PS-2

Optimized transcranial direct current stimulation for hand motor recovery in stroke

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Background

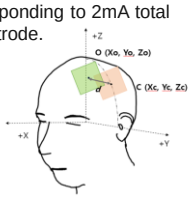
Transcranial Direct Current Stimulation (tDCS) is a noninvasive treatment that modulates cortical excitability via the application of weak current through the scalp. Several tDCS studies on post-stroke motor recovery showed potential benefits, but their active clinical application is limited due to inconsistent results. Heterogeneity in tDCS effects may be explained by brain structural variability due to stroke lesions or anatomical traits. This study aimed to evaluate the usefulness of optimized tDCS considering inter-individual brain structure variability in stroke patients.

Methods

We generated individualized MRI-based head models of 21 stroke subjects and simulated tDCS using the 'Neurophet tES LAB 3.0' software. In the conventional tDCS, electrodes were placed on C3/C4 of the 10-20 EEG system. For optimized tDCS, a stimulation target was designated as motor hand knob on MRI, and electrode positions that maximize the electric field in the target area were chosen through a software algorithm. The stimulation electrodes were modeled as 5 x 5 cm sponge-based electrodes, and current density corresponding to 2mA total current was applied to the anode electrode.

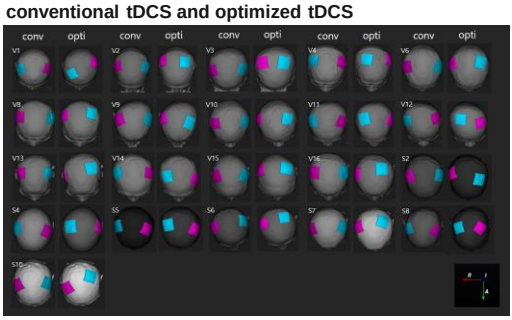
To quantitatively compare the electrode position of the optimized tDCS and the conventional tDCS, the Euclidean distances between two tDCS electrodes (*d*) were obtained.

$$D = d_{cathode} + d_{anode}$$



Results

Figure 1. Comparison of electrode montages for conventional tDCS and optimized tDCS



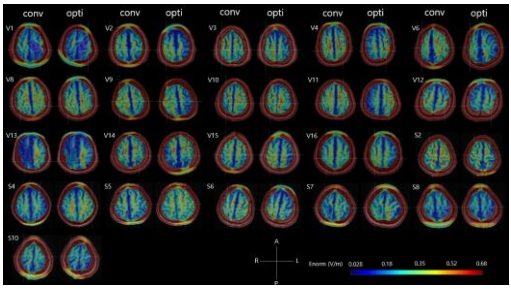
Montage pairs of conventional tDCS (left) and optimized tDCS (right) determined through simulation for each patient are displayed on the individualized head models. The pink electrode represents the anode and the cyan electrode represents the cathode.

Table 1. Distance between conventional tDCS electrodes and optimized tDCS electrodes

distance	$d_{cathode}$ (mm)	d_{anode} (mm)	*D* (mm)
median [IQR]	37.87 [31.19-41.76]	23.28 [17.60-29.99]	60.21 [57.14-66.94]

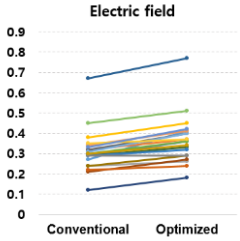
In the electrode positioning for optimized tDCS, the position change of the cathode was larger than that of the anode. (p<0.001)

Figure 2. Comparison of electric field distribution between conventional tDCS and optimized tDCS



Electric field distributions at the target area (hand motor cortex) for the conventional tDCS (left) and the optimized tDCS (right) in 21 stroke patients. The center of the intersecting line corresponds to the target area. The magnitude of the electric field is expressed by the background color

Figure 3. Electric field intensity at target region in conventional tDCS and optimized tDCS



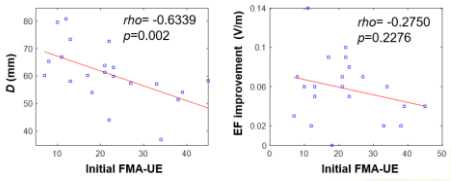
The electric field strength at the hand knob area was significantly higher in the optimized tDCS compared to the conventional tDCS. The mean improvement by optimized montage over conventional one was 20%.

Table 2. Difference in electrode position between conventional tDCS and optimized tDCS depending on the location of the brain lesion

	Non-cortical lesion (N=13)	Cortical lesion (N= 8)	*p-value*
D	58.28 [53.35-60.51]	69.80 [61.37-76.49]	0.010
EF improvement	0.060 [0.037-0.072]	0.065 [0.035-0.080]	0.6631

The distance (D) between the conventional tDCS electrode and the optimized tDCS electrode was larger in group with cortical brain lesions than in the group with non-cortical brain lesions

Figure 4. Correlation of initial upper extremity function with difference in electrode position between conventional tDCS and optimized tDCS



Scatter plot shows strong negative correlation between *D* and the initial FMA-UE of subjects

Conclusion

Optimized tDCS can help overcome variability in brain structure and achieve higher electric field strength in the target region in stroke patients compared to conventional tDCS.

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