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Cortical Activation Response During Acupuncture Intervention for Hemiplegia Limbs in Stroke Patients: a Preliminary fNIRS Study

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***Abstract*— Observation of the cortical response to specific therapy in real-time would provide valuable evidence for the neural mechanisms underlying stroke rehabilitation. This study aimed to explore the cortical response during acupuncture in hemiplegic limb acupoints for stroke patients. Nineteen stroke patients were recruited for the measurement of cerebral hemodynamics during resting state and acupuncture state based on functional near-infrared spectroscopy (fNIRS). Wavelet amplitude (WA) was used to describe the cortical activation based on the time-frequency analysis of fNIRS signals. Results showed significantly higher WA of bilateral prefrontal and motor cortex during acupuncture state than the resting state. Additionally, significantly negative correlation was observed between the motor score and increased WA in the contralesional hemisphere. These findings suggest that there were increased cortical activation of bilateral hemispheres and patients with severe motor dysfunctions had more activation of contralesional hemisphere in response to the acupuncture intervention. This study provides preliminary evidence about the neural mechanism underlying acupuncture for motor impairment and suggests the role of fNIRS in stroke rehabilitation assessment.**

I. Introduction

Acupuncture is widely used in the treatment of motor dysfunctions after stroke. It is particularly important to make use of the advances in neuroimaging technology to combine acupuncture with brain science and clarify the neural mechanism between acupuncture and brain functional reorganization, so as to promote the scientific nature of acupuncture. Functional near-infrared spectroscopy (fNIRS) can non-invasively quantify the cortical hemodynamics during stroke rehabilitation therapy[1]. Thus, the present study aimed to explore the cortical response during acupuncture in hemiplegic limb acupoints for stroke patients using fNIRS based on the neurovascular coupling mechanism.

II. Materials and Methods

A. Participants

A total of 19 patients with stroke (mean age 58.5 ± 10.9, 4 female) with hemiplegia motor impairment were enrolled in this study. Inclusion criteria were: (1) first unilateral stroke as documented by radiologic evidence; (2) ability to understand and follow instruction. Clinical characteristics of the patients including age, sex, stroke information and Fugl-Meyer assessment (FMA) were collected. Written informed consent was signed before all procedures. The experimental procedure was in accordance with the ethical standards specified by Human Ethics Committee of National Research Center for Rehabilitation Technical Aids and the Helsinki Declaration of 1975 (revised in 2008).

B. Experimental design and data acquisition

A within-subjects cross-sectional study was applied to determine the effect of acupuncture of hemiplegic limbs on the cortical reorganization. Patients were required to complete a 10-min resting-state and a 10-min acupuncture intervention session both in sitting position, with mind relaxed and refrained voluntary movement in a silent room. A continuous-wave fNIRS system (Nirsmart, Danyang Huichuang Medical Equipment Co, Ltd, China) using two wavelength (760, 850 nm) was utilized to collect the fNIRS data with a sampling rate of 10 Hz. 32 customized channels were placed on the scalp overlying the bilateral prefrontal and motor cortex according to the international 10-20 system, as shown in **Fig.1(A)**. The emitter-detector distance was 3 cm. A professional Traditional Chinese Medical therapist performed acupuncture intervention for each subject, and the selected acupoints are shown in the **Fig.1(B)**.

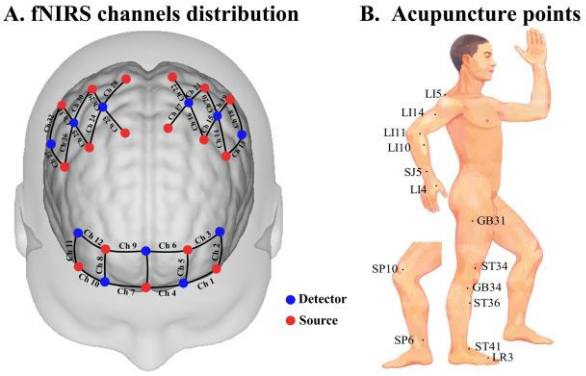

Figure 1. Experimental design. (A) Schematic arrangement of fNIRS probe array. (B) Acupuncture points in the hemiplegic upper and lower limbs.

C. Data pre-processing and Cortical activation analysis

Firstly, the absorbance signals collected by fNIRS were bandpass filtered at 0.0095-2 Hz (zero-phase, fifth-order Butterworth filter) to reduce the uncorrelated noise components and low-frequency baseline drift. Then, concentration changes in oxygenated hemoglobin (Δ[oxy-Hb]) were converted from the filtered light density signals by modified Beer-Lambert law[2]. Data preprocessing including motional artefacts and physiological interference removing was performed on Δ[oxy-Hb] signals[1].

Continuous wavelet transform was used to decompose signals in the time-frequency domain and provide localized phase and amplitude information [3], which is defined as:

$$W(s,t) = \int_{-\infty}^{\infty} \Psi_{s,t}(u) \cdot g(u) du \quad (1)$$

where Ψ represents Morlet wavelet. s is the scaling factor and its corresponding frequency is $f = 1/s$. $g(u)$ is the original

time series. This study focused on low-frequency oscillations in the interval of 0.01-0.08 Hz, mainly reflecting the cerebral hemodynamic response[4].

At a specific frequency f and time point t_n, wavelet coefficients are defined as:

$$w_k(t_n) = W_k(f,t_n)\cdot e^{i\emptyset_k(f,t_n)} = a_k(f,t_n) + ib_k(f,t_n) \quad (2)$$

where *k* represents the number of channels. *n* ranges from 1 to N, where N indicates the length of the time series. The amplitude information of Δ[oxy-Hb] signal at a certain frequency and time point is defined as $W_k(f,t_n)$:

$$W_k(f,t_n) = \sqrt{[a_k^2(f,t_n) + b_k^2(f,t_n)]} \quad (3)$$

Wavelet amplitude (WA) is defined as the average result of signal in the time domain. It can be expressed as a power index and used to characterize the cortical activity intensity.

D. Statistical analysis

The Kolmogorov-Smirnov and Levene tests were used to determine whether parameters were normally distributed at the group level. Significant differences for the channel-wise WA between the acupuncture state and rest state were evaluated by Paired-sample T-test. In the channels revealed to be significant, the Pearson correlation analysis was used to assess the relationships between changes of WA and FMA in stroke patients. Statistical significance was set at $p < 0.05$.

III. RESULTS

A. Brain activation response to acupuncture intervention

Fig. 2 shows the WA values changes in responding to acupuncture intervention in stroke patients. Results showed increased WA in bilateral hemispheres, which were significantly in channel 1, 6, 11, 13, 14, 15, 26, 30 during acupuncture as compared with the resting state ($p < 0.05$, without correction due to the exploratory nature of the study).

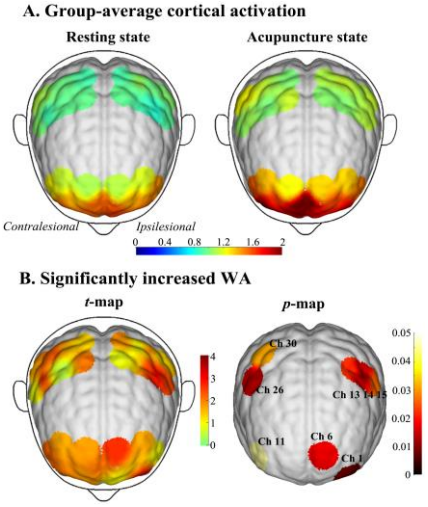

Figure 2. Brain activation response to acupuncture intervention

B. Correlation Between WA changes and Clinical evaluation

Significant negative correlation was observed between FMA and task-evoked increases in channel-wise WA in channel 11 and channel 26 ($p < 0.05$). These results suggest that patients with severer motor dysfunction showed more cortical activation in response to acupuncture intervention in the dorsolateral prefrontal and pre-motor and supplementary motor area of contralesional hemisphere.

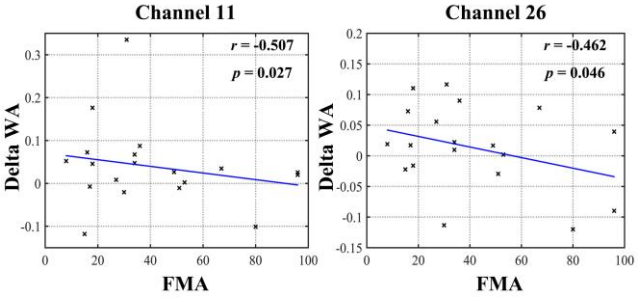

Figure 3. Correlation Between WA changes and FMA

IV. CONCLUSION

In conclusion, significantly higher WA values observed in the acupuncture state suggested an increased functional hemodynamic response in the brain related to the intervention. These results might indicate that acupuncture of hemiplegic limb meridians can modulate the blood circulation of brain tissue and promote plastic brain reorganization related to the motor function of stroke[5]. Apart from cortical activation, brain functional network analysis which could provide more information about the neural mechanism of acupuncture merits further research in the future[6]. Additionally, longitudinal follow-up trials should be designed in the future to verify the relationship between induced plasticity changes and clinical functional recovery.

ACKNOWLEDGMENT

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