Proton Density Change in Spinal Cord fMRI Induced by acupoint stimulation

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Introduction: Functional activation was observed in proton density-weighted spin-echo fMRI. This effect of Signal Enhancement by Extravascular Protons (SEEP)[1] was proposed to appear alongside with BOLD during functional activation. Previous reports have shown that activation could be detected both in the brain and the spinal cord during sensory-motor stimulation[2-5]. It was also shown that spinal cord fMRI is a reliable tool for functional localization, and it has been proven useful in investigating sensory and motor functions in the cervical and lumbar segments of the spinal cord. The present study aims to study the functional activation induced by acupoints simulation at low-field using proton density-weighted fMRI. Sensorimotor deficit-implicated acupoints stimulation was given to normal subjects using a block design paradigm. This study is the first attempt to investigate the effect of acupoint stimulation in cervical spinal cord.

Materials and Methods: fMRI studies were carried out on 28 normal volunteers (mean age of 25.96±5.25 years old, 14 males) with a 0.2T Profile MRI System (General Electric Medical System, Milwaukee, WI). A 9-inch GP coil was used to image the neck region from C5/C6 to T1. Electro-acupuncture stimulation was applied to acupoints LI4 and LI11 in the right hand. According to traditional Chinese acupuncture literature, LI4 and LI11 are the treatment acupoints for sensory-motor deficit. The fMRI stimulation paradigm is shown in Fig 1. Proton density-weighted imaging and fast spin echo pulse sequence were used with parameters: TR=1s, TE=24ms, ETL=6, NEX=2, slice thickness=10mm, with 1.25x1.25 mm^2 in-plane resolution. A software package was used to correct for the inter-scan motion using a 6-parameters rigid-body model and the data were resliced to a voxel size of 0.625x0.625x1.2 mm^3 to be near isotropic. An image mask was used in the image registration process to mask off the throat and neck muscle to improve the registration accuracy. Subjects with excessive motion were excluded. The exclusion criteria were determined by maximum translation of more than 4.2mm or with maximum rotation of more than 0.04 radian in any of the three orthogonal directions during the acquisition. These exclusion threshold values for the motion parameters were set prior to fMRI analysis to avoid any bias. The total number of subjects satisfying these criteria was 11 out of 28. SPM99 was then used for statistical analysis. Masked statistical maps were generated (P<0.006) which were overlaid on the proton density-weighted images for analysis.

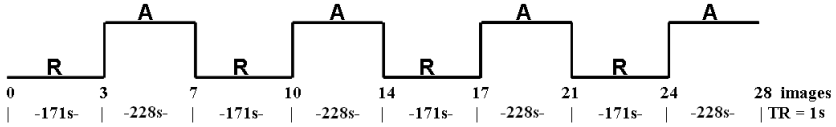

Fig. 1: fMRI stimulation paradigm. A stands for rest and B stands for stimulation

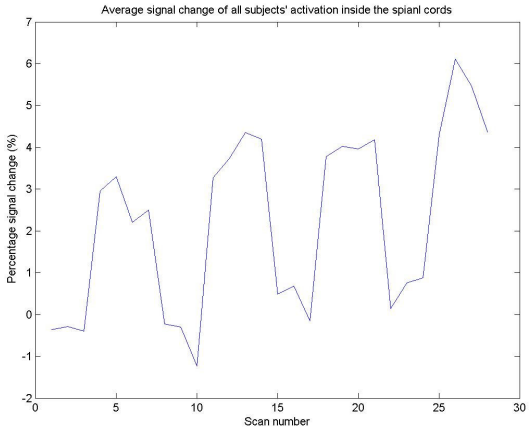

Fig. 3: Average percentage signal change over 8 subjects.

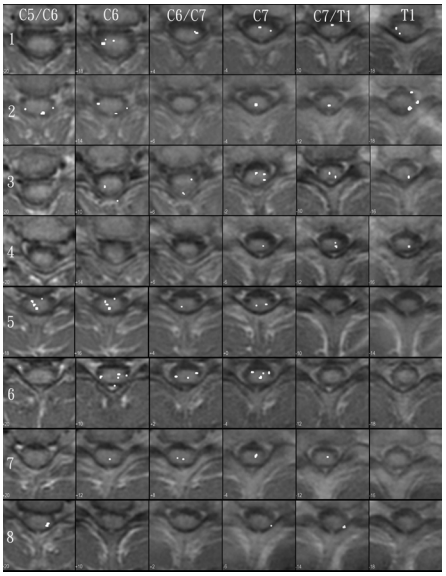

Fig. 2: Activation maps of the 8 subjects. Each row represents one subject and each column represents one spinal level from C5/C6 to T1.

Results: 8 out of 11 subjects included (72.7%) had positive activation found in the grey matter of the spinal cords. Figure 2 shows all the subjects' activation maps overlaid on the original proton density-weighted images of corresponding locations. Only one slice per level is shown for each subject. The discrete activation can be found in the anterior, posterior and lateral grey horns. The activation is likely to be localized at spinal levels from T1 to C5.with the peak of activity at C7 never level. Figure 3 shows the average percentage signal change over 11 subjects. The percentage change is about 4%. The spinal cords are deliberately divided into 3 parts for easy comparison. It can be seen that all the 3 regions: anterior, middle and posterior parts of the spinal cords have more or less the same amount of activation among subjects. The proton density change was detected in the cervical spinal cord sensorimotor areas bilaterally.

Discussion and Conclusions: This initial study demonstrates that SEEP spinal fMRI can be used to reliably assess the activity in the cervical spinal cord during upper limb sensorimotor deficit-implicated acupoint stimulation. In spite of the effects of motion, we were able to detect consistent areas of motor and sensory activities that correspond well with spinal cord neuroanatomy. The proton density change was detected in the cervical spinal cord sensorimotor areas bilaterally. In general, with the sensorimotor stimulus applied to the right hand, the activity is expected to be primarily on the right hand side of the spinal cord in the dorsal horn of the gray matter, with a spread of activity to adjacent segments and some spread to the contralateral side of the cord. With stimulation of the acupoints LI4, we observed activity spread across spinal cord segments from T1 to C5 with the peak of activity at C7 nerve level. This is consistent with stimulation of the Median nerve and the Ulnar nerve. Stimulation of the acupoint LI11 is expected to stimulate the Lateral Antibrachial Cutaneous nerve. Our findings show that acupoints are sites sensitive to needle stimulation, with ability to modulate the activities of selected spinal cord sites.

Reference: 1. Stroman PW et al., Magn Reson Med 2002;48(1):122-127. 2. Stroman PW et al., Magn Reson Med 2003;49(3):433-439.
3. Stroman PW et al., Neuroimage 2003;20(2):1210-1214. 4. Ng MC et al., *Proc. 4th IASTED VIIP*, 2004; Marbella, 926-930
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