Investigating possible fMRI responses in the median nerve during wrist stimulation by Transcutaneous Electrical Nerve Stimulation (TENS)

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Target Audience fMRI Scientists, Physicists, Musculoskeletal Radiologists, Neurologists

Purpose Indirect measurement of neural activation through the BOLD response lacks spatial resolution and has low temporal resolution (6-12s) due to the slow hemodynamic response. Direct electromagnetic detection can potentially provide a more spatially and temporally accurate measurement of neural function [1, 2]. The aim of this study was to investigate whether fMRI responses can be measured during median nerve activity. The median nerve was stimulated at the threshold of action potential generation using transcutaneous electrical nerve stimulation (TENS).

Methods All volunteer experiments were performed in accordance with local ethical committee guidelines and approval. Functional images were acquired on a 1.5 Tesla MR Scanner (SignaHdx, GE Healthcare, Milwaukee, USA) with an 8 channel wrist coil using a gradient echo EPI sequence. The median nerve was activated using a battery operated TENS device (TPN300, Physio-Med Services, Glossop, UK) located within the magnet room with extended twisted pair cables attached to electrodes placed on the hands of six healthy volunteers. Two frequencies (2.5 and 3.5Hz) and a pulse width of 260μs were used for stimulation. The stimulation amplitude was adjusted until the volunteer could feel an electrical shock but without producing muscle twitch or hand movement. Short TR=88ms with TE = 25ms and 500 dynamic scans for investigating fast responses to electrical stimulation (effective response bandwidth 5.7Hz) were used. The sequence used matrix = 64x64 providing 3.75 mm in plane resolution, slice thickness=5mm, flip angle=90^{o}. Data were analysed using a MATLAB program written in-house based on SPM methodology with a Z-score of 2.5 and Fourier Transform of the ROI time series with peaks with SNR > 3:1 and frequency equal to the stimulation frequency +/-0.1Hz identified as significant responses.

Results

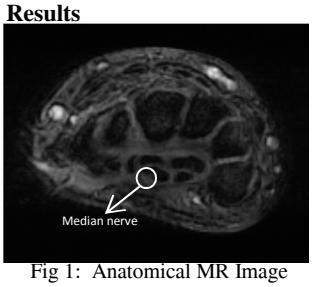

Fig 1: Anatomical MR Image

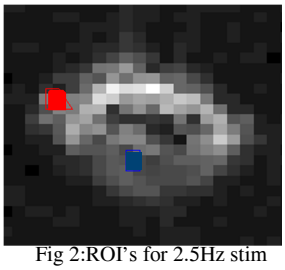

Fig 2:ROI's for 2.5Hz stim

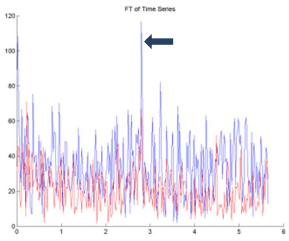

Fig 3: FT of MR time series 2.5Hz

ROI's were selected in the median nerve and in muscle tissue, Figs 1 and 2. Fig, 3 shows a typical response at 2.5 Hz recorded from the ROI in the median nerve (blue) but not from muscle tissue (red).

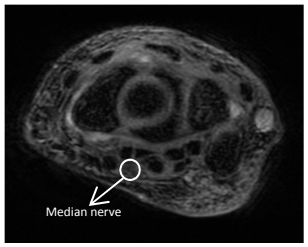

Fig 4: Anatomical MR Image

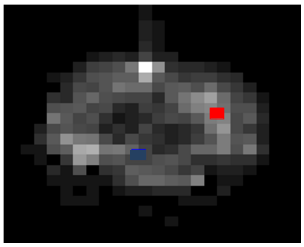

Fig 5: ROI's for 3.5Hz stim

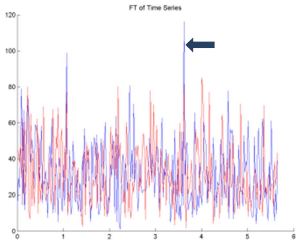

Fig 6: FT of MR time series 3.5Hz

Localization of the median nerve and selected ROI's are shown in figures 4 and 5. The FFT of the corresponding time series is shown in figure 6. A response is seen from the median nerve (blue) at 3.5 Hz but not from muscle tissue (red).

Discussion Evidence of fMRI responses in the median nerve during wrist stimulation by TENS was observed at relatively high stimulation frequencies (2.5 and 3.5 Hz). Responses with SNR > 3:1 were observed at the correct frequency in 12 out of 16 experiments on the six volunteers.

Conclusion Although not as reliably observed as the BOLD signal, the fast fMRI technique did appear to detect a weak nerve response to strong electrical stimulation in these experiments and has great potential to increase the spatial and temporal accuracy in detecting neuronal function if improved acquisition sensitivity can be achieved.

References 1. Chow LS et al. Investigating direct detection of axon firing in the adult human optic nerve using MRI. Neuroimage 2006;30:835-846 2. Poplawsky AJ, Dingledine R, Hu XP. Direct detection of a single evoked action potential with MRS in Lumbricus terrestris. NMR in Biomedicine 2012;25:123-130.