Combining electrophysiology and imaging in epilepsy:
EEG-fMRI, electrical and magnetic source imaging, DTI

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Epilepsy is singularly characterised by the occurrence of events, namely epileptic seizures. Our understanding of the generators that give rise to seizures and abnormal patterns commonly seen on EEG between seizures (interictal), epileptic spikes, is limited with important implications for clinical management particularly in focal epilepsy where the surgical removal of the generators offers the possibility of a cure. In generalised forms of epilepsy, such as idiopathic generalised epilepsy (IGE), there is greater interest in understanding the mechanisms than the localisation. Increasingly these generators are thought of as networks potentially involving regions distributed throughout the entire brain, in part due to the findings of whole-brain, tomographic imaging and mapping techniques such as structural and functional MRI.

Except in rare cases, the occurrence of seizures and interictal spikes is totally unpredictable with no or very little scope for modulating these phenomena in humans. The study of the generators of epileptic activity must go through the study of the signals that can be measured during such activity, most commonly: EEG, MEG and fMRI. In focal epilepsy, the most clinically relevant aspect of these generators is their location, a crucial form of information if surgery is being considered. All these technique are able to provide localising information and we will show how they compare and can be combined when used to map epileptic activity. Furthermore, the inter-relationship between electrophysiology and putative haemodynamic changes associated with epileptic activity may provide insights about the underlying physiological processes.

We will focus on a review of the methodology and findings of combined (and in particular simultaneously acquired) scalp and intracranial EEG and fMRI, MEG and structural MRI applied to the study of spontaneous epileptic discharges. Data fusion techniques will be reviewed and illustrated. We will describe the use of biophysically-informed models to infer causal relationships between activities in brain networks.