

Clinical neurophysiology is one of the lesser known medical beasts, small enough to pass unnoticed, yet diverse enough to throw up surprises. EMG and EEG form its backbone, but what of the less well understood branches that are continually evolving and moving in new directions? This new series takes us on a tour of some of these exciting new avenues, ably guided by some of the experts responsible for shaping them. The aim of each article is to provide an

overview of a new technique and discuss its role in clinical practice, both now and in the future. In this exciting series we are starting with a discussion of magnetoencephalography (MEG) by Fergus Rugg-Gunn. In future issues we can look forward to hearing about electrotonus, fMRI-EEG, single pulse electrical stimulation and other techniques – words which at present may carry no meaning for some readers, but all will be revealed in the fullness of time.



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Magnetoencephalography – Current Use and Future Applications

Magnetoencephalography (MEG) is a non-invasive neurophysiological technique that measures the magnetic fields generated by intracellular neuronal currents in the brain. The recorded magnetic field pattern is analysed to determine the localisation of either spontaneous, for example epileptic, or evoked, for example, somatosensory, neuronal activity. The resulting map of magnetic dipoles is typically superimposed on a co-registered MRI scan to facilitate accurate neuroanatomical localisation.

The first MEG recordings of cortical activity took place in 1968 using a single channel biomagnetometer. Data from a large number of recordings was averaged to elucidate normal resting alpha activity. In the late 1970's, a number of important advances, including the construction of specially shielded rooms to reduce interference from ambient electromagnetic noise, the development of gradiometers which measure magnetic field gradients rather than the actual field and the introduction of superconducting quantum interference devices (SQUIDs) greatly improved the sensitivity of MEG. These innovations permitted, for the first time, the detection of spontaneous and evoked neuronal activity (Figure 1).

More recently, whole head magnetometers comprising up to 275 sensors have been developed which through more extensive spatial coverage produce greater accuracy of dipole localisation and spatiotemporal propagation within an acceptable time period.

The magnetic fields detected by MEG originate from dipolar intracellular currents associated with dendritic inhibitory and excitatory post-synaptic potentials within sulcal pyramidal neurons orientated tangentially with the cortical surface. MEG is insensitive to radially orientated neurons located on the gyral crown, which comprise approximately one third of cortical neurons, and which dominate the EEG. The magnitude of the magnetic fields produced from about 10^4 – 10^5 synchronous potentials, typical for an evoked auditory or somatosensory response, is in the order of 100 femtotesla, with

epileptic activity in the region of 1-2 picotesla (Figure 2).

MEG has high temporal resolution, in the milliseconds range, which is comparable to EEG, and favourable to functional MRI which has a temporal resolution of several seconds. Modern multi-channel, whole-head MEG systems possess good spatial resolution; in the order of <5mm localisation error, with a mean scattering of source localisations of 10mm for neocortical generators, compared to a mean scattering of 20mm for EEG. In addition, magnetic fields are less distorted by the resistive properties of the skull and scalp and retain localisation accuracy following craniotomy and resective surgery. MEG is, however, an expensive investigative tool with a modern multichannel whole-head magnetometer, shielded room, liquid helium and computer hardware costing in the region of £1.5 million. This is beyond the reach of all but the most dedicated specialist units.

Clinical Applications

Epilepsy

The clinical potential of MEG was first demonstrated in studies of patients with epilepsy with the detection and localisation of, for example, rolandic spikes using single channel detectors. Currently, the main application of MEG in epilepsy is the characterisation of epileptic foci through the source localisation of interictal epileptiform activity,¹ although, infrequently, ictal abnormalities are recorded by chance. The sensitivity of MEG for the identification of interictal epileptiform discharges, typically spikes, is approximately 50-70%, with 89% localisation accuracy, using standard equivalent current dipole source localisation techniques (Figure 3). This is possibly further enhanced by using advanced analysis methods such as dynamic source modelling. MEG has been reported to be of superior localising accuracy to scalp EEG and of equivalent accuracy to invasive EEG recordings in predicting the epileptogenic zone in patients undergoing presurgical evaluation. In 41



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Figure 1: Single channel MEG recording of normal alpha rhythm.

