Somatotopic Representation of Acupoints in Human Primary Somatosensory Cortex: An fMRI Study

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Introduction

Some neuroimaging studies have determined brain areas activated or deactivated by manual or electric acupuncture stimulation.1,2 These studies have suggested that the limbic system and subcortical structures play an important role in the effect of acupuncture. However, virtually no acupuncture study has focused on the somatosensory cortex, although the somatosensory cortex as well as the limbic and subcortical areas are central to processing tactile information. In the present functional magnetic resonance imaging (fMRI) study, we investigated somatotopic representation of multiple acupoints on the upper and lower limbs in the human primary somatosensory cortex (S1). To our knowledge, this is the first study that clearly shows somatotopic mapping of acupoints in S1.

Materials and Methods

All experiments were undertaken with the informed consent of each subject following the guidelines approved by the Human Studies Committee of Meiji University of Oriental Medicine. Eleven healthy volunteers participated in the experiments. Subjects were screened and excluded if they had evidence or history of psychiatric and neurologic disorders. The brain activity of each subject was measured with a 1.5T magnetic resonance (MR) scanner (Signa LX NVi, GE, USA) using a standard head coil. The functional scans were acquired using gradient echo echo planar imaging (GE-EPI) sequence (repetition time [TR] = 3 s; echo time [TE] = 50 ms; fractional anisotropy [FA] = 90°; 64×64 matrix; 5-mm slice thickness; field of view [FOV] = 220×220 mm; 30 slices). Tactile stimulation was conducted by rubbing 6 acupoints in the right upper and lower limbs (Fig. 1a). A small area of skin (~4 cm²) involving each of the acupoints was repeatedly rubbed in one direction with a scrubbing sponge. We used rubbing instead of acupuncture stimulation to raise neural activity in the level to obtain clearer fMRI data in S1 because our primary aim was to establish somatotopic mapping of the acupoints. Experiments were executed in a design using of 30-s blocks: after a resting block, stimulation and resting blocks were repeated 4 times. In the stimulation block, one acupoint was stimulated for 30 s, whereas in the resting block, the subjects were not stimulated throughout 30 s. In an experimental session, one acupoint was stimulated, and the order of the sessions was independently randomized for each subject. All data were analyzed using statistical parametric mapping (SPM) 99 software (Wellcome Department of Imaging Neuroscience, London, United Kingdom). Head movement was corrected, and functional data sets were normalized to the standard MNI template. The normalized data sets were spatially smoothed with an 8-mm full width at half maximum (FWHM) Gaussian kernel. Group SPMs were then constructed across stimulation blocks and subjects, and threshold values set for corrected p < 0.0001.

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Results and Discussion

In the group analysis of 11 subjects, we found significant activation in the contralateral S1 for all acupoints investigated (Fig. 1b). The activated regions were located along the postcentral gyrus. The cortical regions representing the acupoints were arranged successively in the same order as on the body surface. The acupoints on the upper limb were represented in the lateral regions, whereas those on the lower limb were represented in the more medial locations. For the upper limb, the cortical representation of the acupoints shifted from distal to proximal as one goes from the lateral to medial cortical regions. For the lower limb, on the other hand, the cortical representation site of the distal acupoint was more medially located than that of the proximal acupoint.

These results were consistent with the somatotopic representation in S1 reported by Penfield3 using direct cortical stimulation and partly confirmed by recent fMRI4 and magnetoencephalography (MEG)5 studies. It is likely that S1, which subserves relatively higher order information processing, such as integration of body parts as well as of somatic and visual information,6 is partly responsible for acupuncture effect. Consistent with this idea, some fMRI studies1,2 have shown increased neural activity in the somatosensory cortex as well as decreased response in the limbic and subcortical areas during acupuncture stimulation.

The number of activated voxels (Fig. 2) was the largest of all the stimulation sites for the finger acupoint (A) was the largest of all the stimulation sites. See Fig. 1a for the stimulated acupoints.
acupoint (A), indicating large cortical magnification for the acupoint, although we could not exclude the possibility that differences in the number of activated voxels reflected unexpected differences in stimulus intensity or quality caused by manual stimulation.

Conclusion

The present study revealed somatotopic mapping of acupoints in S1. More detailed investigation of the functional relationship between the somatotopic and non-somatotopic regions, including the limbic and subcortical areas, may provide a basis for understanding the mechanisms of acupuncture treatment.

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References