Epilepsy monitoring unit observations yield key clinical, research benefits

by **Elizabeth Tyler-Kabara, MD, PhD**

Since January 2009 greater than 90% of the patients age eight-years-old and older admitted for monitoring with subdural strip and grid electrodes have been enrolled in a clinical study to explore the use of electrocorticography (ECoG) in brain computer interfaces. This has provided the preliminary data for two clinical trials for the use of brain computer interfaces as neural prosthetics in patients with spinal cord injuries. Additionally, observations made during recordings done in the EMU have led to a study about optimization of electrode spacing.

Electrocorticography has proved to be a valuable technique for the localization of epileptic foci. It is used both intraoperatively and in the EMU. Many researchers have attempted to improve the sensitivity of ECoG recordings by redesigning electrodes with tighter electrode spacing and reduced electrode size in expectation of improved resolution. We began designing electrodes to optimize the ability to identify as many unique features of the ECoG signals for use with a brain computer interface. In the literature we found that in some circumstances, the depth of the neural sources, or neurons, were often neglected, leading to unintended consequences of these changes. We have focused on estimating the trade-offs implicit in electrode size and spacing in order to provide a design with improved resolution at useful signal-to-noise ratios.

We used a model of the brain and real data to estimate the spatial resolution of various electrode designs and to evaluate the signal to noise ratio. An analytic model of the volume conductor was created and solved using electromagnetic reciprocity for the sensitivity of a subdural disc electrode to each point in the cortical volume. ECoG recordings from 10 human subjects undergoing monitoring for intractable epilepsy were used to identify realistic electrode impedance, and signal-to-noise levels.

Electrode disc radius was found to affect not only the effective resolution of the recording, but also the depth of sensitivity in cortex. Thus, very small electrodes are unable to record from all but the shallowest synapses of Layer I, while very large electrodes show relatively minor loss of sensitivity even well past the neocortex. In order to maintain sensitivity of at least 50% through to Layer 5, an electrode with a radius of at least 1.8mm was required. At this electrode radius, the expected resolution of a grid is between 3mm and 5mm depending on depth, suggesting one possible interelectrode spacing. This suggests traditional clinical grids, which typically have an interelectrode distance of 1 cm and a radius of 2.5 mm, undersample the cortical surface by ~2-3 times. In contrast, an electrode with radius 0.5mm is able to achieve a resolution of 1-4mm depending on depth, but has only 26% sensitivity to layer 5 compared to layer 1.

This model suggests theoretical and practical limits to the resolution of ECoG recordings (both over the cortical surface and in depth), and important parameters to consider to achieve useful recordings. Precise identification of the volume of sensitivity of an electrode may allow researchers and clinicians to better analyze ECoG signals and to provide an improved understanding of the underlying neurobiology and pathology of these complex waves. This suggests that specific grid configurations could be designed to optimize recordings from cortex versus deeper lesions. This could be used to better located seizure foci.

These studies represent collaboration between the Departments of Neurological Surgery, Physical Medicine and Rehabilitation, and Neurology. •