Novel use of a custom stereotactic frame for placement of depth electrodes for epilepsy monitoring

Technical Note

R. MORGAN STUART, M.D., AND ROBERT R. GOODMAN M.D., PH.D.

Department of Neurological Surgery, Columbia University College of Physicians and Surgeons, New York, New York

The authors describe the first reported application of a miniature, customized, one-time use, skull-mounted stereotactic frame for the implantation of depth electrodes for epilepsy monitoring.

Using a platform template, 4 skull fiducial markers were placed 1 week prior to surgery. A brain MR image and a CT scan were subsequently obtained. All planning (longitudinal trajectories into the hippocampi) was done preoperatively using personal computers in the office. No further workstation planning was necessary on the day of the operation. The StarFix microTargeting Platform system was secured to the previously implanted skull fiducial screws. Pin fixation was not required. The platform was used to identify the area of entry for the depth electrodes on the right and left sides. On each side, a 12-contact depth electrode was advanced to the depth of the targets without difficulty. A temporal craniotomy was then performed to place subdural electrodes.

The desired location of the electrodes was confirmed on postoperative imaging studies. There were no complications associated with the electrode implantation. The depth electrodes demonstrated symmetrical, robust coverage of each hippocampus, with epileptiform discharges observed bilaterally. This first application of the StarFix platform for placing depth electrodes for epilepsy monitoring was both safe and feasible. With this technique, the patient does not need to be pinned or placed in a head holder, no imaging or computer planning is required on the day of implantation (which means there is no time pressure when the meticulous target/trajectory planning is done), and with bilateral posterior implants both bur holes can be made simultaneously. For these reasons this system may be preferable to existing methods of depth electrode implantation.

KEY WORDS • depth electrode • epilepsy • stereotactic frame

INVASIVE monitoring techniques for the localization of an epileptogenic foci in patients with partial epilepsy are well described.1 Whereas subdural grid and strip recording electrodes provide a means of localizing foci on the cortical surface, the placement of depth electrodes is often necessary to investigate intraparenchymal brain structures such as the amygdala and hippocampus, and stereotactic guidance has proved useful in placing electrodes accurately within such structures.1,2,5 The application of a miniature, customized, one-time use, skull-mounted stereotactic frame, the StarFix microTargeting Platform (510[K], No. K003776, 2/23/01; FHC Inc.) for implantation of deep brain stimulation electrodes has been previously reported, and the accuracy of this novel platform has been shown to compare favorably with traditional stereotactic frame systems.3 We describe the first reported use of this system for successful implantation of bilateral depth electrodes for epilepsy monitoring.

Abbreviation used in this paper: EEG = electroencephalography.

Case Report

History. This 28-year-old, right-handed man had enjoyed good health until the age of 26 years, when, while sleeping, he experienced an episode of generalized tonic–clonic shaking, with tongue biting and postictal confusion. Since then, he has experienced smaller episodes during the day, consisting of a rising sensation starting in the pelvis moving up to his chest. This is accompanied by mild diffuse shaking with intense bad memories. He feels abnormal for hours afterward. These events occur 2–5 times a day. He also complains of memory and cognitive difficulties, as well as depression. The results of his neurological examination were unremarkable. Trials of valproate, levetiracetam, lamotrigine, and gabapentin were all unsuccessful in controlling his seizures. A fluorodeoxyglucose PET scan showed left mediotemporal hypometabolism, and a brain MR image showed normal findings.

Routine scalp EEG revealed right temporal slowing, frequent right temporal epileptiform discharges, and occasional left temporal epileptiform discharges. Six seizures
were recorded. Electrographic onset appeared diffuse, but in each of the 4 seizures with electrographic correlates, the discharge subsequently became better developed over the right hemisphere, maximal in the temporal region, findings consistent with an epileptogenic focus in the right temporal region. However, the presence of left temporal epileptiform discharges, although far fewer, raised the possibility of a second epileptogenic focus on the left side.

The patient was therefore recommended to undergo implantation of bilateral temporal electrodes and depth electrodes for monitoring with the goal of determining the location of his seizure onsets.

**Operation and Surgical Technique.** Placement of the FHC platform fiducial screws was performed 1 week prior to electrode implantation. The patient was positioned supine with the head placed on a cerebellar headrest. Initially his head was turned to the left. The platform template was used to identify the desired location for placement of 3 skull fiducial screws. This was planned for the presumed right bur hole entry point in the area superior to the right lambdoid suture. One point was in the region above and behind the right ear, one area was in the high parietal area posterior to the midline, and then one was essentially at the midline above the inion. The skin was incised with a no. 11 blade, and the fiducial screws at each location were then advanced perpendicular to the skull surface until they were tight. The post was then screwed into the top of each screw sequentially. Staples were used to approximate the scalp edges adjacent to the protruding posts. One of the midline screws did not have a post attached to it, and instead the scalp was approximated with staples. Then the patient was repositioned with his head turned to the right, and 2 similar screws and posts were placed on the left side, to facilitate subsequent placement of an electrode through a left parietal bur hole. A brain MR and a CT image were obtained to facilitate planning for electrode implantation using the FHC software (Fig. 1). After imaging, the protruding posts were removed and the scalp re-closed. The subgaleal skull fiducial screws produced only a slight elevation of the scalp during the interval between fiducial and electrode implantation.

Depth electrodes were implanted 6 days later. The patient was intubated without difficulty after induction of general anesthesia. The patient was positioned supine, his head placed in a cerebellar head holder and his neck moderately flexed; his head and upper body were elevated significantly. The head was draped, and the FHC platform (Fig. 2) was secured to the 4 previously implanted skull fiducial screws by reopening the incision overlying each of the anchor screws, and then advancing the screws through the platform to each of the anchor screws (Fig. 3). Once this was in place, the platform was used to identify the area of entry for the depth electrodes on the right and left sides. Implantation was performed via linear incisions and bur hole craniectomies using the Midas Rex drill, and small dural openings.

A slotted cannula was inserted with the tip advanced to be ~20 mm short of the target depth. A 12-contact depth electrode was then advanced through the slotted cannula to the depth of the target (178 mm from the top of the guide). The stylet of the electrode was then removed, the slotted cannula was withdrawn, and a Weck clip was placed on the electrode at the outer table of the skull to identify the depth of the electrode. The electrode was brought out through the scalp using the Ad-Tech Medical tunneling cannula, and

![Fig. 1. Screen shots of trajectory planning for bilateral depth electrode implantation.](image1)

![Fig. 2. Computer-generated renderings of the actual FHC platform used in this case.](image2)
Custom stereotactic frame for placement of depth electrodes

Fig. 3. Close-up view of the platform and anchoring screw.

Fig. 4. Postoperative skull radiograph (left) and coronal MR image (right) demonstrating good positioning of the electrodes at the targets.

the Weck clip was then removed from the electrode. The exiting electrode was secured to the scalp using a 2-0 silk suture by placing a U-stitch around the exiting electrode and then securing the electrode with the suture as a retention suture. The wounds were closed in standard fashion. Bilateral temporal craniotomies were then performed before implanting 3 temporal strip electrodes in the standard fashion. The patient tolerated the procedure well and there were no intraoperative complications.

Intraoperative Monitoring. Continuous monitoring with digital video and EEG was performed postoperatively using the XLTek digital video/EEG system. The video/EEG system spike and seizure detection algorithms were used for digital EEG analysis throughout the monitoring period, to screen the EEG in real time and to mark the data file with pointers to electrographic seizures and interictal discharges. The intracranial electrodes demonstrated symmetrical, bilateral coverage of the temporal lobes. Epileptiform discharges were seen bilaterally in the hippocampal depth electrodes, although they were much more frequently observed in the right hemisphere than the left. Neocortical epileptiform discharges were frequently seen over the right temporal neocortex. Eight seizures were recorded in all, 7 of which were subtle or subclinical, and 1 of which was a typical complex partial seizure with secondary generalization. All originated from the right hippocampal depth initially with a pseudotumefaction of epileptiform discharges and the development of hippocampal gamma activity prior to early spread to mesial and lateral subtemporal electrodes. No seizures, clinical or subclinical, originated over the left hemisphere.

Based on the EEG recordings, it was believed that the epileptogenic zone involved the right mesial temporal lobe, including anterobasal temporal regions, due to findings of electrographic ictal onsets documented in the right hippocampal depth spreading to other mesial temporal structures, as well as robust interictal epileptiform discharges coming from the right hippocampal depth, mesial and lateral subtemporal strips, and anterolateral strip. The interictal EEG evidence was suggestive of a less active, although independent, irritative zone in the left mesial temporal lobe.

Postoperative Course. Postoperative MR images, CT scans, and plain radiographs of the skull were obtained. The positioning of the electrodes was satisfactory in all modalities (Fig. 4). There were no complications associated with either electrode implantation or prolonged monitoring. The patient underwent continuous video and EEG monitoring for 8 days, and the electrodes were removed uneventfully. Monitoring identified a total of 8 clinical, subclinical, and electrographic seizures originating from the right hippocampus and interictal discharges from both hippocampi (abundant from the right and rare from the left). The patient underwent an uneventful right medial temporal resection performed 3 weeks after electrode removal, without subsequent morbidity. At 1-year follow-up, the patient was on gabapentin monotherapy and experiencing brief nocturnal seizures (once every 2 months).

Discussion

The use of the StarFix microTargeting Platform system for the placement of depth electrodes to monitor epilepsy has not, to our knowledge, been previously reported. We demonstrate here the feasibility of using this system for this application. In our single reported application, the implantation was accomplished with excellent accuracy and without morbidity. This technique does require a minor operative procedure at least several days prior to the planned electrode implantation to permit time for the customized frame to be manufactured and delivered. However, since the time of the case described here, the system has been improved, no longer requiring post extensions to be attached to the skull fiducial screws at the time of imaging, which significantly simplifies this step. It remains to be determined, with further experience, whether there may be morbidity (such as pain, failure to maintain secure placement, or infection) associated with the implanted skull fiducial screws. There are several reasons why this method may be preferable to existing methods for depth electrode implantation. With no imaging or computer planning required on the day of implantation, there is no pressure on the surgeon to perform the meticulous target and trajectory planning expeditiously while the patient remains intubated in the operating room. The entire planning process can instead be performed at the surgeon’s leisure at an office or using a personal computer. Furthermore, if bilateral posterior implants are required, as is typically the case, both bur holes can be made simultaneously, rather than sequentially, reducing time in the operating room. The patient also does not need to be pinned or placed in a headholder, allowing for subtle adjustments in positioning to be made during the procedure. In cases in which these considerations are particularly relevant, the use of this system for depth electrode implantation for epilepsy monitoring could be advantageous and preferable to existing methods. One alternative approach involves the use of a skull-mounted guide. This
method can utilize surface registration, but it does not provide the accuracy needed for deep brain stimulation and depth electrode implantation. Accuracy is enhanced by preoperative implantation of skull fiducials, similar to the technique described in this report. This approach also allows planning before the implantation procedure but requires interaction with the neuronavigation platform during the implantation stage and does not readily allow precise matching of the implant to the preplanned trajectory. These factors may lead surgeons to prefer the StarFix Platform method. One particular advantage is that it allows the surgeon to precisely follow the preplanned trajectory.

References
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