Editorial

Stereoelectroencephalography using computerized tomography– or magnetic resonance imaging–guided electrode implantation

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De Almeida, et al., report on their experience with the use of stereotactic depth electrodes (DEs) in a large series of patients at the Montreal Neurological Institute (MNI) for medically refractory epilepsy. Their study represents one of the largest reported series and is useful in helping to define the overall risk and success of this method of seizure localization. The surgeon who performed these procedures, Dr. André Olivier is among the most experienced practitioners of stereotactic techniques in the world. The authors used stereotactic techniques and implanted electrodes developed at their site rather than those commercially available to most centers. When counseling patients, personnel at each center should quote morbidity rates based on the procedures performed at that particular institution. Centers with less experience in performing certain procedures may have slightly higher complication rates than those reported here.

Even when used by the most experienced surgeons, there is a small but significant risk of clinically relevant hemorrhage when multiple DEs are implanted, especially in the frontal lobes. If the risk is 3% per frontal lobe with multiple electrodes, then the risk of hemorrhage approaches 6% in the more complex cases involving a frontal lobe in which bilateral implantations are needed. These risks should be weighed against the relative increase in the information provided by DEs compared with subdural surface electrodes.

Although the use of DEs has been standard in the evaluation of patients with temporal lobe epilepsy, this practice has been based on the relative difficulty of recording from medial structures using scalp or even surface subdural electrodes. The rapidity with which electrical impulses can travel between medial temporal lobes can further complicate the analysis when surface electrodes are used. The fact that surface recordings have been shown to mislateralize in patients with normal findings on magnetic resonance (MR) imaging adds to the concern in the evaluation of temporal lobe epilepsy. Depth electrodes provide localized recordings from a region very near each electrode. When a single structure such as the amygdala or hippocampus is suspected of containing the epileptic focus, this degree of specificity is an advantage. When a relatively large region is in question, as is often the case in frontal lobe epilepsy without specific MR imaging data or other abnormalities, DEs will not allow precise localization unless multiple electrodes are used, as was done in the authors’ series. Clinical information such as seizure symptoms, scalp electroencephalography (EEG) recordings, or, more recently, subtraction single-photon emission computerized tomography or magnetoencephalography data can help to delimit the region from which recordings are needed. Nonetheless, relatively numerous electrodes are required to cover one or both frontal lobes when there are few radiological or clinical hints about the site of seizure onset. Personnel at most epilepsy surgery programs would use surface grids with numerous electrodes in these cases, especially if clinical data allow for the localization of seizure onset. Multiple stereotactically implanted DEs rather than a large surface recording grid provides a more or less three-dimensional recording volume as electrodes span from the surface to the depths of the frontal lobes. The associated risk of hemorrhage must be taken into account given this added information. Furthermore, surface electrode grids offer the additional advantage of allowing extraoperative mapping of functional areas, something rarely accomplished with multiple DEs.

As the authors of this series imply, the use of implanted EEG recording electrodes, which declined in the 1980s following the advent of MR imaging and other imaging modalities, has recently been increasing. This trend represents an understanding of the limitations of imaging in predicting electrophysiological events and less reluctance on the part of epilepsy surgery centers to treat more complex cases. Although hemorrhage is the most feared and potentially morbid side effect of surgically implanted electrodes, other complications are important to consider, for example, infection, including meningitis and abscess. These complications were extremely infrequent in the series under discussion even though prophylactic antibiotic agents were not used. Contemporary data suggest that the use of perioperative antibiotics reduces the risk of postsurgical infection, espe-
cially if foreign material is implanted. The current series reinforces that the best way to avoid infections—and all complications, for that matter—is the use of an impeccable sterile surgical technique. Perhaps the complication rate could be reduced even further if antibiotics were used. Although the authors imply that relatively small amounts of leaking cerebrospinal fluid (CSF) are common during or following invasive electrode use, it should be noted that continuous CSF leakage is associated with an increased risk of infection; thus, efforts should be made, including tunneling of electrodes and suturing of leakage sites, to stop CSF leaks relatively quickly to reduce the morbidity of this technique. Note that the statement that CSF leakage may be a cause of postoperative headache is puzzling. Many centers use dexamethasone for a short time following electrode implantation in an effort to reduce the side effects associated with CSF inflammation. One should remember that this drug can raise the seizure threshold temporarily and must be tapered rapidly.

Finally, numerous advances in the understanding of brain function have been achieved by using intracranial electrodes to study brain function while simultaneously recording seizures. Although ethical considerations preclude the placement of electrodes in regions not supposed to be part of a seizure focus, electrodes are placed throughout much of the brain in patients with epilepsy, making this a fertile field for research.

References

8. Mam melancher AN, Lopez N, Akhtari M, Sutherland WW: Magnetoencephalography-directed surgery in patients with neocortical epi-
11. O'Brien TJ, So EL, Cascino GD, Hauser MF, Marsh WR, Meyer FB, et al: Subtraction SPECT coregistered to MRI in focal malfor-

RESPONSE: We thank Dr. Barbaro for his meticulous review of our paper and stress that his comments have raised important points for consideration.

During recent years, clinical studies, imaging techniques, and surface EEG have evolved sufficiently to allow the identification of the epileptogenic area in most cases. Nonetheless, there remains a group of patients in whom noninvasive studies fail to disclose an epileptic focus, but for whom there is a sound hypothesis indicating that such a focus does indeed exist and can be operated on. This group represents a subset of patients that can benefit from invasive monitoring. Invasive monitoring permits recording straight from the epileptogenic area, and when the results of recording show no epileptic focus, surgery can be ruled out, sparing patients from an inappropriate treatment option. Conversely, when a focus is disclosed, surgery can be performed. This ability to define the appropriateness of surgical intervention is the most important advantage of the invasive monitoring technique and the reason why the number of such procedures has increased in the 1990s.

Note that one of the most striking developments in epilepsy surgery during the last 15 years has been in the field of migration disorders. In such cases it is often necessary to demonstrate the epileptogenic nature of a lesion located in the paraventricular area or deep within a sulcus. Stereoelectroencephalography (SEEG) using electrodes within or close to the lesion along with others more diffusely distributed can demonstrate the site of origin, the hierarchy of involvement, and the spread of epileptic activity.

Invasive monitoring is an old and well-established approach. We emphasize that the technique of SEEG is not restricted to recording from DEs (that is, from deep structures such as the amygdala, hippocampus, and cingulate gyrus) but also involves recording from intermediate (depth of sulci) and surface electrodes (neocortex). It is even possible to arrange cortical electrodes in a grid fashion, which is the equivalent of chronic electrocorticography. Note, however, that the number of electrodes is limited and that this fact underlines the need to exploit fully the noninvasive techniques, as stressed by Dr. Barbaro, and to maximize the chances of identifying the generator of seizures.

Other commonly used devices include grid and strip electrodes. Each technique carries its own indications and risks. Nevertheless, in most cases more than one method may be