Cervical spinal fMRI study: Modulation of functional activation signal by task difficulty, hand skill and handedness

M. C. Ng[1,2], H. F. Lau[3,4], E. X. Wu[3,4], E. S. Yang[1], Y. Hu[2], and D. K. Luk[2]

[1]Jockey Club MRI Centre, The University of Hong Kong, Pokfulam, Hong Kong, [2]Department of Orthopaedics and Traumatology, The University of Hong Kong, Pokfulam, Hong Kong, [3]Department of Electrical and Electronic Engineering, The University of Hong Kong, Pokfulam, Hong Kong, [4]Laboratory of Biomedical Imaging and Signal Processing, The University of Hong Kong, Pokfulam, Hong Kong

Introduction: Contralateral activations in the brain were revealed in 1973[1]. Since then, researchers have been investigating the relationship among hand skill, handedness, brain structure and functional activation using MRI[2-5]. Ipsilateral activation component has also been reported by researchers in brain BOLD fMRI studies with unilateral finger motion[3,5]. Our group has recently shown that bilateral activation was detected in the cervical spinal cord during unilateral fingers-tapping using spinal BOLD fMRI[6]. In the current study, we would like to investigate the effect of the handedness, hand skill and task difficulty on the activation signal in the cervical spinal cord.

Methods: Spinal BOLD fMRI has been performed on 10 healthy right-handed volunteers performing 4 sessions (left-easy (LE), right-easy (RE), left-difficult (LD) and right-difficult (RD)) of unilateral fingers-tapping tasks in 2 difficulty levels (easy and difficult) in 3T System.

Exercise paradigm: In order to describe the easy and difficult tasks, each digit is named by a number starting with the thumb as 1 and ending with the little finger as 5. The easy task requires the thumb to touch the digits sequentially in the order of (2 3 4 5) whereas the difficult task in the order of (4 2 3 5). The exercise paradigm used was a block design consisting of 4 cycles of alternated rest and motor periods, with each motor and rest period acquiring 10 scans. All subjects' performances were monitored during the studies to ensure that the motor task was performed properly by every subject. They were also instructed to perform both the easy and difficult tasks with a constant rate at around 1-2 Hz.

Scanning: Subjects were asked to lie supine in a 3T MR system (Philips Achieva) and a CTL spine coil was used to image the neck region enclosing C1/C2 to C6/C7 spinal levels. BOLD fMRI images were acquired with gradient echo echo-planar-imaging (GE-EPI) sequence with parameters: flip angle: 45 degrees, repetition time (TR): 2.5s, echo time (TE): 15ms, resolution: 1*1.33*5mm^3, number of averages: 3 and dynamic resolution: 7.5s.

Post-processing and analysis: The data obtained were then processed off-line. 2D rigid-body registration (by AIR[7]) was done on the data volumes to eliminate the bulk motion effect. The resliced data sets were then analyzed by using SPM99[8]. A box-car function was used to model the hemodynamic response. Statistical maps SPM{t} were then generated for all the subjects (P<0.001), which were masked for analysis. The mean t-values of the activation areas inside the cervical spinal cords were compared between the LE and LD tasks and between the RE and RD tasks using non-parametric Wilcoxon signed ranks test and sign test for paired samples.

Results: Seven out of ten subjects recruited had activation in all 4 fMRI sessions. Figure 1 shows the activation maps of one of the subjects. Activation can be detected inside the spinal cord in different tasks. Figure 2 shows the mean activation t-value inside the cervical spinal cords in different tasks. Our results showed that the mean t-value of activation areas in LD is significantly higher than in RD in both Wilcoxon signed ranks test (p = 0.018) and sign test (p=0.016). There is no significant difference between LE and RE.

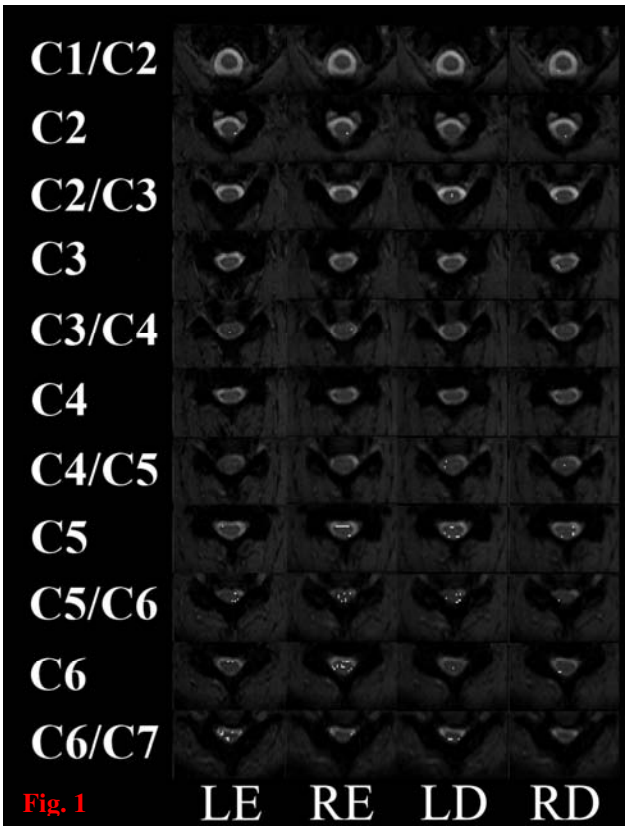

Fig 1: masked activation maps of one of the subjects in 4 tasks overlaid on the EPI (radiological orientation).

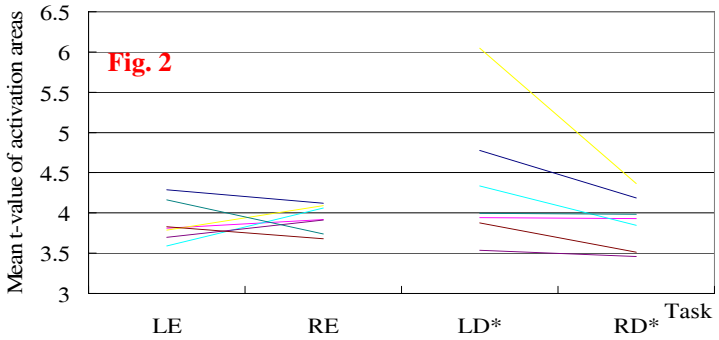

Fig 2: mean t-value of the activation areas in the cervical spinal cords of 7 subjects in different tasks. (One color represents one subject and * means significantly different)

Discussion and Conclusions: Our results showed that functional activation induced in fingers-tapping tasks can be detected inside the cervical spinal cord by using BOLD fMRI technique. Bilateral activations were detected as in the previous study[6]. The observation that the mean t-value of activation areas in LD is significantly higher than in RD, may imply more neuronal activities involvement in LD than RD. This may be related to the hand skill, handedness of the subjects, and the neural plasticity involved. More neuronal firings may be required to perform the difficult fingers-tapping task with left hand than with the right hand. There is no significant difference detected between LE and RE. This may be ascribed to the smaller hand skill difference in performing LE and RE. Our results support the idea of the modulation of functional activation signal in the cervical spinal cord by the hand skill, handedness and task difficulty.

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References : **1.**Brinkman J, et al. Brain 1973;96(4):653-674. **2.**Herve PY, et al. Neuroimage 2005;25(4):1133-1145. **3.**Li A, et al. AJNR Am J Neuroradiol 1996;17(4):651-655. **4.**Kim SG, et al. Science 1993;261(5121):615-617. **5.**Singh LN, et al. Neuroreport 1998;9(8):1861-1866. **6.**Ng MC, et al. ISMRM2006; Seattle, U.S.A. p 996. **7.**Woods RP, et al. J Comput Assist Tomogr. 1998;22(1):153-165. **8.**Friston KJ, et al. Human Brain Mapping 1994;1:153-171.