Dynamic functional connectivity analysis of Taichong (LR3) acupuncture effects in various brain regions*

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Abstract
The present study conducted a multi-scale dynamic functional connectivity analysis to evaluate dynamic behavior of acupuncture at Taichong (LR3) and sham acupoints surrounding Taichong. Results showed differences in wavelet transform coherence characteristic curves in the declive, precuneus, postcentral gyrus, supramarginal gyrus, and occipital lobe between acupuncture at Taichong and acupuncture at sham acupoints. The differences in characteristic curves revealed that the specific effect of acupuncture existed during the post-acupuncture rest state and lasted for 5 minutes.

Key Words: acupuncture; dynamic; functional; magnetic resonance imaging; Taichong (LR3); wavelet transform

INTRODUCTION
Acupuncture has been regarded as an alternative and complementary therapeutic intervention. However, little is known about the neural mechanisms underlying acupuncture. Previous studies have focused on the neuronal response during short periods of acupuncture stimulation with block designs, which is referred to an “acute-effect”. In addition, block-designed functional magnetic resonance imaging (fMRI) acupuncture studies have demonstrated central neural system modulation effects of acupuncture. In an acute-effect study, electrical stimulation at Sanjiao (SJ8) and Yamen (Du15), the language-implicated acupoints, significantly activated the left and right inferior frontal gyri, as well as the left superior temporal gyrus, which are regions related to processing of language tasks⁴. Wu et al⁵ observed that the excitatory effect of electroacupuncture persisted for 90 minutes after stimulation termination. In addition, a network model analysis based on a graph theory provided additional evidence for reorganization of the functional connectivity network related to the acupuncture post-effect in a resting-state brain⁶. Bai et al⁷ compared various acupuncture modulatory post-effects on the resting brain network, concluding that the existence of functional brain network alternations reflects the post-effect.

Evidence from task-based and resting-state fMRI studies has suggested that functional connectivity results in dynamic changes within time scales of seconds to minutes¹²⁻¹⁷. In addition, temporal variability in phase relationships between various brain regions in a visual task was obtained with fMRI data¹⁸. A previous study¹⁷ also determined that resting-state functional connectivity is not static with time-frequency coherence analysis, which was based on wavelet-transform.

Previous acupuncture studies have demonstrated that many brain regions are activated by acupuncture stimulation, and these effects remain in resting-state fMRI following acupuncture. However, the brain activity changing process from acupuncture stimulation to a post-acupuncture resting state remains poorly understood. The present study analyzed dynamic behaviors of connectivity across the course of a single scan.
RESULTS
Quantitative analysis of participants
Twelve subjects were recruited (Table 1) and randomly assigned to Taichong (LR3) and sham acupoint groups, which underwent acupuncture at Taichong of the right foot and at a sham acupoint surrounding Taichong, respectively. All participants were included in the final analysis.

Brain regions of interest (ROIs) for dynamic functional connectivity analysis
Regional homogeneity \(^{18}\) in the occipital lobe, declive, supramarginal gyrus, precuneus, and postcentral gyrus increased following stimulation at Taichong compared with acupuncture at the sham acupoint \((P < 0.005\) (uncorrected), minimum cluster size: five voxels; Figure 1). Therefore, these brain regions served as ROIs for dynamic functional connectivity analysis.

Wavelet-transform coherence (WTC) between Taichong and sham acupoint groups
After extracting time series from the ROIs of both acupuncture groups, WTC characteristic curves were obtained from the Taichong group and sham acupoint group (Appendix A). The entire experimental process was divided into three stages: the first stage (prior to stimulation) consisted of the preceding 60 scans; the second stage (during stimulation) consisted of scans 61–120; the final 280 scans comprised the third stage (following stimulation). Using the two-sample \(t\)-test, mean WTC coefficients of declive and precuneus, postcentral gyrus and supramarginal gyrus, and postcentral gyrus and occipital lobe in Taichong group were greater than the sham acupoint group \((P < 0.05; \) Table 2).

The acupuncture effect lasting time \((T_0)\) of declive and precuneus in the Taichong group was longer than 11 minutes, and \(T_0\) of postcentral gyrus and supramarginal gyrus, and postcentral gyrus and occipital lobe in the Taichong group was approximately 11 minutes, which suggested that the effect of acupuncture existed during post-acupuncture rest state and lasted for nearly 5 minutes (Table 3).

Table 1 Baseline data of Taichong (LR3) group and sham acupoint group

| Subject | Age (year) | Gender | Body height (cm) | Body mass (kg) | Left/right-handedness | Psychiatric or neurological disorders |
|---------|------------|--------|------------------|----------------|------------------------|---------------------------------------|
| Taichong group 1 | 28 | Male | 174 | 71 | Right | No |
| 2 | 25 | Male | 178 | 67 | Right | No |
| 3 | 26 | Female | 165 | 53 | Right | No |
| 4 | 28 | Female | 161 | 52 | Right | No |
| 5 | 27 | Male | 176 | 76 | Right | No |
| 6 | 23 | Female | 156 | 45 | Right | No |
| Sham acupoint group 1 | 27 | Male | 172 | 66 | Right | No |
| 2 | 29 | Female | 156 | 49 | Right | No |
| 3 | 25 | Female | 159 | 51 | Right | No |
| 4 | 24 | Male | 175 | 67 | Right | No |
| 5 | 28 | Male | 170 | 66 | Right | No |
| 6 | 27 | Female | 163 | 54 | Right | No |

Figure 1 Comparison of regional homogeneity in brain regions between Taichong (LR3) and sham acupoint groups using two-sample \(t\)-test analysis.

R: Right; L: left; \(T\): \(t\)-value. Values from the \(t\)-test represent ability to pass the test, which indirectly reflects differences between the groups.
The present study initially explored correlational changes involved in acupuncture using a time-frequency method. Preliminary analysis of dynamic brain behavior was revealed during the entire acupuncture process, which focused on the acupoint-related network. In previous studies\[19-22\], model-dependent analysis methods have been based on a block design, which requires prior knowledge of event timing from which an anticipated hemodynamic response is modeled. However, this type of analysis is not possible without a predictable hemodynamic response that reflects actual blood oxygenation level-dependent signal changes induced by acupuncture. In the present study, a single block design and model-independent approach were used to explore time-varying interactions between brain regions. Regional homogeneity is a data-driven method for analyzing subject fMRI time series to assess neighboring voxel blood oxygenation level-dependent signal similarities\[23\]. Regional homogeneity is based on the theory\[18\] that, for a given task condition, brain activity over neighboring voxels will exhibit high coherence with time. If the acupuncture effect remains following needle removal, then brain activity will remain active in the acupuncture network regions. Using the regional homogeneity analytic strategy, post-effect differences were detected between subjects who experienced acupunctural stimulation at the Taichong acupoint and subjects who received stimulation at the sham acupoint. Brain regions, including occipital lobe, declive, supramarginal gyrus, precuneus, and postcentral gyrus, which have a close relationship with Taichong acupoint\[24\], were selected as ROIs for the present study.

The multi-scale dynamic functional connectivity approach measured correlation changes by synthetically using information from different time and frequency resolutions. The information provided by the wavelet transform coherence graph presented additional challenges when studying multiple subjects. This was handled by summarizing the dynamic information as a characteristic curve. As shown in Appendix A, the curve exhibited clear fluctuations in coherence magnitude within the course of a single scan. Compared with the mean WTC coefficient during the second stage in the sham acupoint group, R2 in Taichong group was > 0.5. This result demonstrated that the ROIs exhibited relationships with the Taichong acupoint, and ROI activities increased during acupuncture at Taichong.

WTC statistical characteristics of acupuncture fMRI data were obtained. Using two-sample t-test analysis, distinct differences in R2 were determined between the Taichong and sham acupoint groups. In addition, mean WTC coefficients during the post-acupuncture rest state were greater than during the post-sham rest state, which suggested a difference between groups during the post-rest state. Needle manipulation time lasted for 360 seconds. As shown in Table 2, T values were > 360, indicating that the acupuncture effect remained during the post-acupuncture state. According to the Δ T value, the acupuncture effect lasted for nearly five minutes\[25\].

In summary, the acupuncture effect was analyzed using a multi-scale dynamic functional connectivity method, which revealed time characteristics of function connectivity between brain regions. Dynamic function connectivity curves provided information for the entire acupuncture process. fMRI data revealed distinct differences in function connectivity between Taichong and sham acupuncture groups, and these acupuncture effects remained for five minutes after acupuncture. These results supported the existence of an acupuncture post-effect.

### DISCUSSION

The present study initially explored correlational changes involved in acupuncture using a time-frequency method. Preliminary analysis of dynamic brain behavior was revealed during the entire acupuncture process, which focused on the acupoint-related network. In previous studies\[19-22\], model-dependent analysis methods have been based on a block design, which requires prior knowledge of event timing from which an anticipated hemodynamic response is modeled. However, this type of analysis is not possible without a predictable hemodynamic response that reflects actual blood oxygenation level-dependent signal changes induced by acupuncture. In the present study, a single block design and model-independent approach were used to explore time-varying interactions between brain regions. Regional homogeneity is a data-driven method for analyzing subject fMRI time series to assess neighboring voxel blood oxygenation level-dependent signal similarities\[23\]. Regional homogeneity is based on the theory\[18\] that, for a given task condition, brain activity over neighboring voxels will exhibit high coherence with time. If the acupuncture effect remains following needle removal, then brain activity will remain active in the acupuncture network regions. Using the regional homogeneity analytic strategy, post-effect differences were detected between subjects who experienced acupunctural stimulation at the Taichong acupoint and subjects who received stimulation at the sham acupoint. Brain regions, including occipital lobe, declive, supramarginal gyrus, precuneus, and postcentral gyrus, which have a close relationship with Taichong acupoint\[24\], were selected as ROIs for the present study.

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### SUBJECTS AND METHODS

#### Design
A randomized, controlled experiment.

#### Time and setting
The study was performed in Beijing, China from February 2004 to April 2004.

#### Subjects
Twelve healthy, right-handed volunteers (six males and six females, aged 26.4 ± 3.4 years) were recruited according to the following inclusion criteria: (1) 22–30 years of age; (2) right-handed; (3) free of acupuncture; (4)
agreed to sign informed consents prior to experimentation. The exclusion criteria comprised the following: (1) suffered from psychiatric or neurological disorders; (2) subjected to medication during the past 3 days; (3) suffered from pain within three months of the study. The study was performed in accordance to the Declaration of Helsinki.

Methods

Acupuncture stimulus

Each subject received a single acupuncture stimulus at Taichong or the surrounding sham acupoint at the right foot. Taichong was located at the dorsum of the foot, and the sham acupoint was near the Taichong acupoint, approximately 10 mm anterior to Taichong. All acupuncture were performed by the same acupuncturist, who had twenty years of clinical experience. A silver needle, 0.30 mm in diameter and 25 mm long, was used.

MRI

The process of data acquisition was performed as previously described[26]. Both verum acupuncture and sham acupoint acupuncture consisted of 60 needle manipulations scans, preceded by 62 resting scans and followed by 280 resting scans. During the manipulations scans, the needle was inserted and twirled clockwise and anticlockwise at 1 Hz. The depth of needle insertion at Taichong was approximately 15 mm, which was the same as the sham acupoint. Scans were acquired on a 1.5-T MR scanner (Sonata, Siemens, Germany) at the AC-PC line. Functional images were obtained using a blood oxygenation T2*-weighted gradient-echo planar imaging sequence with an in-plane resolution of 3.44 mm (repetition time of 3 000 ms, echo time of 50 ms, flip angle of 90°, field of view of 220 mm × 220 mm, a matrix of 64 × 64, slice thickness of 6 mm, and a gap of 1.2 mm).

fMRI pre-processing

All functional data were pre-processed using Statistical Parametric Mapping software (SPM8, http://www.fil.ion.ucl.ac.uk/spm/software/). Due to instability of initial signals, the first two images were discarded. The remaining images from each subject were corrected for differences in slice acquisition times, realigned to the first image, normalized to a ICBM-defined template from the NIH P-20 project, and re-sampled to 3 mm × 3 mm × 3 mm. In the present study, no subjects exhibited head movements exceeding 1.0 mm on any axis or head rotation > 1°.

Definition of the network ROI

Because sustained effects of acupuncture could continue into the post-stimulus period, some brain regional homogeneity in the true acupuncture group could vary from the sham acupuncture group. Regional homogeneity methodology was applied to identify possible post-effects of acupuncture in certain brain regions while stimulating at the Taichong acupoint. Initially, time series linear detrending was applied to all data. Subsequently, during the resting data, a band-pass filter (band: 0.01 -0.08 Hz) was used to reduce the effect of breath and heartbeat. In addition, using a whole Brain Mask, Kendall’s coefficient concordance [27] was computed for each voxel together with the surrounding 26 voxels, and an individual Kendall’s coefficient concordance map was obtained. Finally, spatial smoothing was applied to the Kendall’s coefficient concordance map using an 8-mm full width at half maximum Gaussian kernel to increase signal-to-noise ratio.

Multi-scale dynamic functional connectivity analysis

Wavelet analysis was applied to fMRI data using the WTC [28] (Appendix B). The WTC map provided various time-frequency characteristics from the two simulated time series, which was suitable for single-subject analysis. Aimed at group analysis, extraction of the characteristic curve resulted in characteristics for statistical analysis from multidimensional information [29].

Initially, unreliable WTC values were deleted based on two factors: (1) an excessive scale and (2) the value was < WTC from the two noise series. “d” represented the smaller distance between time point and starting point or terminal point of the time series. If the scale was > 0.707 d, the WTC value at this time point was considered to be unreliable. Aimed at the second factor, a Monte Carlo procedure, based on time-series bootstrapping [29-30], was used to obtain WTC values from the two noise series. A 300 time series of pairs was generated with the same vector autoregressive model coefficients as the original time series. The vector autoregressive model to time series x and y is described as follows:

\[
\begin{align*}
    x(t) &= \sum_{i=1}^{p} a_i x(t-i) + \sum_{i=1}^{p} b_i y(t-i) + u^x(t) \\
    y(t) &= \sum_{i=1}^{p} a_i x(t-i) + \sum_{i=1}^{p} b_i y(t-i) + u^y(t)
\end{align*}
\]

The optional model order “p” was selected according to the Bayesian information criterion score, and “f” served as the time index. For each bootstrap time series pair, WTC was computed. The mean WTC value averaging 300 WTC maps was considered the WTC level of two noise series. If one WTC value was < the mean WTC value, it was deleted as an unreliable value. All WTC values were treated accordingly.

Subsequently, extraction of the characteristic curve was performed from the remaining WTC points. The median from the remaining scales at one time point was selected as the WTC value for this time point. As an example, there was a pair of time series that consisted of two positively correlated sinusoids with a Pearson correlation coefficient of 0.961 8. The characteristic curve was obtained as shown in Figure 2. As depicted in Figure 2, characteristic values were positive, with a mean value of 0.923 9, which was
consistent with the Pearson correlation coefficient of the simulated time series. The characteristic curve obtained from the multi-scale dynamic functional connectivity analysis provided coherence at each time point. Further detailed testing of multi-scale dynamic functional connectivity method is provided in Appendix B.

**Analysis of acupuncture effects**

The time series from both acupuncture groups were extracted from the ROIs: occipital lobe, declive, supramarginal gyrus, precuneus, and postcentral gyrus. The continuous wavelet transforms of these ROI time series were calculated. Due to a single-block design, the experimental period was 1 200 seconds and the frequency of acupuncture activity was 0.008 8 Hz. The fMRI data at pre-acupuncture state or pre-sham state and post-acupuncture state or post-sham state were all resting state fMRI. Studies have reported that resting state fMRI frequency ranges between 0.01 ~ 0.1 Hz, and signals with frequency > 0.1 Hz were considered high-frequency noise. Extraction of a characteristic curve in acupuncture fMRI data was performed under 0.1 Hz. Further details of characteristic curves from both groups are shown in Appendix A. When the WTC coefficient was decreased to 30% of $R^2$, it was determined that no specific effect remained, and the time point was marked as $T_0$. The specific effect lasting time was then calculated as $T = T_0 - 360$.

**Statistical analysis**

Group comparisons were evaluated using the regional homogeneity maps with voxel-wise independent two-sample $t$-test [Matlab R2010a (MathWorks, Natick, MA, USA)]. Statistical significance was thresholded at $P < 0.005$ (uncorrected) with a minimum cluster size of 5 voxels. Data from WTC statistic characteristics were also analyzed using the two-sample $t$-test. $P < 0.05$ was considered statistically significant.

**Author contributions**: Wenjuan Qiu and Bin Yan conceived the study. Bin Yan designed and performed the acupuncture experiment and provided acupuncture fMRI data. Wenjuan Qiu and Hongjian He finished the fMRI data analysis. Wenjuan Qiu and Li Tong wrote the manuscript, and Wenjuan Qiu was responsible for corrections. Jianxin Li was in charge of manuscript development and revision.

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**REFERENCES**

[1] Li G, Liu HL, Cheung RT, et al. An fMRI study comparing brain activation between word generation and electrical stimulation of language-implicated acupoints. Hum Brain Mapp. 2003;18(3): 233-238.

[2] Wu MT, Sheen JM, Chuang KH, et al. Neuronal specificity of acupuncture response: a fMRI study with electroacupuncture. Neuroimage. 2002;16(4):1028-1037.

[3] Beijing College of Traditional Chinese Medicine. Essentials of Chinese Acupuncture. Beijing: Foreign Languages Press. 1980.

[4] Wang W, Li KC, Shan BC, et al. Study of acupuncture point Liv3 with functional MRI. Zhonghua Fangshe Xue Zazhi. 2008;40(1): 29-35.

[5] Liu LH, Yan J, Yi SX, et al. Effects of electroacupuncture on gastric myoelectric activity and substance P in the dorsal vagal complex of rats. Neurosci Lett. 2004;356(2):99-102.

[6] Bai LJ, Qin W, Tian J, et al. Detection of dynamic brain network modulated by Acupuncture using a graph theory model. Ziran Kexue Jinzhan. 2009;19(7):827-835.

[7] Liu J, Qin W, Guo Q, et al. Distinct brain networks for time-varied characteristics of acupuncture. Neurosci Lett. 2010;486(3): 353-358.

[8] Bai LJ, Qin W, Liang JM, et al. Spatiotemporal modulation of central neural pathway underlying acupuncture action: a systematic review. Curr Med Imaging Rev. 2009;5(3):167-173.

[9] Bai L, Qin W, Tian J, et al. Time-varied characteristics of acupuncture effects in fMRI studies. Hum Brain Mapp. 2009; 30(11):3445-3460.

[10] Liu P, Zhang Y, Zhou G, et al. Partial correlation investigation on the default mode network involved in acupuncture: an fMRI study. Neurosci Lett. 2009;462(1):183-187.

[11] Zhang Y, Qin W, Liu P, et al. An fMRI study of acupuncture using independent component analysis. Neurosci Lett. 2009;449(1):8-9.

[12] Fair DA, Cohen AL, Dosenbach NU, et al. The maturing architecture of the brain’s default network. Proc Natl Acad Sci U S A. 2008;105(10):4028-4032.

[13] Supekar K, Musen M, Menon V. Development of large-scale functional brain networks in children. PLoS Biol. 2009;7(7): e1000157.

[14] Beason-Held LL, Kraut MA, Resnick SM. Stability of default-mode network activity in the aging brain. Brain Imaging Behav. 2009; 3(2):123-131.
[15] Waites AB, Stanislavsky A, Abbott DF, et al. Effect of prior cognitive state on resting state networks measured with functional connectivity. Hum Brain Mapp. 2005;24(1):59-68.

[16] Müller K, Lohmann G, Neumann J, et al. Investigating the wavelet coherence phase of the BOLD signal. J Magn Reson Imaging. 2004;20(1):145-152.

[17] Chang C, Glover GH. Time-frequency dynamics of resting-state brain connectivity measured with fMRI. Neuroimage. 2010;50(1):81-98.

[18] Zang Y, Jiang T, Lu Y, et al. Regional homogeneity approach to fMRI data analysis. Neuroimage. 2004;22(1):394-400.

[19] Kong J, Kaptchuk TJ, Webb JM, et al. Functional neuroanatomical investigation of vision-related acupuncture point specificity—a multisession fMRI study. Hum Brain Mapp. 2009;30(1):38-46.

[20] Hui KK, Liu J, Makris N, et al. Acupuncture modulates the limbic system and subcortical gray structures of the human brain: evidence from fMRI studies in normal subjects. Hum Brain Mapp. 2000;9(1):13-25.

[21] Fang J, Jin Z, Wang Y, et al. The salient characteristics of the central effects of acupuncture needling: limbic-paralimbic-neocortical network modulation. Hum Brain Mapp. 2009;30(4):1196-1206.

[22] Zhong ZP, Wu SS, Liu B, et al. Acupuncture at the acupoints of different meridians at the same anatomy level: a study with functional magnetic resonance imaging. Nan Fang Yi Ke Da Xue Xue Bao. 2010;30(6):1363-1365, 1372.

[23] Chen WL, Qian ZY, Zhang ZQ, et al. fMRI study of temporal lobe epilepsy using ReHo analysis. Shengwu Wuli Xuebao. 2008;24(6):460-464.

[24] Qiu WJ, Yan B, Li JX, et al. A resting-state functional MRI study of the post-effect of acupuncture. Harbin: The 2011 IEEE International Conference on Complex Medical Engineering. 2011.

[25] Long Y, Liu B, Liu X, et al. Resting-state functional MRI evaluation of after-effect of acupuncture at Zusanli point. Zhongguo Yixue Yingxiang Xue Jishu. 2009;25(3):373-376.

[26] Yan B, Li K, Xu J, et al. Acupoint-specific fMRI patterns in human brain. Neurosci Lett. 2005;383(3):236-240.

[27] Geroğ KM. Rank Correlation Methods. Oxford: Oxford University Press. 1995.

[28] Torrence C, Compo GP. A practical guide to wavelet analysis. Bull Am Meteorological Soc. 1998;79:61-78.

[29] Sun WG, Cheng BY. Application of cross wavelet transform to analysis on regional climate variations. Yingyong Qixiang Xuebao. 2008;19(4):479-487.

[30] Efroïn, B, Tibshirani R. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Stat Sci. 1986;1(1):54-74.

[31] Kurganskiĭ AV. Study of cortico-cortical functional connectivity with vector autoregressive model of multichannel EEG. Zh Vyssh Nerv Deiat Im I P Pavlova. 2010;60(6):740-759.

[32] Lowe MJ, Mock BJ, Sorenson JA. Functional connectivity in single and multislice echoplanar imaging using resting-state fluctuations. Neuroimage. 1998;7(2):119-132.

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