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Magnetic Source Imaging Laboratory

DANIEL 1S A 28-YEAR OLD MAN who was diagnosed with a tumor in the left frontal part it age 17. As a result of this brain tumor, Daniel also suffered recurrent seizures. At the time of initial diagnosis, the tumor was considered inoperable because of its proximity to presumed functional language cortex. Because of concerns about loss of speech following surgery, Daniel and his family elected to treat the tumor in a more conservative manner. However, more recent evaluation of Daniel's tumor revealed growth and surgery was considered necessary. Fortunately, Daniel and his treating physicians have been able to utilize a new functional neuroimaging technology called Magnetic Source Imaging to accurately identify both the language cortex and seizure focus in relation to his brain tumor. With this information, Daniel's neurosurgeon, Mary. Beth Dunn, M.D., was able to maximize the resection of his tumor without invading functional cortex, which ultimately led to a more favorable outcome.

Magnetic Source Imaging (MSI)/ magnetoencephalography (MEG) is now being performed at United Hospital in St. Paul. (This is the only clinical site utilizing this technology in the state of Minnesota and one of 14 sites nationally). The primary indication for this state-of-the-art technology is presurgical evaluation of epilepsy and brain tumor patients. MEG is used to identify the epileptogenic zone in relation to structural brain pathology, as well as to map the location of cortical functions including motor, sensory and primary language areas. MSI is the co-registration of the MEG activity data to a 3T MM to accurately localize the seizure and functional mapping data on the MRI brain image. The MSI laboratory opened in November 2004 as part of United Hospital's John Nasseff Neuroscience Institute. To date, nearly 130 adult and pediatric patients have undergone this safe, non-invasive, painless procedure.

How does MSI work? Very small magnetic fields produced by intracellular currents in the brain are detected with an array of highly sensitive magnetometers. The technique of recording these magnetic fields is magnetoencephalography. MEG detects minute biomagnetic signals produced by the brain, either spontaneously or in response to stimulation, without use of an external magnet. The topographic distributions of the brain's magnetic fields can be analyzed to determine the source of the activity and this information can be mapped onto the patient's existing MM. MEG is a direct measure of neuronal activity unlike other functional neuroimaging techniques, such as functional MRI (fMRI), PET and SPECT that reflect changes in brain metabolism.

MSI has several advantages of other functional neuroimaging techniques. MEG has very high temporal resolution. The events recorded can be measured in sub-milliseconds, whereas fMRI, PET, and SPECT measure metabolic changes in seconds to minutes. Spatial resolution is also excellent. Unlike EEG that tends to show distortion across the skull, MEG accurately localizes seizure activity with millimeter precision and can generally detect deeper seizure sources than those recorded by a chronically implanted subdural electrode array. Localization of the epileptogenic focus can help determine whether or not the patient is a good surgical candidate. MSI mapping of the functional cortex is especially useful to the neurosurgeon in planning which areas of cortex can be safely resected. This allows the surgeon to determine the safest approach to the surgical target, and in some cases, estimate potential postoperative deficits. The information from MSI can also be used to minimize the craniotomy size or use of invasive cortical mapping. This particular procedure is now widely accepted in the planning of epilepsy surgery and brain tumor treatment, and can offer critical information to maximizing a successful outcome for the patient.

The procedure of MEG data recording involves having the patient lie on a bed in a magnetically-shielded room. A helmet-like dewar with 148 channels is placed over the subject's head for recording spontaneous interictal epileptic activity and/or evoked magnetic fields produced by sensory, motor and auditory or visual tasks. For seizure localization and

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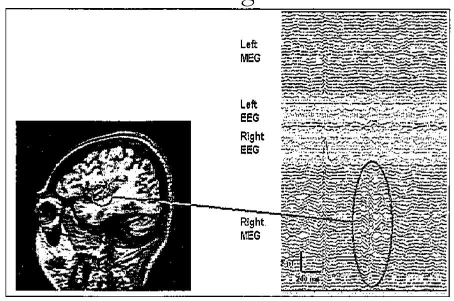
functional mapping, the entire session lasts approximately three hours. Children as young as five have been successfully mapped using the evoked language procedure. Sedation can be safely used in pediatric or mentally handicapped populations. The FDA has cleared MEG for use since 1987. HCFA approved MEGs for clinical use by issuing CPT codes of 95965, 95966 and 95967 for the use of this procedure, especially (and only) for patients with epilepsy and surgical mapping needs.

Several cases illustrate the value of MSI in the presurgical evaluation of epilepsy and brain tumor patients. Patient #1 is a 53-year old, right-handed woman who was evaluated in a metro-area emergency room for recent onset of left facial numbness and tingling. Work-up for a cerebrovascular etiology revealed a large right frontal brain tumor in the premotor areas with moderate associated edema. Neurosurgical consultation led to a stereotactic brain biopsy for the patient, which resulted in diagnosis of a grade II astrocytoma. MSI was ordered to map any interictal seizure activity and sensory/motor function. The MSI revealed no identifiable seizure activity, while mapping of the left index and middle finger sensory function showed localization very near and adjacent to the tumor. Moreover, motor mapping with the left index finger showed the tumor to be infiltrating the primary motor strip. Based on these findings, a surgical option was not pursued because the patient would likely experience a significant residual left-sided motor deficit. Instead, the patient was offered radiation and chemotherapy to treat her neoplasm. In this case, MSI was invaluable in identifying eloquent motor cortex without the use of an invasive intracranial procedure.

The second case involves a 13-year old, right-handed boy with epilepsy and cortical dysplasia who was referred for MSI after failing surgical treatment of his seizures. At age six, he underwent focal resective surgery of the right posterior temporal-occipital lobe but continued to have seizures on a weekly basis following his operation. The MSI showed clear epileptogenic activities involving the remaining abnormal cortex both anterior and posterior to the prior surgical cavity. The MSI findings were then



corroborated by subsequent intraoperative corticography, which led to complete resection of the seizure field. Seven months following surgery, the patient remains seizure-free and has no postoperative neurologic deficits. This case demonstrates the ability of MSI to accurately define an epileptogenic seizure field, which is crucial for subsequent presurgical planning as well as negating the need for possible additional invasive procedures.

MEG/MSI is a unique and effective diagnostic tool for evaluating brain function and epileptogenic seizure localization for a variety of surgical planning applications. Moreover, MSI is superior to fMRI in functional mapping for patients with vascular malformations and brain tumors given that fMRI relies on a hemodynamic response that may be disturbed in these patients. MSI is also the preferred cortical mapping procedure for large brain tumors where traditional subdural grids may be contraindicated due to concerns about increased intracranial pressure.

Future applications for MEG include measuring cerebral plasticity as it relates to functional recovery from cerebrovascular events and determining biological markers for dyslexia.

The Magnetic Source Imaging Laboratory is a collaborative program between Minnesota Epilepsy Group, P.A., and United Hospital.

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