Invasive EEG evaluations provide critical data for patient management

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The success of any planned resective surgery depends critically on our ability to localize the epileptogenic zone, that is, the area of the brain necessary and sufficient for seizure initiation, and whose removal/disconnection is necessary to stop seizures.

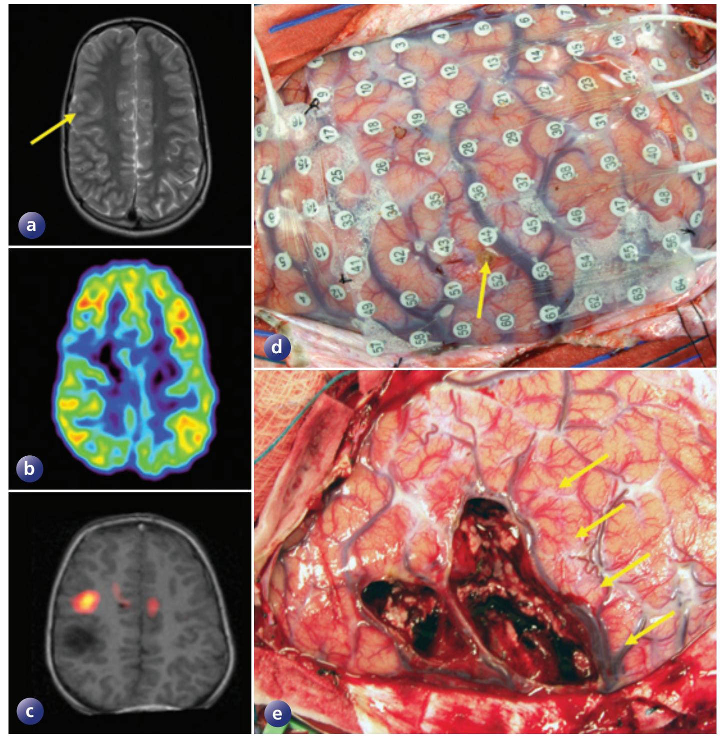
With modern advances in structural (high field MRI) and functional/metabolic imaging (PET and ictal-interictal SPECT), and the routine use of scalp video-EEG to record actual ictal-EEG data, the indications for invasive monitoring have become more refined. Within the realm of pediatric epilepsy surgery, however, numerous scenarios arise where chronic invasive intracranial EEG recordings using subdural and/or depth electrodes provide data that is essential for optimal patient management.

A comprehensive non-invasive pre-surgical workup (which includes a thorough description of seizure semiology; ictal and interictal video-EEG data; MRI, PET and/or SPECT imaging; and neuropsychological testing) can eliminate the requirement for invasive EEG recordings in many epilepsy surgery patients, provided that all the data are concordant in their lateralization and localization. That being said, one or more of the pre-surgical localizing studies may yield information that is discordant with the others. Moreover, less invasive studies may fail to lateralize or localize the epileptogenic focus entirely. In neocortical epilepsy, for instance, scalp EEG is localizing only in approximately 50% of cases, and may falsely localize the site of onset in 5-10% of patients. In these circumstances, if there still exists a reasonable hypothesis regarding the localization of the presumed epileptogenic focus, even when considering the non-diagnostic or discordant piece(s) of information, a period of invasive EEG recordings is often successful in determining seizure onset.

In pediatric epilepsy surgery, neuroimaging may be normal despite clinical evidence of localization-related epilepsy. Since there is no “lesion” to guide the resection, data from invasive EEG recordings proves invaluable for directing a resection. Even in those circumstances where scalp-EEG accurately identifies a seizure focus that has a concordant imaging abnormality, invasive monitoring may still be indicated. The most common examples of the latter are those in which seizures are associated with multifocal damage to the brain, or in which the epileptogenic zone is thought to be larger than the structural or metabolic abnormality seen on imaging (e.g. common pediatric epilepsy substrates such as malformations of cortical development, tuberous sclerosis, head trauma, and meningoencephalitis).

Finally, invasive monitoring is critically important in those cases where the ictal pattern or lesion is close to eloquent cortex. Although our ability to noninvasively identify functional areas of cortex using functional MRI or functional MEG is improving, cortical mapping using implanted subdural electrodes is still considered the gold standard technique for precisely mapping the relationship between the epileptogenic zone and functional areas of the brain.

From a diagnostic perspective, the advantages of invasive EEG recordings over scalp-EEG lie in the improved spatial resolution and sensitivity of electrodes placed directly on the surface of (or within) the brain. It has been estimated that an interictal spike needs to activate 6cm^2 of contiguous cortex to be detected by a scalp electrode. The same epileptoform discharge recorded with intracranial electrodes will be approximately an order of magnitude larger in amplitude compared



Case illustrating the utility of invasive electrodes for brain mapping in a 9yo male with right frontal partial seizures. MRI shows an area of thickened cortex in right frontal lobe (arrow) (a). This area coincides with an area of decreased blood flow on PET (b) and focal hypermetabolism on SISCOM (subtraction ictal SPECT co-registered to MRI) (c). Subdural and depth electrodes (arrow) were placed to localize seizure onset and to map motor cortex (d). Final view of premotor resection area showing relationship to motor cortex (arrows) (e). The child is seizure free six months following surgery. The pathology was cortical dysplasia.

to scalp-EEG. An additional advantage of intracranial recordings is the ability to sample areas of the brain that are not well evaluated by scalp-EEG. Surgical placement of subdural electrodes along the orbitofrontal lobes or in the interhemispheric corridor, or placement of depth electrodes into the hippocampus or other deep lesions, often provides information that is vital to designing an appropriate surgical resection.

The procedure to obtain invasive EEG recordings poses the risk of infection, hemorrhage and cerebral edema. In addition, the child’s hospital stay is lengthened by the time it takes to obtain the ictal onset and functional mapping information that is required to plan a definitive resective procedure (usually 5-7 days). Although surgically placed EEG electrodes offer improved sensitivity compared to scalp-EEG, this comes at the cost of limited brain coverage. This property highlights the critical importance of a multi-disciplinary pre-operative epilepsy surgery case conference where all of the non-invasive information is reviewed and a hypothesis regarding the area of the brain that is responsible for generating seizures is formulated, so that the invasive electrodes are placed in the optimal location for recording seizure onset, not just seizure spread.

Invasive EEG recording is neither something to be avoided nor used indiscriminately. The decision to use this important tool is based on a through assessment of all available non-invasive information as to the postulated area of seizure onset, the perceived benefit of intracranial EEG recordings, as well as an assessment of surgical risk. •