen Hospital (Beijing, China) via Electronic Medical Record from May 2018 to December 2020. Patients who had a stroke with right or left hemiplegia who match the inclusion criteria will be regarded as the potential participants. If the patients are eligible and interested in taking part in the study, they will be fully informed of the project information including the study procedures, potential benefits and risks. Written informed consent will be obtained from the patient or their legally authorised representative before the allocation. Every participant has the right to withdraw from the study without any conditions.

Inclusion criteria

Patients will be included if they meet the following criteria: (1) patients with ischaemic stroke; (2) single subcortical lesion restricted to the motor pathway involving the internal capsule, basal ganglia, corona radiate and its neighbouring regions in the unilateral hemisphere; (3) right-handed before stroke; (4) age range from 40 to 75 years old; (5) within 6 weeks after the onset of stroke; (6) in conscious and stable condition; (7) no psychiatric medications have been taken in 1 month; (8) informed consent is signed by the patient or his/her immediate family.

Exclusion criteria

Patients will be excluded if they meet any of the following criteria: (1) a history of neurological or psychiatric disorders; any other health problems or poor physical conditions that may influence participation; (2) being pregnant or lactating; (3) any other brain structure damage or abnormalities identified by MRI examinations; (4) any history of alcohol or drug dependency; (5) any MRI contraindications.

Sample size considerations

For the following two reasons, we referred to the number of participants in relevant published articles when calculating the sample size. On the one hand, in fMRI

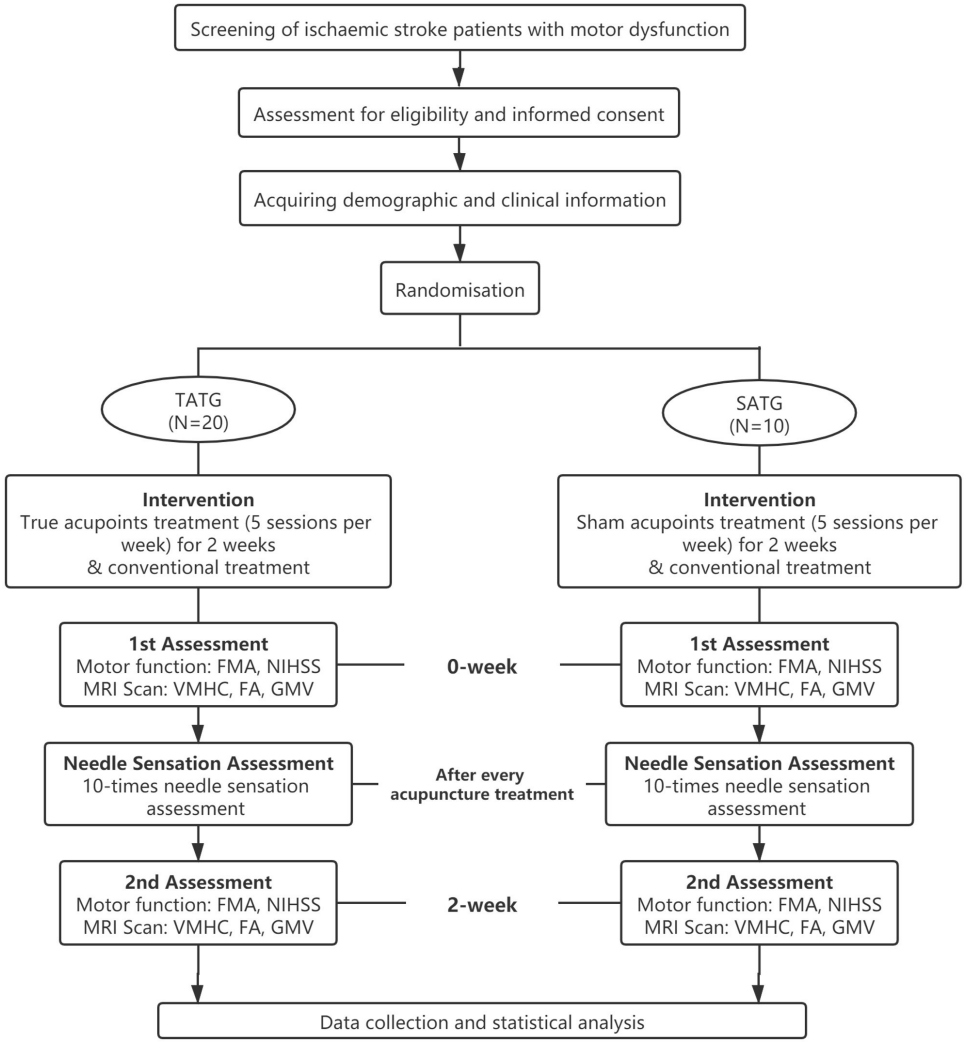

Figure 1 Flowchart of study design. FA, fractional anisotropy; FMA, Fugl-Meyer Assessment; GMV, gray matter volume; NIHSS, National Institutes of Health Stroke Scale; SATG, sham acupoints treatment group; TATG, true acupoints treatment group; VMHC, voxel-mirrored homotopic connectivity.

studies, millions of voxels are used to estimate the blood oxygen level dependent (BOLD) signal indirectly, and conventional power calculations often make no sense. On the other hand, the number of participants is often constrained by scanning time and costs. Therefore, considering the published acupuncture-neuroimaging literature focusing on patients who had a stroke, 16–32 subjects show enough statistical power for brain functional analysis[20 21]; in addition, according to our previous studies, 20 subjects represent a reasonable sample size for stable cerebral response.[14 18] Under the condition of high homogeneity of lesion location in this study, we conclude 30 patients would ensure enough statistical power and provide repeatable results.

Randomisation and blinding

An external professional statistician will generate a random sequence using Excel's rand function. Thirty patients who meet the inclusion criteria will be randomly assigned into either TATG or SATG (2:1 ratio). The TATG and SATG will be coded A and B, respectively. The code will be kept in an opaque envelope and subsequently sealed. These envelopes will be sent to the chief principal who is not involved in patient recruitment and will take direct charge of treatment allocation. The acupuncturists are aware of the treatment group. While, rehabilitation therapists, motor function evaluators and participants are blinded to the treatment group.

Patient and public involvement

Patients in this trial will not be involved in the design, recruitment or conduction of the study. After the MRI scanning, the patients will be informed of the results of neuroimaging data in the form of pictures. The doctor in charge of the patient will be also informed of the results to optimise treatment and the rehabilitation scheme.

INTERVENTIONS

In addition to conventional standard medical care and rehabilitation, all the participants will receive true or sham acupoints treatment.

Acupuncture interventions

Shou Zu Shi Er Zhen, a preferred acupuncture prescription for poststroke motor dysfunction established by Leting Wang, will be taken as the acupuncture intervention prescription. Dr Wang is a famous acupuncturist with more than 40 years of experience practicing in the Beijing Hospital of Traditional Chinese Medicine (TCM). The prescription, named after the acupoints locations and its bilateral acupoints selection principles, consists of 12 acupoints bilaterally from five transport acupoints and original acupoints of 12 meridians. Focused on the pathogenesis of stroke, the prescription is designed to regulate qi and blood, balance yin and yang and attach importance to spleen and stomach which has the function of nourishing muscles.

In addition, two doctors with master's degrees and more than 3 years of clinical experience in acupuncture will be trained together and will use the same techniques. After the first MRI scanning, the participants will receive 10 sessions acupuncture treatment (five times per week for 2 weeks).

True acupoints treatment group

1. Location of acupuncture prescription: LI4 (Hegu), PC6 (Neiguan), LI11 (Quchi) for bilateral upper extremities; ST36 (Zusanli), GB34 (Yanglingquan), SP6 (Sanyinjiao) for bilateral lower extremities.
2. Acupuncture procedures: all participants will be in supine position. After skin disinfection routinely, 12 sterile acupuncture needles for single use (size 0.25×40 mm, Ande brand, manufactured by Ande Medical Appliance in Guiyang, Guizhou Province, China) will be inserted vertically for 1.0–1.5 cun with 6–8 times reinforcing-reducing manual stimulation at the frequency of 1 Hz until the patients experience *Deqi* (a sensation including sourness, numbness, tingling, aching and propagated feeling along the meridians). The needles will be left in the acupoints for 30 min without any further manipulations.
3. Treatment course: every participant will receive five sessions of treatment per week for 2 weeks. A fixed acupuncturist will conduct the whole treatment course for one participant. After each acupuncture treatment, participants will be asked to express the kind and intensity of *Deqi* so as to finish the NSAS. The acupuncturist will give a treatment compliance judgement (completion rates) at the end of acupuncture treatment.

Sham acupoints treatment group (SATG)

Based on Liu *et al*'s method of sham acupoints[22] and after consultation with two experienced acupuncturists, we will take the location which is 1 inch beside the true point as the sham acupoint. Hence, we do not overemphasise the *deqi* experience of the participants in SATG. Except for the locations of acupoints, other aspects of treatment procedures and course in SATG will be the same as TATG's.

Conventional treatment

All the participants will receive conventional treatment including the conventional standard medical care and rehabilitation.

Conventional rehabilitation treatment, comprised physical therapy (PT) and occupational therapy (OT), will be applied by qualified rehabilitation therapists. The rehabilitation programmes will be carried out five times per week for 2 weeks and the rehabilitation treatment (PT and OT) will last for approximately 1 hour each time. Conventional standard medical care will comply with *Chinese guidelines for diagnosis and treatment of acute ischemic stroke 2018*.[23] The concomitant medications will be recorded in printed case report forms (CRFs) with details (the using-frequency, the dosage and the administration).

MEASUREMENTS

The measurements consist of three parts including neuroimaging scanning assessments, motor function assessments and needle sensation assessment. The study schedule is exhibited in table 1.

Demographic and basic clinical information collection

The demographic information (name, sex, age, height, weight and working status), the history of stroke (time since the attack, lesions location and symptoms) and the history of other concomitant diseases will be obtained at the baseline. Vital signs (blood pressure, pulse, respiration rate and temperature) will be measured before each scanning.

MRI scanning and neuroimaging outcomes

MRI scanning protocol

MRI examinations, including resting-state BOLD imaging (BOLD fMRI), diffusion tensor imaging (DTI) and high-resolution anatomical T1-weighted imaging (T1W1), are designed for detecting cerebral functional and structural changes.

The MRI examination will be performed with a 3.0 Tesla scanner (Siemens, Sonata, Germany) before and after the entire acupuncture treatment at Dongzhimen Hospital, Beijing, China. Before each scanning, participants will be asked to rest for 20 min, and will be informed of MRI examination procedures and attentive matters. During the scanning process, all participants will be required to wear earplugs to isolate noises, keep eyes closed, not fall asleep and stay still. All participants will be in the supine position with the head fixed by foam pads to minimise the head movements as far as possible during the scanning.

The functional images will be collected by using a T2×WI Gradient Echo-Planar Echo Imaging sequence with parameters as follows: repetition time, 2000 ms; echo time, 30 ms; matrix, 64×64; field of view, 225×225 mm^2; slice thickness, 3.5 mm; gap, 1 mm; phase encode direction, A>>P; flip angle, 90°. The BOLD scanning will last for 8 min 10 s. The structural images will be collected by using a T1-weighted three-dimensional anatomical

Table 1 Study schedule of enrolment, intervention and assessments. At the baseline, and after the whole acupuncture treatment, Fugl-Meyer Assessment (FMA) and National Institutes of Health Stroke Scale (NIHSS) will be used to evaluate the motor function. MRI scanning will be performed to detect the brain functional and structural change before and after the treatment period. Needle Sensation Assessment Scale (NSAS) will be conducted after each acupuncture treatment session

	Screening period	Before intervention	Intervention period (10 sessions treatment)		After intervention
Time points	(−3 days to −1 day)	Baseline (0 day)	0 week	2 weeks	End (14 days)
Enrolment					
Eligibility screen	×				
Informed consent	×				
Randomisation	×				
Allocation	×				
Interventions					
Acupuncture treatment (true/sham)			●	●	
Conventional therapy			●	●	
Assessments					
MRI scanning					
VMHC, FA, GMV		×			×
Motor function assessment					
FMA, NIHSS		×			×
Needle sensation assessment					
NSAS			●	●	
Safety					
Adverse events		×	●	●	×

FA, fractional anisotropy; GMV, gray matter volume; VMHC, voxel-mirrored homotopic connectivity.

sequence with parameters as follows: slice thickness, 1.0 mm; repetition time/echo time, 1900 ms/2.52 ms; field of view, 256×256; matrix, 256×256; flip angle, 9°. The T1W1 procedures will last for 4 min 10 s. The DTI data will be obtained using a single-shot, gradient-recalled echo-planar imaging sequence with parameters as follows: slice thickness, 2.0 mm; repetition time/echo time, 11 000 ms/94 ms; field of view, 256×256; matrix, 128×128; flip angle, 90°. The DTI procedures will last for 5 min 10 s.

Neuroimaging outcomes

The neuroimaging outcomes will be acquired after the MRI scanning and analysis, including voxel-mirrored homotopic connectivity (VMHC), fractional anisotropy (FA) and grey matter volume (GMV). VMHC will be taken as the primary outcome and the primary effect indicator. GMV and FA will be regarded as secondary outcomes.

As a functional parameter, VMHC is expressed as functional connectivity between any pair of symmetry interhemispheric voxels, which is an optimal parameter to reflect the bilateral functional connections.[15 16]

FA is a DTI parameter reflecting fibre density, axonal diameter and myelination of white matter.[24] It has been verified from the systematic reviews and meta-analysis that FA is a biomarker for the prognosis of stroke recovery.[25]

GMV is a morphological parameter indicating the volumetric change of grey matter. It has been verified that the increased GMV in motor-related and cognitive-related cerebral regions are in positive correlation with motor recovery.[26 27]

Motor function assessments and outcomes

The following motor assessment scales, including Fugl-Meyer Assessment (FMA) and National Institutes of Health Stroke Scale (NIHSS), will be conducted at the baseline and after the entire acupuncture treatment by a trained assessor who is blind to the random sequence. The results of FMA and NIHSS will be taken as the secondary outcome in this trial.

Fugl-Meyer Assessment

The FMA is highly recommended as a clinical and research tool for measuring sensorimotor stroke recovery, which has been demonstrated worldwide for more than 40 years in stroke population.[28] The FMA scale is a 100-point rating system consisting of upper/lower-extremity motor function, extensor and flexor muscle synergy, stability, balance, reflex and joint function in supine, sitting and standing position. The motor function is ranged from 0 to 2 points according to the level of completion. The total scores of upper extremity range from 0 to 66, and total

scores of lower extremity range from 0 to 34. The higher the scores, the better the motor function.[29]

National Institutes of Health Stroke Scale

The NIHSS is a reliable and valid scale for measuring different levels of stroke severity.[30] The NIHSS comprises 15 items including consciousness, eye movements, visual field, facial movements, muscular strength of extremities, ataxia, sensation, language, speech and neglect. Depending on the level of completion, every item scores range from 0 to 1, 0 to 2, 0 to 3, 0 to 4 or 0 to 9. The total scores of 15 items sum up to a range from 0 to 58. The level of scores indicates the level of neurological impairments. The higher the scores, the worse the illness.

The assessment of NIHSS for every patient with cerebral infarction has become routine in our clinical work. Although NIHSS is an extra non-fund supported outcome in this study, we still regard it as one of the secondary outcome indicators.

Needle sensation assessment

The NSAS will be conducted after every acupuncture treatment by the acupuncturists. The result of NSAS is a possible prognostic marker associated with the effectiveness of acupuncture and recovery of motor function, which will be taken as the additional outcome.

Deqi is a needle response describing how the patients feel when they receive the needle insertion, which is regarded as a unique key predictor and an essential role in the therapeutic effectiveness of acupuncture for stroke recovery.[31] The self-designed NSAS we adopt has been tested in our previous studies,[32] which includes *Deqi* features (sourness, numbness, tingling, aching and propagated feeling along the meridians) and rating of *Deqi*. Patients will describe the intensity of needle sensation by Visual Analogue Scale (0 stands for none, 10 stands for unbearable).

Incidence of adverse events

Any adverse events which may happen during the acupuncture treatment, including acupuncture syncope reaction (eg, sweating, fainting, dizziness and so on), broken needle, infection and local haematoma, will be recorded with details such as the occurrence date, lasting time, severity degree and the causality with the acupuncture treatment.

Any adverse events which may happen during the MRI scanning, mainly the occurrence of claustrophobia will also be recorded with details as above.

Serious adverse events will be reported to the principal investigator immediately.

Quality control, data collection and management

All researchers will receive a series of training sessions before the start of this study, to ensure that they fully understand the study protocol and standard procedures. All the rehabilitation treatments will be conducted by qualified physical therapists who will receive standard operating procedures of the required physical rehabilitation techniques before the start of the study. The clinical data are required to be recorded in printed CRFs simultaneously at the visit points. The completed CRFs will undergo the double-entry verification in EpiData Entry software. If the unconformity is found, the third person will search for printed CRFs to ensure consistency.

The medical imaging technicians will monitor the qualities of neuroimaging data after every scanning. If the data are of unsatisfactory quality (such as obvious head motion), we will call for the patients to receive an additional scanning. All the neuroimaging data will be stored in dedicated hard drives after every scanning completed.

STATISTICAL ANALYSIS

Clinical data analysis

Clinical data including demographic information, motor function scale variables and needle sensation rating, will be analysed by a statistician using Statistical Package for the Social Science V.20.0 (IBM Corp, Armonk, New York, USA). All the clinical data will be presented as mean±SD. Clinical data of the two groups will be compared by the two-sample t-test. The paired t-test will be carried out to make comparisons between the baseline and the end of acupuncture treatment. A p value <0.05 will be considered statistically significant.

Neuroimaging data processing and analysis

Resting-state fMRI data processing and analysis

For fMRI data, processing and statistical analysis will be performed with Data Processing Assistant for Resting-Sate fMRI software (http://rfmri.org/DPARSF) based on MATLAB (Mathworks, Natick, Massachusetts, USA). The preprocessing procedures are as follows: (1) discard the first-10-time points image to eliminate the effect of inhomogenous magnetisation, (2) the slice timing and head motion correction, data with excessive head motion (>2.0 mm) or rotation (>2°) will be excluded, (3) regressing out nuisance covariates (including Fristion's 24-parameter regression, white matter, CSF and global mean signals), as well as removing the linear trends, (4) spatial normalisation based on Montreal Neurological Institute (MNI) space and resampled to 3×3×3 mm^3, (5) smoothing with a Gaussian kernel of 6×6×6 mm^3 full width at half-maximum, (6) bandpass filtering (0.01–0.08 Hz).

For VMHC computation, briefly, after normalising to the symmetric template and applying the refined transformation to the functional data, we will calculate the Pearson's correlation between preprocessed time-series of each pair of symmetric interhemispheric voxels.[15] Correlation values will be then *Fisher Z* transformed. The resultant values are referred to as the VMHC, which will be used for further group-level analysis.[33]

The two-sample t test will be used to compare VMHC values between TATG and SATG. The paired t-test will be conducted when comparing VMHC values before and after acupuncture treatment within the groups. All brain maps of clusters significant will be defined by a cluster-level

threshold of p<0.05 and a voxel-wise level threshold of p<0.005 based on Gaussian Random Field (GRF) theory. Pearson correlation analysis will be performed with a threshold cluster level of p<0.05 (GRF corrected) to test the correlations between the clinical data and VMHC. All the reported neuroimaging statistics will be coloured and mapped in MNI space.

Structural data processing and analysis

For DTI data, preprocessing and statistical analysis will be processed with FSL (FMRIB Software Library) (https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/) and SPM12 (https://www.fil.ion.ucl.ac.uk/spm). FA will be obtained using the tract-based spatial statistics analysis in FSL.[34 35] GMV will be generated by voxel-based morphometry analysis using SPM12 software.

For DTI data analysis, non-parametric, permutation-based tests were carried out in group comparison by randomise tool in FSL with 5000 permutations and threshold-free cluster enhancement. The threshold for statistical significance will be set at p<0.01, corrected for multiple comparisons. For GMV analysis, two-sample t-test will be conducted between TATG and SATG. A paired t-test will be applied to test GMV change before and after acupuncture intervention in both groups, respectively. The threshold for statistical significance will be set at p<0.05 using family-wise error correction. Pearson correlation analysis will be performed with a threshold cluster level of p<0.05 (GRF corrected) to test the correlations between the clinical data and structural data.

DISCUSSION

Brain plasticity, strongly linked to the prognosis of poststroke hemiplegia, is becoming a research highlight worldwide.[36–38] Acupuncture is an effective therapeutic strategy for poststroke motor impairment but its mechanism remains elusive. Luckily, the rapid development of MRI techniques has provided a direct tool for investigating how the brain responds towards acupuncture intervention. The neuroimaging evidence will help illustrate the central principles and the effects of acupuncture.

Previous fMRI studies on patients who had a stroke have shown that functional reorganisation is coupled with structural remodelling during the motor recovery; this indicates the necessity of a combined research of the brain function and structure.[39 40] In this study, the application of VMHC method will add to the understanding of functional changes of bilateral homotopic regions following the subcortical infarction. The DTI technique will display the integrity of bilateral corticospinal tracts and their interactions for motor output after stroke. These MRI techniques will help to reflect bilateral function and structure after stroke objectively. Based on bilateral connections, the integrated research of function and structure reorganisation will give us a comprehensive presentation of acupuncture-induced brain recovery.

Deqi (needle sensation), or called *qi arrival* in TCM ancient books, is defined as a diverse sensation, and is an indispensable part of acupuncture treatment.[41] In theory of TCM, *deqi* is a sign that qi and blood in meridians and collaterals are activated to regulate the function of internal organs and to balance yin and yang. It has been confirmed by clinical studies and literature reviews that *deqi* is tightly linked with the effectiveness of treatment.[42 43] Compared with the sham acupuncture treatment, hemiplegic patients treated with true acupuncture exhibited a tendency to a larger activation in the contralateral motor cortex and a better motor function outcome,[44] indicating that the *deqi* sensation may become a stable predictor of therapeutic effects.[32] In our study, we will also record the needle sensation and its intensity to preliminarily probe the essential association between *deqi* and the neuroimaging phenomenon.

Among acupuncture researchers, the choice of the sham acupuncture applications or sham acupoints as the placebo of the true acupuncture is still in dispute, although both of them aim to eliminate the placebo effect. Because many Chinese patients have personal acupuncture treatment experiences, have the conception of *deqi* or even know locations of some acupoints, it is a little difficult to blind Chinese patients using either the sham acupuncture apparatus or sham acupuncture manipulation.[45–47] Therefore, we choose the sham acupoints as the placebo intervention in this study. In clinical practice, despite the *deqi* sensation tends to appear in true acupuncture group, the sham one can also generate weak or moderate feelings.[48 49] Hence, we do not overemphasise the experience of *deqi* in SATG.

In summary, combined with the assessment of motor function and *deqi*, this neuroimaging trial aims to investigate the neural mechanism of acupuncture treatment for poststroke hemiplegia from the viewpoint of cerebral connections. We expect that our findings can provide a new perspective to illustrate the mechanism of acupuncture treatment and promote the widespread application of it.

Ethics and dissemination

The protocol has been approved by the ethics committee of Dongzhimen Hospital affiliated to Beijing University of Chinese Medicine (DZMEC-KY-2018-04). The results of the neuroimaging trial will be disseminated through peer-reviewed publications and conferences.

Trial status

This study is under participant recruitment. The first patient was included on 30 May 2018, and the recruitment will be finished before 31 December 2020. At present, 24 patients have been recruited.

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Acknowledgements We would like to thank Diane Garsetti (Rutgers, the State University of New Jersey) and Ying Gao (New Oriental English School, Zhengzhou, China) for providing language help.

Contributors LJ and HG contributed equally in drafting this manuscript. LJ prepared the informed consent and finished trial registration. ML and YW are in charge of acupuncture treatment. ZD is in charge of the motor assessment of participants. PC and XH are in charge of screening and recruitment. LT is in charge of guidance of acupuncture treatment. ZT is in charge of MRI scanning operation. HZ is in charge of neuroimaging data processing and analysis. YZ conceived and designed the study and is the corresponding author of the manuscript. All authors discussed, revised and approved of the final manuscript.

Funding This study was supported by The Natural Science Foundation of Beijing (grant number: 7182104).

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

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REFERENCES

1 Zhou M, Wang H, Zeng X, *et al*. Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: a systematic analysis for the global burden of disease study 2017. *The Lancet* 2019;394:1145–58.
2 , Feigin VL, Nguyen G, *et al*, GBD 2016 Lifetime Risk of Stroke Collaborators. Global, regional, and Country-Specific lifetime risks of stroke, 1990 and 2016. *N Engl J Med* 2018;379:2429–37.
3 Gao Y, Jiang B, Sun H, *et al*. The burden of stroke in China: results from a nationwide population-based epidemiological survey. *PLoS One* 2018;13:e0208398.
4 Gittler M, Davis AM, Michelle Gittler AMD. Guidelines for adult stroke rehabilitation and recovery. *JAMA* 2018;319:820–1.
5 Pollock A, Baer G, Campbell P, *et al*. Physical rehabilitation approaches for the recovery of function and mobility following stroke. *Cochrane Database Syst Rev* 2014;4:Cd001920.
6 NIH Consensus Development Panel on Acupuncture. Nih consensus conference. acupuncture. *JAMA* 1998;280:1518–24.
7 Yang A, HM W, Tang JL, *et al*. Acupuncture for stroke rehabilitation. *Cochrane Database Syst Rev* 2016;8:Cd004131.
8 Zhang S, Wu B, Liu M, *et al*. Acupuncture efficacy on ischemic stroke recovery: multicenter randomized controlled trial in China. *Stroke* 2015;46:1301–6.
9 Sperry RW, Organization C. Cerebral organization and behavior: the split brain behaves in many respects like two separate brains, providing new research possibilities. *Science* 1961;133:1749–57.
10 Ward NS, Brown MM, Thompson AJ, *et al*. Neural correlates of motor recovery after stroke: a longitudinal fMRI study. *Brain* 2003;126:2476–96.
11 Rehme AK, Fink GR, von Cramon DY, *et al*. The role of the contralesional motor cortex for motor recovery in the early days after stroke assessed with longitudinal fMRI. *Cereb Cortex* 2011;21:756–68.
12 Dodd KC, Nair VA, Prabhakaran V. Role of the contralesional vs. ipsilesional hemisphere in stroke recovery. *Front Hum Neurosci* 2017;11:469.
13 Swayne OBC, Rothwell JC, Ward NS, *et al*. Stages of motor output reorganization after hemispheric stroke suggested by longitudinal studies of cortical physiology. *Cereb Cortex* 2008;18:1909–22.
14 Zhang Y, Li K-S, Ning Y-Z, *et al*. Altered structural and functional connectivity between the bilateral primary motor cortex in unilateral subcortical stroke: a multimodal magnetic resonance imaging study. *Medicine* 2016;95:e4534.
15 Zuo X-N, Kelly C, Di Martino A, *et al*. Growing together and growing apart: regional and sex differences in the lifespan developmental trajectories of functional homotopy. *J Neurosci* 2010;30:15034–43.
16 Zuo X-N, Xing X-X. Test-Retest reliabilities of resting-state fMRI measurements in human brain functional connectomics: a systems neuroscience perspective. *Neurosci Biobehav Rev* 2014;45:100–18.
17 Almeida SRM, Vicentini J, Bonilha L, *et al*. Brain connectivity and functional recovery in patients with ischemic stroke. *J Neuroimaging* 2017;27:65–70.
18 Han X, Bai L, Sun C, *et al*. Acupuncture enhances communication between cortices with damaged white matters in poststroke motor impairment. *Evid Based Complement Alternat Med* 2019;2019:1–11.
19 Ning Y, Li K, Fu C, *et al*. Enhanced functional connectivity between the bilateral primary motor cortices after acupuncture at Yanglingquan (GB34) in right-hemispheric subcortical stroke patients: a resting-state fMRI study. *Front Hum Neurosci* 2017;11:178.
20 Qiu K, Jing M, Sun R, *et al*. The status of the quality control in Acupuncture-Neuroimaging studies. *Evid Based Complement Alternat Med* 2016;2016:1–14.
21 Friston K. Ten ironic rules for non-statistical reviewers. *Neuroimage* 2012;61:1300–10.
22 Liu Z, Liu Y, Xu H, *et al*. Effect of electroacupuncture on urinary leakage among women with stress urinary incontinence: a randomized clinical trial. *JAMA* 2017;317:2493–501.
23 Chinese Society of Neurology Chinese Stroke Society. Chinese guidelines for diagnosis and treatment of acute ischemic stroke 2018. *Chin J Neurol* 2018;51:666–82.
24 Basser PJ, Pierpaoli C. Microstructural and physiological features of tissues elucidated by quantitative-diffusion-tensor MRI. *J Magn Reson B* 1996;111:209–19.
25 Kumar P, Kathuria P, Nair P, *et al*. Prediction of upper limb motor recovery after subacute ischemic stroke using diffusion tensor imaging: a systematic review and meta-analysis. *J Stroke* 2016;18:50–9.
26 Fan F, Zhu C, Chen H, *et al*. Dynamic brain structural changes after left hemisphere subcortical stroke. *Hum Brain Mapp* 2013;34:1872–81.
27 Wang P, Jia X, Zhang M, *et al*. Correlation of longitudinal gray matter volume changes and motor recovery in patients after pontine infarction. *Front Neurol* 2018;9:312.
28 Fugl-Meyer AR, Jääskö L, Leyman I, *et al*. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. *Scand J Rehabil Med* 1975;7:13–31.
29 Gladstone DJ, Danells CJ, Black SE. The fugl-meyer assessment of motor recovery after stroke: a critical review of its measurement properties. *Neurorehabil Neural Repair* 2002;16:232–40.
30 Kwah LK, Diong J. National Institutes of health stroke scale (NIHSS). *J Physiother* 2014;60:61.
31 Zhao M-Y, Zhang P, Li J, *et al*. Influence of *de qi* on the immediate analgesic effect of SP6 acupuncture in patients with primary dysmenorrhoea and *cold and dampness stagnation*: a multicentre randomised controlled trial. *Acupunct Med* 2017;35:332–8.
32 Bai L, Cui F, Zou Y, *et al*. Acupuncture de Qi in stable somatosensory stroke patients: relations with effective brain network for motor recovery. *Evid Based Complement Alternat Med* 2013;2013:1–9.
33 Zhou Y, Milham M, Zuo X-N, *et al*. Functional homotopic changes in multiple sclerosis with resting-state functional MR imaging. *AJNR Am J Neuroradiol* 2013;34:1180–7.
34 Smith SM, Jenkinson M, Johansen-Berg H, *et al*. Tract-based spatial statistics: voxelwise analysis of multi-subject diffusion data. *Neuroimage* 2006;31:1487–505.
35 Douaud G, Smith S, Jenkinson M, *et al*. Anatomically related grey and white matter abnormalities in adolescent-onset schizophrenia. *Brain* 2007;130:2375–86.
36 Jeong S-J, Lee H, Hur E-M, *et al*. Korea brain initiative: integration and control of brain functions. *Neuron* 2016;92:607–11.
37 Okano H, Sasaki E, Yamamori T, *et al*. Brain/MINDS: a Japanese national brain project for marmoset neuroscience. *Neuron* 2016;92:582–90.
38 Poo M-M, Du J-L, Ip NY, *et al*. China brain project: basic neuroscience, brain diseases, and Brain-Inspired computing. *Neuron* 2016;92:591–6.
39 Zhang J, Zhang Y, Wang L, *et al*. Disrupted structural and functional connectivity networks in ischemic stroke patients. *Neuroscience* 2017;364:212–25.

40 Miao P, Wang C, Li P, *et al*. Altered gray matter volume, cerebral blood flow and functional connectivity in chronic stroke patients. *Neurosci Lett* 2018;662:331–8.
41 Yuan H-W, Ma L-X, Qi D-D, *et al*. The historical development of deqi concept from classics of traditional Chinese medicine to modern research: exploitation of the connotation of deqi in Chinese medicine. *Evid Based Complement Alternat Med* 2013;2013:1–5.
42 Pan Q, Ma L, Yang Y, *et al*. [Application of data mining on the relationship between *deqi* and effect]. *Zhongguo Zhen Jiu* 2017;37:668–72.
43 Zhang Z, Wang Y, Sun J, *et al*. [Progress of fMRI-based *deqi* research in recent 10 years]. *Zhongguo Zhen Jiu* 2018;38:445–50.
44 Schaechter JD, Connell BD, Stason WB, *et al*. Correlated change in upper limb function and motor cortex activation after verum and sham acupuncture in patients with chronic stroke. *J Altern Complement Med* 2007;13:527–32.
45 Streitberger K, Kleinhenz J. Introducing a placebo needle into acupuncture research. *Lancet* 1998;352:364–5.
46 Wayne PM, Krebs DE, Macklin EA, *et al*. Acupuncture for upper-extremity rehabilitation in chronic stroke: a randomized sham-controlled study. *Arch Phys Med Rehabil* 2005;86:2248–55.
47 Li H, Liu H, Liu C, *et al*. Effect of "Deqi" during the Study of Needling "Wang's Jiaji" Acupoints Treating Spasticity after Stroke. *Evid Based Complement Alternat Med* 2014;2014:1–8.
48 Grillo CM, Zotelli VLR, Lúcia Bressiani Gil M, *et al*. Would a placebo acupuncture needle be able to induce Deqi? *J Acupunct Meridian Stud* 2018;11:273–9.
49 Kwon OS, Kim J, Choi K-H, *et al*. Trends in deqi research: a text mining and network analysis. *Integr Med Res* 2018;7:231–7.