Measuring variability in the BOLD response to interictal epileptiform discharges: an EEG/fMRI study.

A. B. Waites[1], D. Flanagan[1], R. A. Masterton[1], D. F. Abbott[1], and G. D. Jackson[1]
[1]Brain Research Institute, Heidelberg West, Vic, Australia

Introduction

Understanding the source of abnormal electrical activity associated with epilepsy remains a great challenge in management of the disease. By simultaneously acquiring EEG and fMRI data, we can utilise their different signal characteristics to localise the origin of interictal epileptiform discharges (IED). However, despite advances in technology, the EEG trace acquired in the MR scanner remains difficult to read categorically. It is of great interest to understand the relationship between EEG events and BOLD events. Specifically, we wish to understand how variable the BOLD response to an IED is, and how this is affected by subject motion and the anatomical location of the event.

Methods

9 patients with partial or generalised epilepsy were considered in this study. The fMRI studies were performed with a 3 tesla GE Signa LX scanner (GE, Milwaukee, WI). Approximately 30 minutes of simultaneous EEG and fMRI were acquired in each case. Analysis was performed using SPM2 (www.fil.ion.ucl.ac.uk/spm) and iBrain (www.brain.org.au/ibrain). Conventional analysis, treating all EEG events as equal, was compared to a flexible modelling approach, where each IED is modelled individually. The goodness of fit of the two modelling approaches was assessed using the adjusted coefficient of determination (R^2a).

Results

Flexible modelling showed that the BOLD response varied significantly between individual IEDs within each of the patients. In the individual shown in Figure 1, we see the BOLD response to individual EEG events, and observe a marked difference in the distribution of cortical involvement. Thus, using a flexible model allowing different responses for each IED allows us to be sensitive to this variability. Further, in Figure 2 we see that the flexible modelling approach better explained the data (assessed using R^2a), leading to increased sensitivity in detecting and localising the BOLD response. In this patient, this occurred both in the focal frontal region (only seen using the flexible model), and in the bilateral regions of activation (detected with both models).

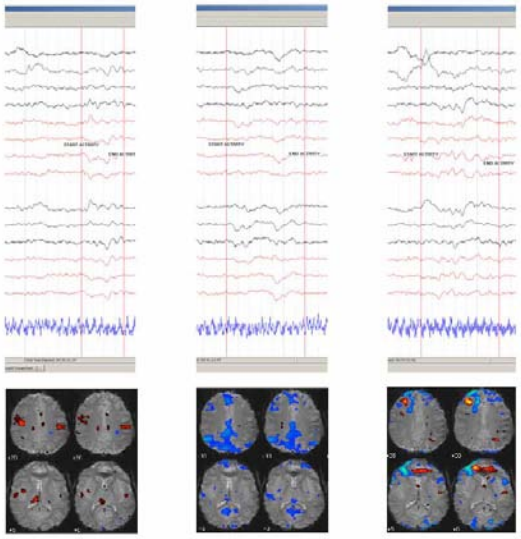

Figure 1: The EEG trace of 3 IED events in one patient are shown, together with the corresponding BOLD response. Events show distinct patterns of BOLD activation.

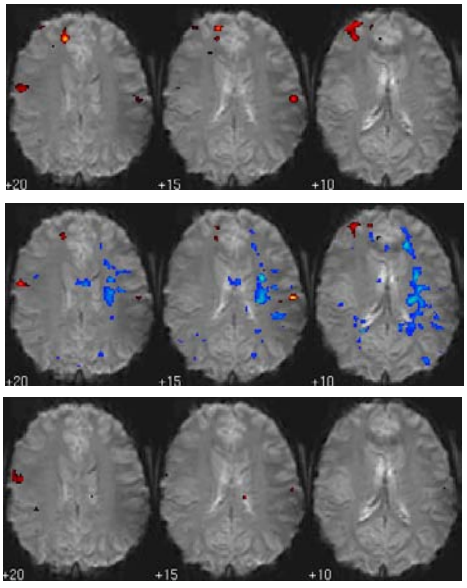

Figure 2: fMRI results for patient A: Flexible model (top panel) and standard model (bottom), and goodness of fit (R^2a) results (middle). R^2a results show the flexible model (hot colours) a better model of cortical signals active in this subject, whereas the standard model having higher R^2a in white matter areas with very low signal response, more sensitive to loss in degrees of freedom.

Discussion

In patients with epilepsy, showing 3-20 IEDs within a thirty-minute period, the BOLD response to IEDs varied significantly, making a standard modelling approach unable to reflect all aspects of the underlying cortical activity. The flexible modelling allowed detection of groups of events with distinct distributions, and provided a better description of the data, as assessed using R^2a. The approach permitted better modelling in regions already detected using the standard model, as well as detecting other regions involved in the disease.

These results have implications for how data analysis of simultaneous fMRI/EEG studies should be performed, as well as promising a new approach to understanding the coupling between cortical electrical events that span a $6cm^2$ region (EEG), and downstream vascular changes (fMRI) This may help us to better understand our findings, ultimately leading to new insights into the epileptic brain activity of individual patients.