Insertion of subdural strip electrodes for the investigation of temporal lobe epilepsy

Technical note

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Temporal lobe epilepsy (TLE) is the most common type of surgically treatable epilepsy, with a considerable number of patients needing invasive electroencephalography monitoring. The authors describe a surgical technique used in the placement of subdural strip electrodes for coverage of the temporal lobe. The electrodes are inserted through an enlarged temporocerebral bur hole using fluoroscopic guidance. With this technique, subdural electrode strips can be safely placed to cover the mesial, inferior, and lateral temporal surfaces, and the seizure focus can be lateralized and localized within the temporal lobe. The technique does not require the use of a craniotomy, stereotactic frame, or neuronavigation systems. The authors compare this technique with previous descriptions of subdural electrode placement for the evaluation of TLE.

KEY WORDS • epilepsy surgery • temporal lobe epilepsy • subdural electrode • invasive monitoring • lateralization

Abbreviations used in this paper: CT = computed tomography; EEG = electroencephalography; MR = magnetic resonance; TLE = temporal lobe epilepsy.
Subdural strip electrodes in temporal lobe epilepsy

Fig. 1. Schematic showing the squared incision behind the ear and enlarged bur hole above the asterion. The dura matter is exposed just above the transverse sinus, and the electrodes are placed underneath and over the temporal lobe.

Fig. 2. Drawing of lateral and inferior views of the left temporal lobe showing placement of mesial, inferior, and lateral subdural strip electrodes.

of the electrodes is confirmed with fluoroscopy (Fig. 3). If needed, electrodes can be placed over the lateral parietal lobe and the mesial and lateral occipital lobe through this same opening. Following insertion, parietal stab incisions are made, and the electrode cables are tunneled and externalized. The cables are then anchored to the skin as they exit the stab incisions.

Placement of the electrodes is postoperatively confirmed by fusing a preoperative T1-weighted spoiled gradient-recalled acquisition MR image to a postoperative CT scan (Fig. 4 left) with the aid of a volumetric mutual information algorithm (Atamai, Inc.; Fig. 4 right). Following surgery, patients are admitted to the epilepsy unit where they undergo 24-hour multiple-channel EEG monitoring (digital EEG system, XLTEK) for up to 6 weeks. Seizures that initially appear to have a bitemporal onset on scalp EEG (Fig. 5) can often be lateralized by monitoring with subdural electrodes (Fig. 6). At the end of the recording, the electrodes are removed while the patient is in the epilepsy unit. Using sterile technique, the parietal stab incisions are locally anesthetized, the anchoring sutures are cut, and the electrodes are pulled out.

We have found that due to adhesions, this technique can be somewhat troublesome in patients who have previously undergone intracranial procedures, including craniotomy and subdural electrode placement. In those who have previously had subdural electrodes, we are generally successful at inserting the strips by extending the bur hole and using a fresh dural opening. When reimplantation is impossible, depth electrodes are used. In patients with a prior temporal craniotomy no change in technique is required, although the electrodes can usually be inserted only up to the posterior margin of the previous cortical resection.

Results

This technique has been used at our institution for more than 20 years. Between January 2000 and July 2006, 170
insertions were performed in 166 patients. Bilateral temporal electrodes were placed in 132 cases. Therefore, in 6.5 years, electrodes were placed over 302 temporal lobes. Forty-five cases had exclusively temporal coverage: five (11%) unilateral, and 40 (89%) bilateral. In the 125 patients with extratemporal electrodes, additional frontal electrodes were placed in 56%, parietal in 22%, and occipital in 25%. The mean age in this group of patients was 33 years, and 48% of the patients were female. The mean duration of implantation was 13 days, and the longest implantation was 42 days. Based on recordings, a therapeutic surgical procedure was recommended in 68% of cases.

Complications occurred in five patients (3.0%). Clinical infection occurred in three patients (1.8%), with bacterial meningitis, subdural empyema, and brain abscess occurring in one patient each. One patient had an intracerebral hemorrhage related to the insertion of an electrode over a previously resected tumor. One patient had a minor cerebrospinal fluid leak that was successfully repaired with resuturing. There were no deaths and no permanent neurological sequelae in this group of patients. In an additional patient, a craniotomy wound infection occurred following a resective procedure performed with the subdural electrodes in situ. It was not possible to determine whether this infection was related to the electrode insertion or the subsequent craniotomy.

**Discussion**

**Subdural and Depth Electrodes**

Penfield and Jasper were the first to use intracranial recordings. They were followed by Ajmone-Marsan and Van Buren who used strip electrodes for localizing epileptogenic foci. In the beginning, this technique did not gain wide acceptance, possibly due to the popularization of depth electrodes by Bancaud and colleagues during the 1960s and 1970s. Depth electrodes permit direct recording from the amygdala and hippocampus, with a low rate of complication, ranging from 1 to 4%. These complications include hemorrhage and its sequelae such as visual field cut and memory deficit. Importantly, hemorrhage in the nonepileptogenic temporal lobe can occur. Most of these complications can be reduced by using relatively avascular routes. Gliosis in the electrode tract has been described, although with uncertain clinical relevance.

The insertion of subdural electrodes, as described, obviates the need to pass electrodes through the brain and offers a good-quality recording of the neocortex and mesial structures. We have found that complications with this procedure are uncommon. In a recent review of our experience with the technique for temporal and extratemporal electrodes, the
We found a similarly low complication rate was found to be less than 3% with no permanent deficit or death.\textsuperscript{7} We found a similarly low complication rate in the current series. In our experience, the use of strips is associated with a dramatically lower complication rate than subdural grids. A comparison between depth and subdural electrodes is not the purpose of this article and has been addressed in other studies,\textsuperscript{11,24,25} although the authors used techniques other than the one reported in this study.

**Subdural Strip Electrode Insertion Techniques**

Wyler and colleagues\textsuperscript{31,32} have described the insertion of subdural strip electrodes through an enlarged bur hole in patients under either local or general anesthesia. Bilateral bur holes were placed 2 cm anterior to the tragus and superior to the zygoma. Two strips with four contacts each were inserted: one was directed medially so that the most medial electrode contact was against the parahippocampal gyrus, and the other was directed posteriorly to lie along the middle or inferior temporal gyrus. Following insertion, a locking suture was passed around the cables and through the dura mater to secure the electrode. The main advantage of this procedure is that it obviates the need for a craniotomy and does not require stereotaxy. It is also appears to be very safe. These authors reported that the total morbidity rate with subdural strips was 0.85% in 175 patients, all related to infection. There were no neurological complications. The main disadvantage of this method is that usually only one contact lies medial to the collateral sulcus. Suboptimal placement of this contact, lateral to the collateral sulcus, can lead to false seizure localization.\textsuperscript{11} Furthermore, with only one contact lying adjacent to the mesial structures, it is possible that the exact seizure focus will not be covered. In our experience, when inserted through posterior bur holes under fluoroscopy, four or five contacts can be placed medial to the collateral sulcus, allowing for a more thorough EEG evaluation of the mesial structures, covering the length of the parahippocampal region. Another disadvantage of this procedure is that a second operation is required to remove the electrodes. By anchoring the electrodes to the skin, we have not found this second operation necessary.

Luders and associates\textsuperscript{12} have described the results of using a combination of strips and grids for temporal coverage. This method was performed using a large question-mark incision encompassing the entire side of the skull, with its base at the zygoma. A craniotomy was performed in a similar manner. The temporal lobe was retracted, and an electrode grid placed under direct visualization. The main advantage of this process is that it permits detailed cortical stimulation for mapping of any eloquent cortex because the large number of electrodes offers good spatial resolution. For most cases of TLE, we have not found extraoperative stimulation to be necessary, as all resections in the dominant temporal lobe are performed under neuroleptic anesthesia together with intraoperative language mapping. Other disadvantages of this procedure include, in many cases, the need to perform bilateral craniotomies and a second procedure to remove the electrodes.

Cohen-Gadol and Spencer\textsuperscript{4} described a modification in the technique for placing a mesial electrode strip. They wrapped the strip around the temporal pole, following the curvature of the lesser wing of the sphenoid. In their experience, this strategy permitted a more extensive coverage of the entorhinal cortex and parahippocampal gyrus. These authors have placed this strip in association with grids and depth electrodes. Drawbacks of this method included the required craniotomy for strip placement and visualization of the sylvian fissure to reach the correct path. Although the authors suggested that the electrodes can be implanted via a bur hole, this tactic was not tried; and they suggested that, if tried, the procedure should be aided by stereotactic guidance.

Gonzalez-Feria and Garcia-Marin\textsuperscript{14} described a suboccipital approach for the implantation of electrodes over the medial surface of the temporal lobe. In that procedure, the authors used a Nelaton catheter through a small occipital craniectomy. The catheter was placed over the mesial surface, and a cylindrical electrode advanced inside. This method is similar to the technique we described in this study, although those authors did not use commercially available
electrodes and did not cover the inferior or lateral surface of the temporal lobe.

Conclusions

The technique described herein provides excellent coverage of the mesial, inferior, and lateral surfaces of the temporal lobe and can be performed without using a craniotomy, stereotactic frame, or neuronavigation system. Following the evaluation, electrodes can be removed while the patient is on the ward by using a local anesthetic. Although it does not offer good spatial resolution for mapping of eloquent cortex, such studies are normally not necessary in cases of TLE if neuroleptic anesthesia is used for dominant temporal lobe procedures. As a standard, we have used three strips of eight contacts for each temporal lobe, but this element can be tailored for individual clinical situations.

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References


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