Brain Connectivity and CBF Canges Fllowing Motor Training by MI-BCI Combined with tDCS in Stroke Patients

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Target audience

Neuroimaging analysts, neurologists, rehabilitationists

Purpose

Robot-assisted motor imagery and brain-computer interface (MI-BCI) is a promising rehabilitation technique for stroke patients who suffer from motor disabilities [1-3]. Transcranial direct current stimulation (tDCS), a technique of noninvasive brain stimulation, is able to modulate the cortical excitability, and hence holds the potential to improve motor function recovery [4, 5]. The primary aim of this study was to investigate the structural and functional changes of the brain after rehabilitation training of MI-BCI combined with or without tDCS in stroke patients with impaired motor function.

Methods

13 patients (53.5±11.8 years old, 9 male and 4 female) who had their first ever subcortical stroke more than 9 months leading to unilateral moderate to severe impairment of upper extremity were recruited with written consent. Patients were randomly assigned to 2 groups, each underwent 10 sessions of MI-BCI training over 2 weeks with either 20 minutes of tDCS (the real group) or 1 minute of tDCS (ramping up and down, the sham group) preceding training. Motor function evaluation (by Fugl-Meyer assessment, FMA) and MRI scans were performed before and after training.

MRI data were collected using a 3T scanner (Siemens Trio, Germany). Perfusion images were acquired using pseudo-continuous arterial spin labeling (pCASL) with labeling duration=1500ms, post-labeling delay=1500ms, and gradient-echo EPI of TR=4000ms, TE=9.1ms, voxel =3x3x5mm^3, and 80 measurements. DTI data were acquired with spin-echo EPI with 61 diffusion sensitizing directions, b=1150mm^{2}s^{-1}, TR=8000ms, TE=87ms, voxel size=2.3mm isotropic. T1-weighted images were acquired with MPRAGE with TI=900ms and TR=1900ms, TE=2.5ms, voxel size=1mm isotropic.

MRI data analysis was performed using FSL [6] and in house MATLAB (The MathWorks, USA) codes. pCASL was motion corrected, pair-wise subtracted, normalized to control image for calculating the cerebral blood flow (CBF), and then nonlinearly registered to the MNI152 template. 4 datasets were excluded from statistical analysis due to artifacts. Each CBF map was normalized by the mean CBF over the whole brain. The asymmetry ratio between the ipsilesional and the contralesional CBF was calculated over the primary motor area (M1) and the hemisphere.

For DTI analysis, datasets with lesions on the left hemisphere were flipped along the left-right direction so that all datasets have lesions on the same side. A tract skeleton based on the mean fractional anisotropy (FA) of all subjects was created and FA, parallel diffusivity (Dp), and radial diffusivity (Dr) of all subjects were projected to the skeleton before voxelwise statistical analysis (TBSS, Tract-Based Spatial Statistics, [7], part of FSL).

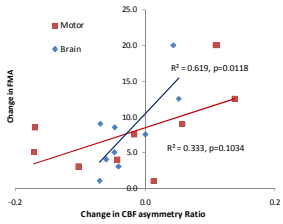

Fig 1. Correlation of change in FMA and change in CBF.

Results

FMA significantly increases after training for all subjects (p=0.016), though the change is not significantly different between the real and the sham groups (p=0.57). The CBF asymmetry ratio over the hemisphere or M1 after training is not significantly different from the pre-training value for the real, sham, or all the patients. The change in CBF asymmetry ratio correlates with the change in FMA in the brain, but not in M1 (Fig 1). Significant FA increase post training is found in the ipsilesional corticospinal tract (*cst*), the midbody of corpus callosum (*cc*), and the corona radiata (*cr*) (Fig 2). In these regions, most voxels show Dr decrease, though only about 30% reach the significance level. In *cst*, the change in FA correlates positively with the change of FMA, and the pre-training FA negatively correlates with the change of FMA, but both are insignificant. *Cc* shows stronger correlation with opposite trends while *cr* is not correlated (Fig 3).

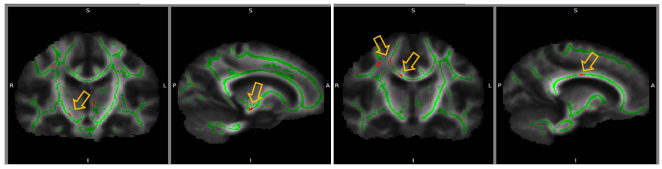

Fig 2. Regions with significant FA increase after training (in red and highlighted by yellow arrowheads) overlaid on the mean FA map (skeleton in green).

Discussion

The correlation between FMA change and the brain CBF asymmetry ratio change suggests that the recovery process may involve regions other than M1. Our findings of increased FA after training in *cst*, *cc* and *cr*, and their correlations with clinical performance suggest remodeling of these tracts involved during the motor learning process. Lack of between-group difference observed in either the clinical score or the CBF, DTI measures by MRI may be due to the low sensitivity of these measures and residual image registration error. Further analysis is needed to investigate the training effects in other brain areas, and the correlation of the CBF and diffusion measures.

Conclusion

White matter and gray matter CBF changes in the brain induced by 2-week motor training with MI-BCI in stroke patients are detected by MRI, which correlate with the improvement in clinical performance. tDCS did not show significant effects on the motor recovery process. These findings will be helpful in understanding the role of neuroplasticity in motor recovery, and in the development of effective therapeutic approach for stroke rehabilitation, as well.

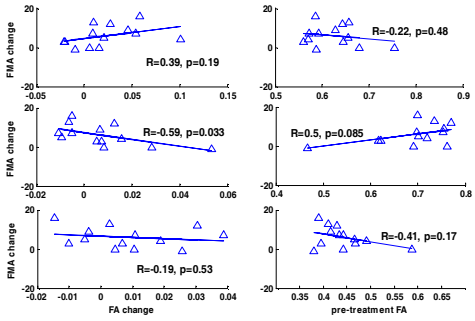

Fig 3. Correlation between FMA change and FA change (left column), and between FMA change and pre-training FA (right) in the three regions showing FA increase (top: *cst*; middle: *cc*; bottom: *cr*).

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