A search for an optimal neuronal marker for spinal cord fMRI

Kenneth A. Weber II[1,2], Yufen Chen[1], Xue Wang[1], and Todd B. Parrish[1]

[1]*Department of Radiology, Northwestern University, Chicago, IL, United States,* [2]*Interdepartmental Neuroscience Program, Northwestern University, Chicago, IL, United States*

Purpose

Functional magnetic resonance imaging (fMRI) has gained rapid popularity as a tool for investigating brain activity and has expanded our understanding of brain networks and function. Several groups have begun to expand fMRI to investigate brainstem and spinal cord activity; however, spinal cord fMRI has lagged behind brain fMRI due to several inherent technical difficulties that include magnetic susceptibilities at bone-tissue interfaces, the small dimensions of the spinal cord, and physiological noise.

Conventional fMRI exploits changes in blood oxygen levels (Blood Oxygen Level Dependent (BOLD) contrast) as a proxy for neural activity. However, gradient-echo echo-planar imaging (GE EPI) based BOLD fMRI is prone to signal loss and image distortion due to its sensitivity to field inhomogeneities, and it has limited resolution, making it suboptimal for spinal cord fMRI. Recent advancements in fMRI acquisition methods employing both BOLD[1] and non-BOLD[2] functional contrasts have been purported to overcome the issues of magnetic susceptibilities at bone-tissue interfaces while being sensitive to neural activity.

The goal of this study is to investigate and compare steady state free precession (SSFP), proton density spin-echo EPI (SE EPI), and short TE half-Fourier single-shot turbo spin-echo (HASTE) sequences for functional neuroimaging to determine their potential for use in spinal cord fMRI by testing them in the motor cortex. The data from these sequences were compared to conventional GE EPI based BOLD fMRI.

Methods

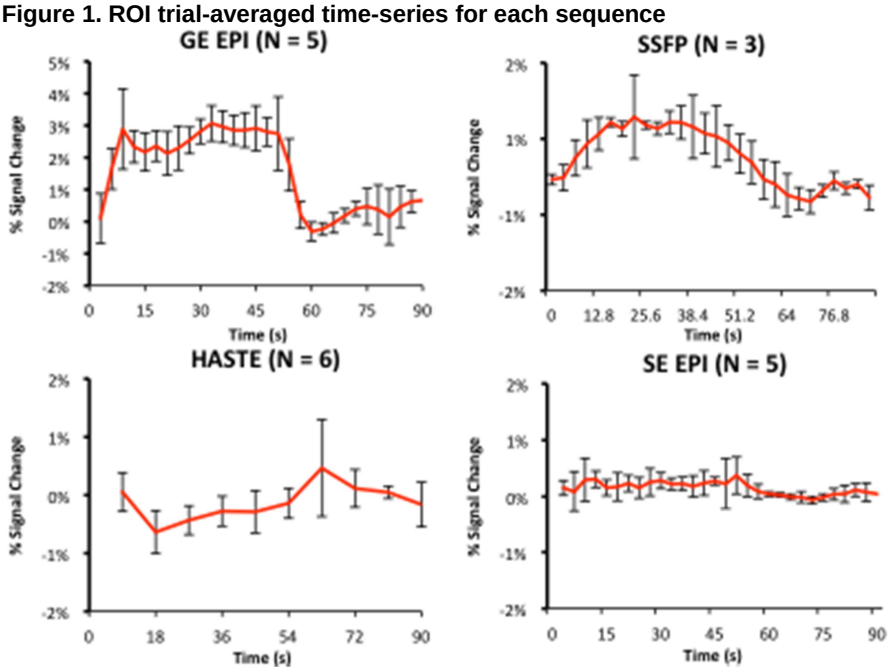
Seven healthy subjects (4 male: 3 female, age = 37.9±8.9 years) participated in a single scanning session. Subjects responded to visual cues by sequential tapping of the thumbs to the fingers (45 s alternating blocks of active and rest for 6 minutes total). Long blocks were used to accommodate the non-BOLD contrast mechanism. Data were acquired over a region of interest (ROI) containing the primary motor (M1) and primary sensory (S1) cortices. The following sequences were used: GE EPI (TE = 20 ms, TR_{3D} (TR of 3D volume) = 3 s, flip angle = 80°, slice thickness = 3.0 mm, and in-plane resolution = 1.7 x 1.7 mm^2), SSFP (TE = 3 ms, TR_{3D} = 3.2 s, flip angle = 30°, slice thickness = 2 mm, and in-plane resolution = 1.1 x 1.1 mm^2), SE EPI (TE = 15 ms, TR_{3D} = 3 s, flip angle = 90°, slice thickness = 3.0 mm, and in-plane resolution = 1.7 x 1.7 mm^2), and HASTE (TE = 36 ms, TR_{3D} = 9 s, flip angle = 135°, slice thickness = 2.4 mm, and in-plane resolution = 1.1 x 1.1 mm^2). Imaging was performed using a 3.0T MR scanner (Siemens TIM Trio, Erlangen, Germany) equipped with a 12-channel head coil. The order of the sequences was randomized.

All analyses were performed using FSL (FMRIB, Oxford, UK). Data were pre-processed (motion corrected, high-pass filtered, and spatially smoothed), statistical activation maps were computed, and group analyses were performed. The average MR signal from a ROI over the bilateral M1 and S1 was baseline corrected, time-locked, and trial-averaged for each sequence and compared.

Results

Group analysis of the GE-EPI data demonstrated significant neural activity in bilateral M1 and S1. SSFP demonstrated significant activation in bilateral M1 and S1 in three of the four subjects; however, no significant activation remained following the group analysis. Individual and group analysis of the SE EPI and HASTE data failed to demonstrate any significant activation. The ROI analysis demonstrated task-related changes in MR signal for the GE-EPI and SSFP sequences with the most pronounced changes with GE EPI. The SE EPI and HASTE data failed to demonstrate task-related changes in the MR signal (Figure 1).

Figure 1. ROI trial-averaged time-series for each sequence



Conclusion

Overall, task-related changes in the MR signal for the SE-EPI and HASTE were not demonstrated in M1/S1. The results are in opposition to previous studies using spin-echo sequences as a functional neuroimaging contrast.[2]

SSFP may be a possible alternative method to conventional GE EPI BOLD fMRI. SSFP offers a high signal to noise ratio, high spatial resolution, sensitivity to BOLD signal change, and distortion-free images. SSFP has not been used previously in spinal cord fMRI.

References

1. Miller KL et al. Magn Reson Med. Jan 2006;55(1):161-170.

2. Stroman PW et al. Magn Reson Med. Mar 2003;49(3):433-439.