Comparison of Motor Maps Obtained with Functional Magnetic Resonance Imaging and Transcranial Magnetic Stimulation: Effects of Motor Imagery, Movement, and Coil Orientation

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Introduction

Transcranial magnetic stimulation (TMS) is a method that allows for noninvasive activation of neurons in localized regions of cortex. TMS is widely used in neuroscience research and treatment of patients with neuropsychiatric disorders (1). The exact activation site on the cortex remains under debate since the previous studies found the discrepancies of the TMS and fMRI motor maps (2, 3). In the present study, we tested whether somatosensory component in the fMRI activity during overt movements may contribute to such discrepancy. We also examined the influence of TMS coil orientation which determines direction of the induced current with consequent differential effects on underlying neuronal elements.

Methods

Six right-handed healthy volunteers participated in this study. Prior to scanning, the subject's head was fitted with an elastic swim cap specially equiped with forty five 4-mm vitamin E capsules corresponding exactly to a 1x2 cm grid of stimulation points which was later used for TMS of the motor cortex (Fig. 1). All fMRI experiments were performed on a 3T Siemens Trio scanner. A single-shot gradient-echo EPI sequence was used to acquire T2*-weighted images over 28 oblique axial slices with TR/TE of 2000/35 ms, matrix of 64x64, FOV 22x22 and slice thickness of 3mm with no gap. A block-design paradigm consisted of periods of rest, executed (EM) and imagined (IM) right index finger movements each lasting 20 seconds. fMRI centers of gravity (fMRI CoG) were defined by the average of the Talairach (TAL) coordinates of the activated pixels in the primary motor cortex. A paired t-test was used to determine whether there was a statistically significant difference between fMRI CoG locations during IMs (IM CoGs) and EMs (EM CoGs). TMS was performed using MAGSTIM 200 with the coil handle pointing anterior, lateral and posterior. For each coil orientation, the scalp TMS center of gravity (TMS CoG) was determined by the center of mass of the motor evoked potential (MEP) distribution on the grid. The TMS CoGs were transformed into the fMRI TAL coordinate system based on their location relative to the fiducials on the T1 images. The TMS CoGs were then projected towards the cortex for 2 cm along the line perpendicular to the plane defined by the tangential lines in the sagittal and coronal views. The distance of the projection was chosen based on previous reports (4).

Results and Discussion

The IM CoGs were 1.17 ± 1.16 mm lateral to the cortical projection sites of the TMS CoGs while the EM CoGs were 9.50 ± 1.15 mm posterior to the projected TMS CoGs (Fig 2). Therefore the IM CoGs closely agreed with the TMS CoGs while the EM CoGs had an almost 1 cm mismatch. These results strongly suggest that the previously reported discrepancies between fMRI and TMS may be due to the somatosensory component of the EM task. In addition, there were no statistically significant differences between the TMS CoGs for three coil orientations suggesting that the mismatch between EM and TMS CoGs was not due to orientation of the magnetic field induced by the coil.

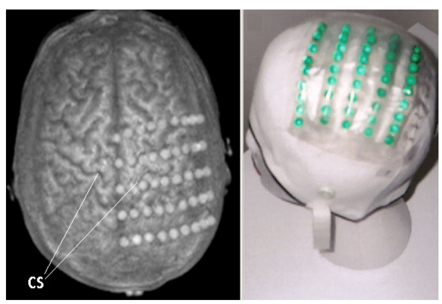

Fig. 1 Swim cap (reconstructed in 3D MRI on the left) showing 45 vitamin E capsules on the left side in a 1x2 cm grid used for TMS mapping. CS – central sulcus.

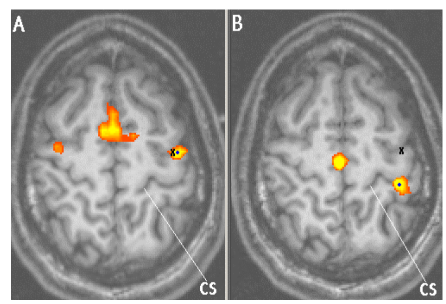

Fig. 2 Same-level axial slices of the fMRI maps. Black cross is the TMS CoG projection point. Blue dot is fMRI CoG. (A) The IM CoG is 1.11 mm lateral to the TMS CoG; (B) the EM CoG is 10.51 mm posterior to the TMS CoG. The IM CoG is 10.56 mm anterior to the EM CoG.

Conclusion

IM CoG closely matches the cortical site of the projected TMS CoG while EM CoG is shifted posteriorly as the result of somatosensory signal. These findings are not significantly affected by changing TMS coil orientation.

Acknowledgements
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