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Changes of cortical activation by wearable repetitive transcranial magnetic stimulation after stroke

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Introduction

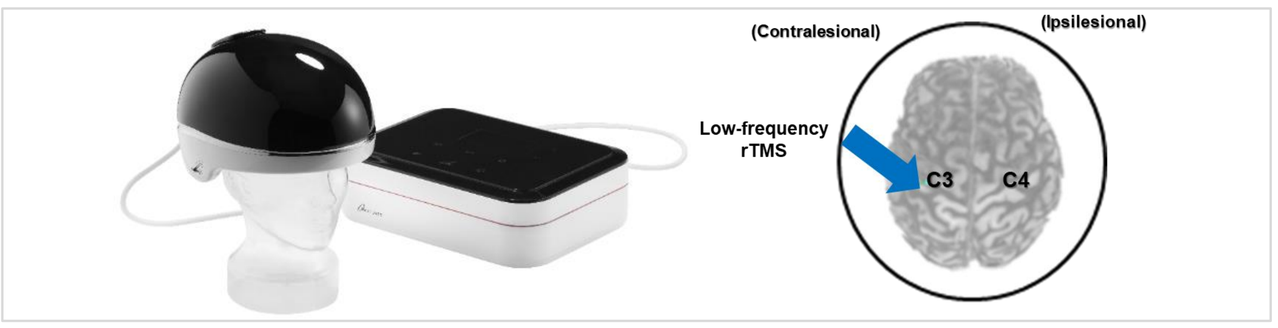
- Stroke remains one of the leading causes of long-term disability worldwide, profoundly affecting motor function and reducing quality of life for millions of survivors.
- Repetitive transcranial magnetic stimulation (rTMS) is a non-invasive brain stimulation technique that modulates cortical excitability, promoting cortical reorganization in stroke patients.
- In this present study, we aimed to investigate the hemodynamic changes of cortical activation by wearable rTMS in subacute stroke patients.

Methods

Study Design and Participants

- Clinical investigation this interventional, single-arm clinical study design. The inclusion criteria were unilateral stroke patients aged between 19 and 80 years, within 2 weeks to 3 months of stroke onset, with motor impairment as indicated by Fugl-Meyer Assessment (FMA) upper extremity score ranging from 0 to 56. The exclusion criteria were with a history of major neurogenic disorders, diagnosis with severe psychiatric disorders, impaired with cognitive function, contraindicated with rTMS application.
- All participants were allocated in the intervention group. Before (T0) and after (T1) intervention, they underwent functional near-infrared spectroscopy (fNIRS) measurement

Intervention

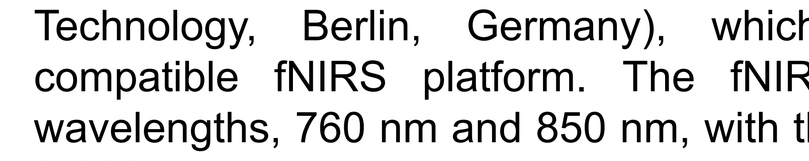


<Figure 1. Wearable rTMS intervention>

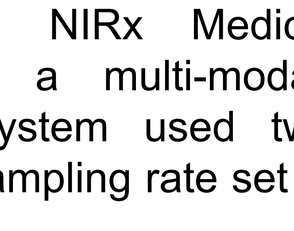
- The wearable rTMS was administered using the BrainStim-MT® device (REMED Co., Seoul, Korea), a miniaturized rTMS system designed to stimulate the motor cortex via a helmet-shaped transducer targeting the C3 or C4 region based on the) based on the 10-20 electroencephalogram (EEG) system.
- Low-frequency (1 Hz) rTMS was applied to the contralesional primary motor cortex (M1) over 20 minutes, twice daily, five days a week, for two weeks (total 20 sessions).

fNIRS Measurement and Analysis

- The hemodynamic change signals were a continuous wave fNIRS measurement system (NIRSport®; NIRx Medical Technology, Berlin, Germany), which is a multi-modal-compatible fNIRS platform. The fNIRS system used two wavelengths, 760 nm and 850 nm, with the sampling rate set to 2.6 Hz.
- During the fNIRS measurements, all patients performed the hand grasp and release task with the affected hand (Figure 2).
- Using 8 sources and detectors, the fNIRS topomap consisted of 20 channels with a distance of 3 cm between each source and detector. The fNIRS topomap covered the bilateral motor area (Figure 3).
- A band pass filter of 0.01–0.2 Hz was applied to fNIRS signals.
- For statistical parametric mapping (SPM) time-series analysis, the changes in oxyhemoglobin (oxyHb) and deoxyhemoglobin (deoxyHb) concentration were analyzed by nirsLAB® software (v.2019.04; NIRx Medical Technologies, LLC, Minneapolis, MN, USA)



<Figure 2. Task fNIRS measurement protocol>



<Figure 3. fNIRS Topomap>

Statistical Analysis

- To determine the statistical significance of the data, we used SPSS version 25.
- Wilcoxon signed-rank test was used to evaluate significant changes in oxyHb and deoxyHb during the task between T0 and T1.

Results

Demographics

- A total 4 participants completed the study procedure. The study basic characteristics of participants were described at Table 1.

Sub No.	Age	Sex	Dx.	Onset duration (days)	Affected side	FMA-UE score of affected side at screening
01	49	M	Right MCA territory of hemisphere and basal ganglia	24	Lt.	4
02	71	M	ICH, Rt. BG and IVH	16	Lt.	50
03	52	F	ICH in the left basal ganglia-corona radiata -thalamus	24	Rt.	4
04	47	M	ICH at right subcortical region of parietal lobe	19	Lt.	5
	50.5 (48.0-61.5)	M:F = 3:1		21.5 (17.5-24.0)	Rt.:Lt. =1:3	4.5 (4.0-27.5)

<Table 1. Demographic information of participants>

Changes of Cortical Activation

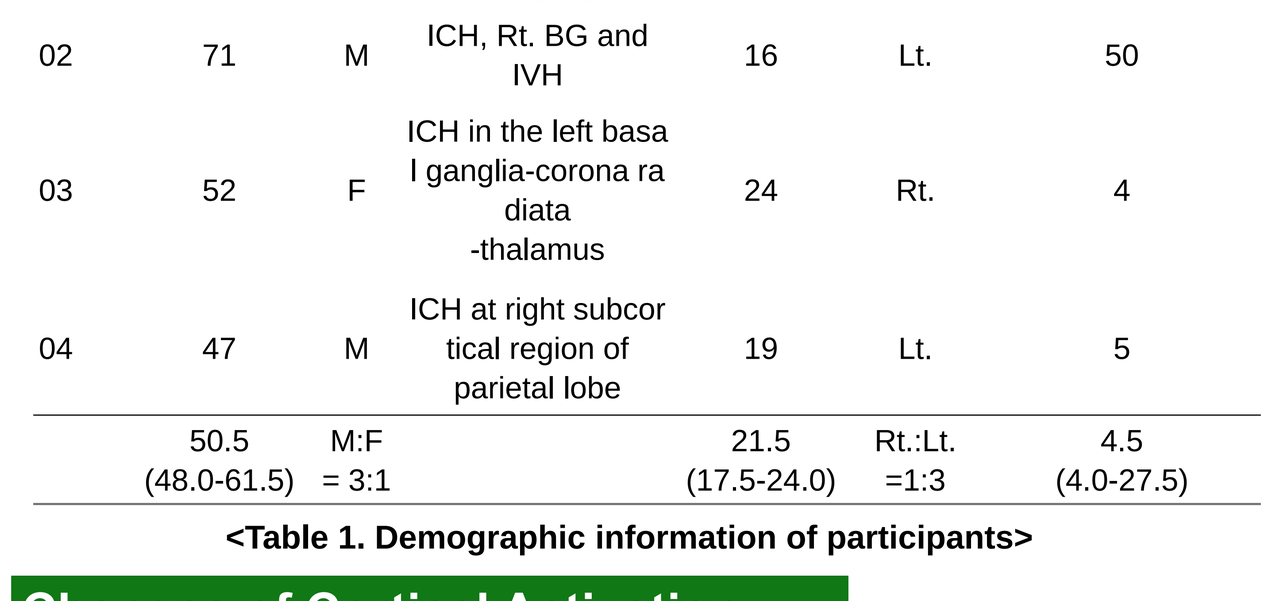


Figure 4. Cortical activation patterns during grasp and release task with affected hand before and after intervention.

- A group SPM analysis revealed that oxyHb concentration increased during the grasp and release task in contralesional hemisphere at T0 (Figure 4).
- However, there was no increment of oxyHb of ipsilesional hemisphere at T0.
- At T1, significant changes in cortical activation were observed in both the C3 (contralesional M1) and C4 (ipsilesional M1) regions during the grasp and release task, with a broader distribution of activation compared with T0.

Changes of oxyHb concentration

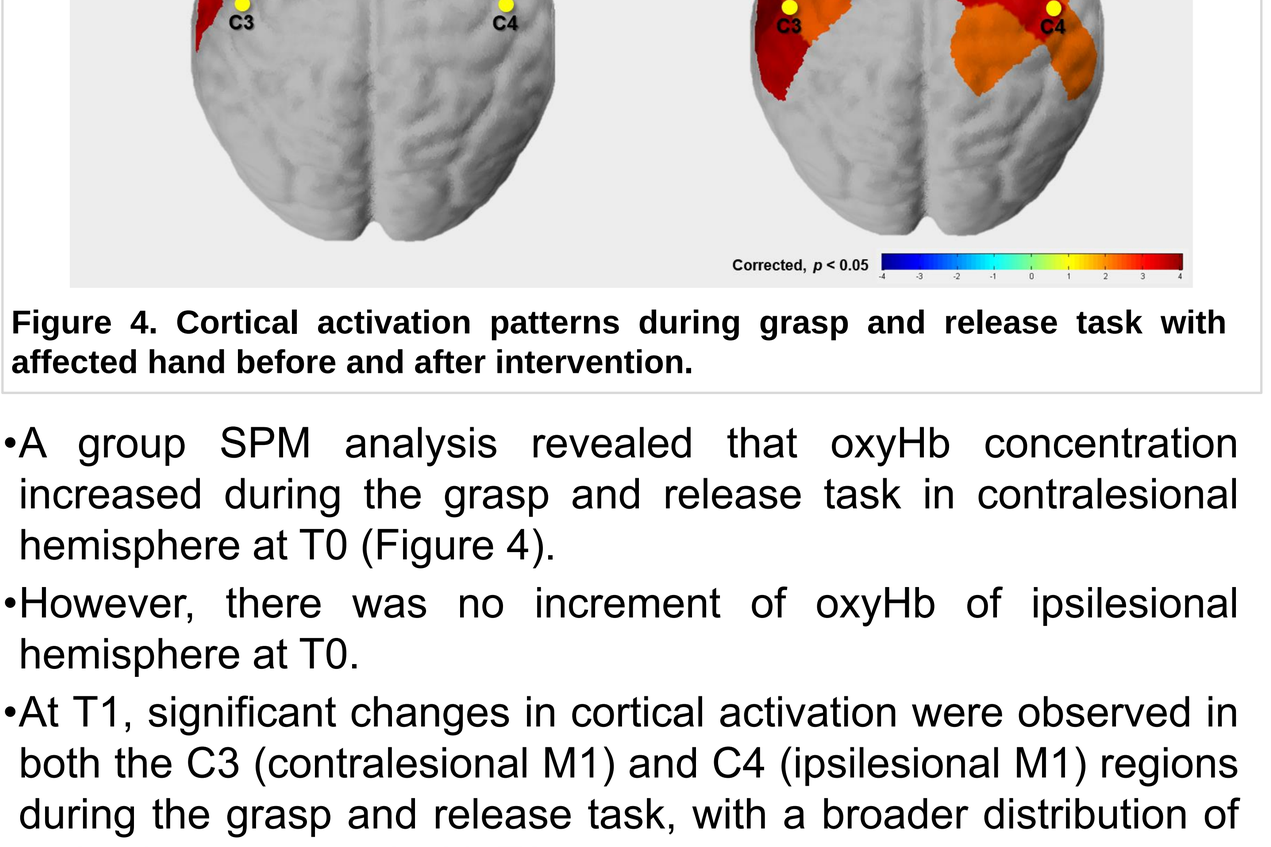


Figure 5. Results of time-series analysis during grasp and release task of affected motor area in each channel.

- Figure 5. describes the average group changes in oxyHb and deoxyHb concentrations of channels during grasp and release task through time-series analysis were presented in Figure 6-B.
- In channel 12,13,14,15 and 16, there were increment of oxyHb concentration during grasp and release task after wearable rTMS intervention.
- However, there were no statistical significances in changes of oxyHb and deoxyHb during grasp and release task in all the channels of affected motor area(Wilcoxon signed-rank test, $p > 0.05$)

Conclusion

- These results of this study suggested that application of wearable rTMS could enhance cortical activation during the task, particularly in the ipsilesional motor cortex. After stroke, application of wearable rTMS can provide the potential benefits to modulate the cortical activation of ipsilesonal motor area.

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