Mapping human proprioceptive projections of the upper limb muscles through spinal cord fMRI

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Abstract

Recent advances in functional magnetic resonance imaging (fMRI) have allowed investigation of the somatosensory and motor networks in the human spinal cord (Landelle et al. 2021; Rowald et al. 2022). Maps of different upper limb myotomes have been revealed by motor tasks (Kinany et al. 2019) but no fMRI study has investigated the precise location of muscle proprioceptive projections in the cervical spinal cord. Here, we explored the rostrocaudal activation patterns during upper limb proprioceptive stimulation to better characterize the spinal proprioceptive circuits in 14 healthy volunteers.
We exploited amagnetic vibrators to specifically stimulate proprioceptive afferences innervating six muscles in wrist, elbow and shoulder joints of participants' left arm. This kind of stimulation activates muscle spindles and elicits illusory sensations of movement by recruiting full sensorimotor pathways (Kavounoudias et al. 2008). Functional MR images were acquired between C2 and C8 vertebrae and preprocessed with the Spinal Cord Toolbox (De Leener et al. 2017).

Group-level analysis revealed a rostrocaudal organization of proprioceptive projections from C3 to C7-C8 that matched the expected proximo-distal location of upper-limb proprioceptive neurons, although a substantial inter-subject variability was observed. Activations were primarily distributed along the extent of the left dorsal hemicord, though ventral and contralateral hemicords were also activated to a lesser extent.
This study reveals muscle proprioceptive maps of the cervical spinal cord based on functional MR recordings. These maps are essential for improving our understanding of the healthy and injured spinal cord, guiding neurosurgical interventions, and helping the design of neuroprosthetic treatments.

Keywords: Proprioception, spinal cord, fMRI, mechanical vibration

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