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Technical Note: Imaging of MR-Compatible Intracerebral Depth Electrodes

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Complex partial seizures of temporal lobe origin may be refractory to anticonvulsant therapy; in these cases surgical ablation of the seizure focus may be necessary. Such surgery requires definite identification of the seizure focus. When surface EEG cannot accurately localize the side of the seizure focus, depth electrode EEG recordings must be obtained [1, 2]. Depth electrodes have been manufactured from stainless steel alloys. The high electron density of these materials causes extensive beam-hardening artifacts on CT scanning, which reduces the diagnostic utility of the scans. Because of the high magnetic susceptibility of these electrodes, post-placement MR scanning has not been performed. This is because torque or other problems that cause brain injury may develop [3]. Also, the magnetic susceptibility effects can cause severe geometric and brightness artifacts. These problems have made it difficult to evaluate radiographically the status of the brain after electrode placement. Newer-generation metallic materials have recently been developed for MR procedures [4, 5]. However, to our knowledge, none of these have been placed within the brain parenchyma and subsequently imaged.

Identification of electrode placement sites has, in the past, been inferred from preplacement studies related to postplacement plain films showing electrode location, because post-placement CT or MR scanning is not possible. We describe the first use of a new electrode system that has been safely imaged within the brain parenchyma of a patient on a 0.3-T hybrid magnet system.

Materials and Methods

The electrodes used in this study were constructed from a platinum alloy into a 0.8-mm-diameter cannula through which nine microwire electrodes were placed. The microwires were also primarily platinum; containing 79% platinum and 21% alloy of rhodium and ruthenium. Phantom images were obtained by using the new platinum electrode as well as the stainless steel electrodes. The phantoms consisted of a 0.4 mmol NiCl solution and was imaged with standard spin-echo sequences, 267/30 (TR/TE).

Platinum electrodes were placed intraoperatively in the temporal lobes bilaterally in a patient with intractable partial complex seizures. The postoperative course was uneventful and 7 days after implantation the patient was brought to the MR scanner. All scans were obtained on a 0.3-T hybrid magnet (Fonar B-3000 M, Melville, NY) with a 256 × 256 matrix with 5-mm slice thickness and 1 × 1 mm pixel size. Inversion recovery (IR) scans used 1276/300/30/2 (TR/TI/TE/excitations), spin-echo sequences were 131/30/1, and field-echo (partial flip angle) sequences were 223/10/3 with a flip angle of 90°.

Results

The phantom studies showed a dramatic reduction in electrode artifacts with the platinum electrodes as compared with the standard stainless steel variety (Fig. 1). MR scanning was without event and there was no change in neurologic status. The electrodes were seen as areas of relative signal void (Fig. 2). Mild magnetic susceptibility effects were seen on both SE and IR sequences. These artifacts were identified as areas of high signal adjacent to the low signal (signal void) of the cannula, and an increase in the apparent size of the cannula. These artifacts were more prominent on the field-echo sequences, with an even greater increase in the apparent size of the electrode [6, 7]. There was no evidence of brain injury resulting from electrode implantation.

Discussion

These new materials make it possible to image patients with intraparenchymal electrodes without the risk of brain injury, and with minimal electrode artifact. This study was performed on a low-field-strength magnet; therefore, additional evaluation on a higher-field-strength unit is necessary. However, with the materials used, and the lack of artifacts seen at 0.3 T, it is unlikely that a greater field strength will present a problem.

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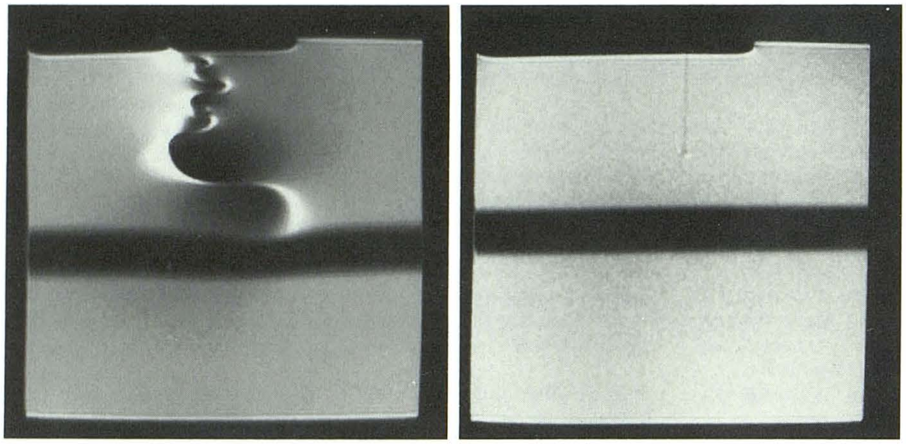
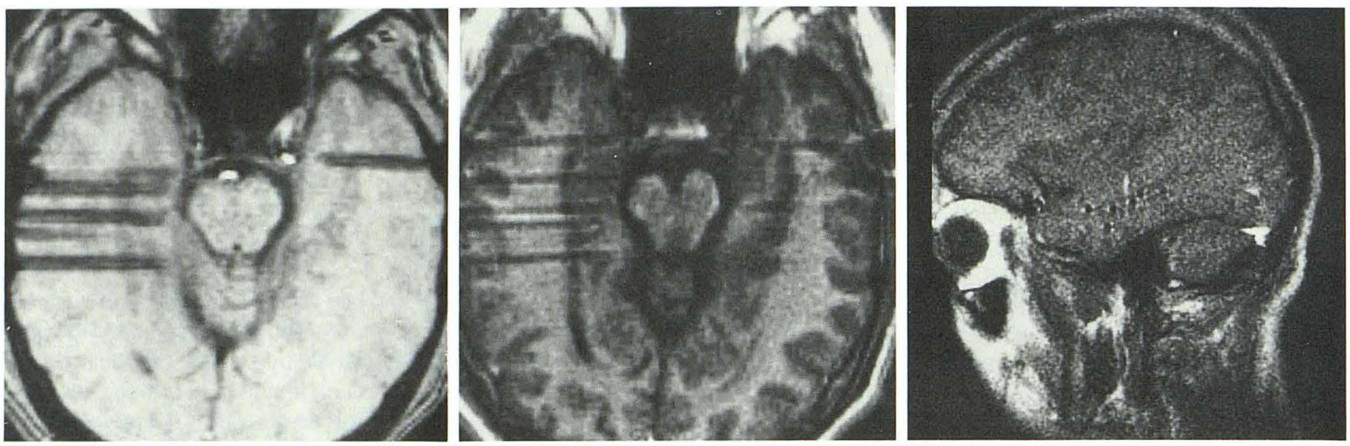


A B

Fig. 1.—*A* and *B*, Phantom studies of standard stainless steel (*A*) and new platinum (*B*) electrode cannulas (SE/267/30). There is severe geometric and brightness distortion caused by the ferromagnetic properties of the stainless steel but minimal artifact from the platinum.



A B C

Fig. 2.—*A* and *B*, Axial field-echo (*A*), axial inversion-recovery (*B*), and sagittal spin-echo (*C*) MR images with the new electrodes in place. Mild brightness distortion was seen on the sagittal scan in the frequency-encoding axis. This was less apparent but still present on field-echo and inversion-recovery sequences. This susceptibility effect did not significantly degrade the image on any sequence, but there was an increase in the apparent size of the electrode, especially on the field-echo scans.

This system has allowed us to look for the first time at a patient's postoperative status with the anatomic detail necessary to evaluate adequately both complications and electrode placement. Further work is now being done with additional materials. This should lead to a greater correlation of the electrophysiologic data with anatomic information. With these and newer materials, it is hoped that other MR-assisted CNS procedures can be developed.

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