Localization of epileptiform activity using spike-triggered fMRI

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Introduction
The localization of epileptic activity is important to understanding the underlying cause of epilepsy and to allow surgical treatment in patients with medically intractable seizures. In many patients this requires invasive investigations. We have developed a method to record safe [1], high quality [2] EEG inside the MR scanner, which allows the detection of subclinical epileptic activity (spikes) on-line and triggering fMRI acquisitions after these EEG events. This method provides a non-invasive tool to localize the neuronal generators of epileptic activity with high spatial resolution [3].

Methods
Twenty-three patients with localization-related epilepsy and frequent interictal epileptiform discharges were studied. Fourteen patients were studied at least twice, a total of forty-three experiments was performed. EEG was recorded inside the MR scanner using the Neurolink system (Physiometrix, MA, USA), a non-ferrous EEG head box and a digital EEG recording system (sample rate 200 Hz, bandwidth 0.12 to 50 Hz), developed in-house. Pulse-artifact subtraction software was used to facilitate EEG interpretation [2]. fMRI was performed on a 1.5 T Horizon MRI scanner (General Electric, Milwaukee, USA) using snapshot gradient-echo echo-planar imaging (EPI) (acquisition time 4.5 s, TE 40 ms, 24 cm field-of-view, 64x64 matrix). Twenty 5 mm axial images were acquired non-periodically 3.5 seconds after a typical spike was observed (active image), or after at least 10 seconds without spikes (control image). The SPM package was used for spatial realignment and statistical analysis. Temporal high-pass filtering was applied and the significance threshold was set to $p<0.001$.

Results
Between 21 and the maximum of 50 spikes were sampled in each study. Eleven of 23 patients (48%) showed focal BOLD signal changes in close spatial relation to the EEG focus. Six of the patients with a positive activation showed focal lesions (hippocampal sclerosis ($n=2$), malformations of cortical development (MCD) ($n=3$), tumour ($n=1$)) on structural MRI. In all six patients, the activation was overlapping or adjacent to the lesion. Twelve of the 23 patients (52%) did not show focal fMRI activation.

Conclusion
Spike-triggered fMRI performed on a 1.5 Tesla MR scanner could identify brain areas involved in generating interictal epileptiform discharges in 48% of patients with localization-related epilepsy and frequent interictal spikes. In these patients, this method can help to identify the epileptogenic zone and assist in the presurgical evaluation if seizures are medically intractable.

Figure 1: Spike-triggered fMRI: BOLD activation map (SPM96) of an individual patient showing a right temporal activation, concordant with EEG spike-focus

Figure 2: Activation of right posterior temporal and parietal lobe, concordant with the EEG spike focus and structural lesion (MCD).

References
1. Lemieux L. et al. MRM 1997; 38: 943-952