Fast MR signal changes associated with 3Hz spike-and-wave complexes in generalised epilepsy

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Introduction

Recent investigations have demonstrated the possibility of detecting magnetic field perturbations caused by neuronal depolarisation currents using MRI [1, 2]. This novel contrast mechanism if proven reliable would reflect brain activity more directly than the BOLD effect. The MR acquisition sequences used to reveal the Neuroelectric activity are similar to those used for conventional BOLD imaging, although the timing requirements of the MR acquisition are much more stringent. In light of this we have reanalysed some of our EEG-correlated BOLD data in attempt to reveal fast, neuroelectric activity. Previously, we presented activations observed in a patient with idiopathic generalised epilepsy using EEG-correlated fMRI [3]. Four runs of 3Hz generalised spike-wave discharge (GSWD) occurred during 35 minutes of data acquisition and time-locked, bilateral, thalamic BOLD increases were reported to be accompanied by widespread, symmetric, cortical deactivation with a frontal maximum.

Methods

Images were acquired on a 1.5T GE Horizon EchoSpeed system using a standard head coil. Seven hundred BOLD sensitive scans were acquired continuously using a T2*-weighted gradient-echo EPI sequence (TE=40ms; TR=3000ms; 21x5mm interleaved slices; Field of View 24x24; 64x64matrix). Images were realigned and then smoothed using an isotropic Gaussian kernel of 8mm FWHM. Using a mask, six separate, voxel-based statistical analyses were then carried out using SPM2 (http://www.fil.ion.ucl.ac.uk/spm/spm2.html) on six individual slices covering the thalamus and main regions of cortical deactivation. For the analysis of slice *n*, a vector of onsets was defined, containing the timing of spikes in each 3Hz GSWD complex relative to the time, during the first volume-acquisition, when slice *n* was acquired. Two different hypotheses were then tested using a single SPM model: 1) To test for seizure related BOLD changes, the vector of onsets was convolved with two basis functions, a canonical hemodynamic response function and its temporal derivative; 2) To test for fast MR signal changes during the 300ms following each spike, ten finite impulse responses (FIR) were proposed, occurring each in 30ms bins one after another in the wake of each onset. By this means, we tested for fast activity while taking into account the slow BOLD response. Two F-statistics were formed to test for the BOLD response and to test for fast changes represented by all 10 FIR regressors. Corrected SPM{F} maps were thresholded at $P<0.05$ and uncorrected maps at $P<0.001$.

Results

Significant BOLD activation was revealed as previously reported and activity was seen also in association with the 10 FIRs for each slice analysed, and clusters of activation survived correction in 2 out of 6 slices.

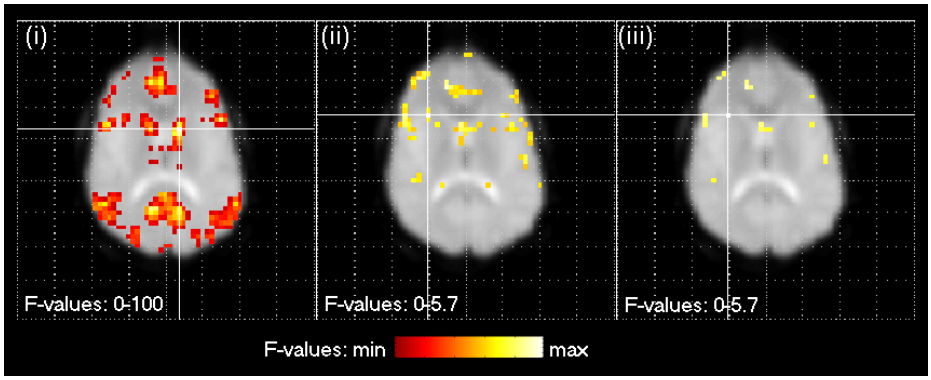

Figure 1: SPM{F} maps of activations in a single slice associated with (i) BOLD ($P<0.05$, corrected) and with immediate, fast changes (<300ms) (ii) $P<0.001$, uncorrected (iii) $P<0.05$, corrected. Maxima are indicated by the crosshairs.

Discussion & conclusion

We modelled the MRI response as the sum of a signal of unspecified shape (set of FIR) in phase with the spike-wave discharges and a convolution of the canonical HRF (and time derivative) and stick functions representing discharge onsets. Due to the slow sampling rate, experimental efficiency was limited with as reflected by the maximum of 5 samples per FIR bin. The resulting distribution of fast activity shown corresponds roughly to regions of BOLD activation, though the maxima don't coincide exactly. Interpretation of the findings is limited in part by the uncertain nature of the electrical generator(s) that underlie this type of activity.

In conclusion, we have demonstrated significant MRI activity at a time scale of the order of 30ms associated with generalised spike-wave discharges but further work is necessary before firm conclusions may be drawn.

References

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