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### Placement of Intracerebral Depth Electrodes during Excisional Surgery for Epilepsy: Value of Intraoperative Ultrasound

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Summary: The authors describe the use of intraoperative US for directing placement of depth electrodes for the localization of seizure foci prior to temporal lobectomy. They used this technique in seven patients (six undergoing temporal and one frontal resection), and encountered no complications.

#### Index terms: Ultrasound, intraoperative; Seizures

Intraoperative electroencephalograph (EEG) monitoring is a valuable procedure to localize the epileptic focus of patients undergoing excisional surgery. Although seizure discharges originating from the convexities are readily evaluated by electrocorticography, discharges that arise from deep hemispheric sites are conventionally recorded with depth electrodes. This is usually accomplished by stereotactic positioning of the electrode on the exposed cortical convexity and inserting it toward the presumed location of the deeper structures (1).

Since the surgical excision of epileptogenic tissue must be planned anatomically, accurate electrode placement is required. Real time ultrasound has previously been used to localize intracerebral masses, guide needle biopsies, and place shunts in cystic cavities and in the ventricles (2–4). We utilized this technique to assist in the positioning of depth electrodes in patients undergoing excisional surgery for epilepsy.

#### Methods

Real time ultrasound was performed intraoperatively in seven patients (six temporal, one frontal) using a Hewlett

Fig. 1. *A* and *B*, Axial (*A*) and coronal (*B*) intraoperative ultrasound images.

In *A*, the electrode is identified with six contacts (*arrows*) traversing the temporal lobe. The last contact, which represents the distal most aspect of the depth electrode, is in the amygdala. The anatomic structures identified include: amygdala (*A*), hippocampus (*H*), parahippocampus (*P*), cerebral peduncle (*CP*), interpeduncular cistern (*IPC*), midbrain (*M*), quadrigeminal cistern (*QC*), vermis (*V*), and aqueduct (*arrowhead*).

In *B*, the most medial contact point of the electrode is identified (*arrow*); however, each of the contacts are not as clearly seen. The anatomic landmarks include: lateral ventricle (LV), distal tip of the shunt catheter (*arrow*-*head*), third ventricle (*open arrow*), suprasellar cistern (*SC*), uncus (*U*), pes hippocampus (*PES*), and parahippocampus (*P*).



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Packard (Andover, MA), Model 77020-AR imager. A 5-MHz phased array transducer with a 60-mm focal point (Model 21210-A) was placed directly on the pia arachnoid in the region of epileptogenicity by the radiologist or neurosurgeon. Images in the axial and coronal planes were obtained prior to electrode placement and deep structures were then identified.

Electrode trajectory and depth of insertion were planned on the basis of the sonographic data. One or more stainless steel 4- or 6-contact intracerebral depth electrodes (PMT



Fig. 2. Two intraoperative depth electrodes. Axial intraoperative ultrasound demonstrates placement of two electrodes. The anterior electrode medial tip appears to be in the striatum nucleus (*arrow*). A second posterior electrode is seen traversing the left temporal lobe with the tip positioned in the middle temporal gyrus region. Anatomic landmarks are: midbrain (M), cerebral peduncles (*CP*), and third ventricle (*arrowhead*). Corporation, Chanhassen, MN) were then positioned under sonographic guidance at deep hemispheric sites within the preoperatively determined epileptogenic field.

#### Results

All electrodes could be distinguished from surrounding neuronal structures as linear regions of increased echogenicity (Figs. 1 and 2); multiple planes were often required to visualize all of the contact points. Visualization of the electrode tip facilitated its positioning in desired anatomic sites (ie, amygdala, hippocampus, parahippocampal, and cingulate gyrus). The relationship of the epileptogenic field to structural lesions (when present) was also defined (Fig. 3). The anatomically determined depth-recorded EEG information was then used by the neurosurgeon and epileptologist to define the plane of resection so as to include the entire epileptogenic region. There were no intraoperative complications associated with this technique.

#### Discussion

Our experience with ultrasound in the operating room suggests that it is a useful adjunctive technique for positioning and anatomically defining intracerebral depth electrodes. One case (Fig. 2) had two electrodes placed suboptimally. These were placed before ultrasound could be performed. The electrode medial tips were then determined intraoperatively to be in the floor of the striatum nucleus anteriorly and the middle tem-



A, Intraoperative coronal ultrasound at the level of the suprasellar cistern (SC) performed before electrode placement. A gangliocytoma (G) is noted in the right temporal lobe as an area of increased echogenicity. The uncus (U), pes hippocampus (*PES*), parahippocampus (P), and lateral occipital temoral gyrus (L) are identified.

*B*, Intraoperative coronal ultrasound performed through the level of the anterior horn of the lateral ventricles (*LV*) after placement of the depth electrode (*arrows*). The tip of the electrode is at the gangliocytoma (*G*).



poral gyrus posteriorly. Subsequent placements were all performed with ultrasound guidance, resulting in accurate positioning in all cases. The anatomic detail provided by ultrasound allows accurate identification of the electrode tip. The placement of the electrode by the neurosurgeon is facilitated by the angle of trajectory and depth, determined from the ultrasound data. EEG data obtained from deep hemispheric sites is used by the electroencephalographer to precisely define epileptogenic regions, especially in nonlesional cases.

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