Changes of Resting-state Functional Connectivity After Dual-site Transcranial Direct Current Stimulation for Enhancing Neural Plasticity of Gait-related Motor Network in Stroke Patients: An fNIRS Study

Jinuk Kim¹, Heegoo Kim¹, Ahee Lee^{1,2}, Jungsoo Lee^{1,2}, Hwang-Jae Lee^{1,2}, Won Hyuk Chang², and Yun-Hee Kim^{1, 2}

¹ Department of Health Sciences and Technology, Samsung Advanced Institute for Health Science and Technology, Sungkyunkwan University, Seoul, Republic of Korea
² Department of Physical and Rehabilitation Medicine, Center for Prevention and Rehabilitation, Heart Vascular Stroke Institute, Samsung Medical Center, Sungkyunkwan University School of Medicine

Introduction

- Transcranial direct current stimulation (tDCS) is one of the non-invasive neuromodulation techniques for corticospinal excitability.
- Recently, multi-channel approaches have been conducted to improve the effectiveness of tDCS.
- In this study, we investigated differences of the resting-state functional connectivity after dual-site tDCS for modulation of gait-related neural network plasticity in stroke patients using functional near-infrared spectroscopy (fNIRS).

Methods

Participants

- Twenty chronic stroke patients (13 males; mean age 56.0 ± 10.2 years) participated in this study.
- Inclusion criteria were 1) First-ever stroke patients between the ages of 20 and 70, 2) unilateral paralysis, 3) After six months or more from stroke onset, and 4) FAC score 3 points or more.

<Table 1. Characteristics of Participants >

Characteristics	Value
Gender (Male: Female)	13 : 7
Age (mean±SD)	56.0 (±10.2)
Lesion Side(Rt. : Lt.)	10 : 10
Stroke Type (Hemorrhage:Infarction)	10 : 10

Experimental Protocol

- A single-blind, randomized cross-over study (Figure 1)
- Four conditions were randomly applied to all participants with 24 hours of washout period between each session (Figure 3).
- Individual stimulation sites were hot spots of MEP to the lower extremity muscles (tibialis anterior).
- Two battery-driven stimulators (DC Plus stimulator, NeuroConn Ltd., Germany) were used for this experiment.
- Each anodal tDCS delivered at 2 mA intensity for 30 minutes.
- Electrode size: Anode; 3.5cm x 5.0cm, Cathode; 5.0cm x 7.0cm

<Figure 1. Experimental Protocol>

<Figure 2. fNIRS Probe Setup>

<Figure 3. Location of the electrodes in the four conditions>

Conclusion

- Dual-site tDCS demonstrated noticeable neuromodulation effect in the MEP amplitude and gait-related motor network connectivity than the sham or conventional single-site stimulation in chronic stroke patients. However, this effect was failed to produce behavioral benefit in clinical assessment of gait parameters in this experiment.

This research was supported by a grant from the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (HI17C1501) and NRF (NRF-2017R1A2A1A05000730, NRF-2017M3A9G5083690) funded by the Korean government.

Functional Near-Infrared Spectroscopy

- The hemodynamic responses were recorded by an fNIRS system (NIRScout®, NIRx Medical Technologies, Germany) before and immediately after the stimulation for each condition.
- fNIRS probes were set up using 12 optical sources and 12 detectors (64 channels) to cover the primary and secondary motor cortical regions bilaterally (Figure 2).
- Pearson correlation coefficient was calculated from oxyhemoglobin signals from each fNIRS channel.

Results

Changes of the gait-related motor network

- Changes of the functional connectivity after each stimulation condition were examined by the correlation coefficient with thresholding value of 0.6.
- The network changes after dual-site stimulation was noticeable compared to single or sham stimulation conditions (Figure 4).
- Connectivity between sensorimotor-related areas such as M1_Leg, SMA, and primary sensory cortex were increased after dual-site stimulation.

<Figure 4. Changes of the gait-related motor network connectivity>

Changes of Other Clinical Assessments

<Figure 5. Changes of MEP amplitude and gait speed>

- MEP amplitude was increased after dual-site stimulation and ipsilesional stimulation but not in other condition.
- 10m walking test showed significantly increased walking speed only after ipsilesional stimulation.
- Other gait parameters did not show significant difference between 4 conditions.