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STEREOELECTROENCEPHALOGRAPHY (SEEG) IN THE UNITED STATES. RE-DISCORVERING AN INVASIVE METHOD FOR EXTRAOPERATIVE MONITORING IN REFRACTORY FOCAL EPILEPSY

Epilepsy surgery is based on the principle that resection of the epileptogenic zone (E.Z.) can result in freedom from seizures. The E.Z. is defined as the area of the brain necessary and sufficient to generate seizures. The corollary to this is that it is the exact amount of brain that needs resected to render the patient seizure free. Precise localization of the E.Z. and its relationship to eloquent cortex is crucial for the success of epilepsy surgery. In certain clinical scenarios, invasive electrode recordings allow accurate localization of the epileptogenic zone and mapping of functional cortical regions.

The most common indications for intracranial electrodes include lateralization or better localization of the E.Z. and functional mapping of eloquent cortical areas. In the first case, preoperative noninvasive studies and semiology often suggest focal epilepsy, but not precisely enough to adequately localize or lateralize the epileptogenic zone. In the United States, the most common invasive monitoring procedure is the implantation of subdural grids and strips. The subdural method of invasive monitoring has several advantages including: (1) extraoperative recording capabilities to record both spontaneous seizures and interictal activity during various stages of arousal, and (2) high spatial resolution, allowing higher degree of precision for superficial cortical recordings and functional mapping. Unfortunately, this method has several limitations and disadvantages including: (1) the limitation in retrieving information from deep cortical and subcortical areas, (2) the need for relatively large craniotomies, and (3) limitations in recording from insula, cingulate gyrus, and posterior orbito-frontal areas.

In order to overcome these challenges and limitations, the stereoelectroencephalography methodology (aka SEEG) may be used as an alternative and/or complementary procedure to the subdural methodology. This technique was developed in the 1950s in France and enables precise recordings from deep cortical and subcortical structures, as well as allowing for bilateral explorations while avoiding the need for large craniotomies. Despite a long safety record (almost 60 years), it remains underutilized in the United States. Therefore, SEEG may be considered a re-discovered methodology that differs in principle from any other current methodology. It allows precise recordings from deep cortical and subcortical areas, as well as for bilateral explorations while avoiding the need for large craniotomies. Despite a long safety record, it remains underutilized in the United States. Therefore, SEEG may be considered a re-discovered methodology that differs in principle from any other current method for extra-operative long-term monitoring used in the diagnosis and treatment of refractory focal epilepsy.

We incorporated the SEEG methodology in our clinical practice in March 2009, implementing our epilepsy center’s surgical capabilities by offering additional diagnostic and treatment options for patients with medically refractory focal epilepsy. SEEG is now routinely indicated in selected patients with refractory focal epilepsy who need further definition of the areas in the brain responsible for the generation of seizures.

SEEG methodology implies a rigorous pre-implantation scrutiny of all available findings obtained during the noninvasive phase to define a coherent hypothesis of the likelihood of localization of the epileptogenic zone. In this decision-making process, the respective weight of pre-surgical evaluation testing may vary greatly, depending on each patient. After a localizing hypothesis is formulated, a tailored implantation strategy is planned, with the goal of confirming or rejecting the pre-implantation hypothesis. In this phase, the exploration is focused to sample the anatomic lesion (if present), the more likely structure(s) of ictal onset and the possible pathway(s) of propagation of the seizures. The desired targets are reached using commercially available depth electrodes, implanted using conventional stereotactic technique through 2.5mm drill holes. Depth electrodes are implanted using orthogonal or oblique orientation, allowing intracranial recording from lateral, intermediate or deep cortical and subcortical structures in a three-dimensional arrangement, thus accounting for the dynamic, multidirectional spatiotemporal organization of the epileptic seizures (Figure 1). Conventional cerebral angiography is performed routinely, providing us with an additional degree of safety and precision without compromising the less aggressive features intrinsic to this methodology. Additionally, SEEG implantation can be also performed by the use of robotic assistant devices. Robotic assisted technique represents an opportunity to decrease radiation exposure, to reduce operative time and cerebral angiogram complications, to minimize patient time under general anesthesia, and to implant trajectories not accessible with a framed system. (Figure 2)

Up to now, 100 patients were successfully implanted using the SEEG methodology.
The epileptogenic zone was located in 97 patients and no permanent morbidity was observed. From this group, 60% underwent resective surgery guided by the information provided by this method. The seizure outcome is still short (mean follow-up of one year), but so far 65% of these patients remain seizure-free or with an important reduction of seizures.

It should be highlighted that this difficult group of patients with medically refractory epilepsy were considered non-surgical candidates in the past, with no further options for curative treatment. The described method brings a new treatment option for patients with refractory focal epilepsy who are not candidates for invasive monitoring techniques using subdural grids due to difficulties of mapping deep areas in the brain or due to the high morbidity associated with larger craniotomies required by subdural grids implantations.

### References