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MR imaging of implanted depth and subdural electrodes: is it safe?☆

Lawrence M. Davis [a,*], Dennis D. Spencer [b], Susan S. Spencer [c], Richard A. Bronen [d]

[a] *Department of Diagnostic Imaging, Brown University School of Medicine, Rhode Island Hospital, 593 Eddy Street, Providence, RI 02903, USA*

[b] *Department of Neurosurgery, Yale University School of Medicine, 333 Cedar Street, New Haven, CT, USA*

[c] *Department of Neurology, Yale University School of Medicine, 333 Cedar Street, New Haven, CT, USA*

[d] *Department of Diagnostic Imaging, Section of Neuroradiology, Yale University School of Medicine, 333 Cedar Street, New Haven, CT, USA*

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Abstract

This study evaluates the safety of imaging chronic epilepsy patients with intracranial depth and subdural electrodes by magnetic resonance (MR). To identify an epileptogenic focus, the precise location of the electrode contacts is necessary, and MR can provide this information. However, many neurosurgeons and neuroradiologists are hesitant to scan patients by MR with these implanted, metallic electrodes for fear of electrode displacement, current induction or heating secondary to the strong magnetic field. In the present study, the subdural electrodes were made of stainless steel with either stainless steel or platinum contacts. The depth electrodes were made of either platinum or a nickel-chromium alloy (nichrome). We reviewed 98 cases in which patients with implanted depth electrodes, subdural electrodes, or both underwent MR scanning. A total of 143 depth electrodes, 688 subdural strips, and 38 subdural grids were implanted in the 98 procedures. MR scanning was performed on a 1.5-T unit and consisted of T1, T2, and/or spoiled gradient echo pulse sequences. There were no documented complications related to the MR scans. Based on this study and a review of the literature, we feel that MR imaging can safely localize intracranial electrodes.

Keywords: Chronic epilepsy; Intracranial depth and subdural electrodes; Magnetic resonance imaging

☆ None of the authors have a financial interest in the equipment used in this study.

* Corresponding author.

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1. Introduction

Intracranial monitoring with subdural and/or depth electrodes is a crucial step in the presurgical evaluation of many patients with medically refractory epilepsy (Risinger and Gumnit, 1995). To identify the epileptogenic focus and to map eloquent cortex, precise anatomic localization of the electrodes is necessary. This localization has been performed with plain films of the skull, computed tomography, magnetic resonance (MR) imaging and integration of plain film and pre-electrode placement MR imaging (Kratimenos and Thomas, 1993; Cordova et al., 1994; Meiners et al., 1996). Despite the ability of MR to localize the electrodes, some neurosurgeons and neuroradiologists are hesitant to scan patients with intracranial electrodes due to safety concerns. Brooks et al. have reported on patients who were studied by MR after stainless steel depth and subdural electrode placement with no adverse outcomes related to MR imaging (Brooks et al., 1992). Zhang et al. have studied the in vitro temperature change in nichrome (an alloy of nickel and chromium) depth electrodes subjected to a 1.5-T magnetic field and spin echo pulse sequences (Zhang et al., 1993). They found that no significant heating occurred and concluded that nickel-chromium electrodes are thermally safe for MR scanning. We reviewed our experience of scanning patients by MR with depth (platinum or nichrome) and/or subdural (stainless steel or platinum) electrodes to further establish the safety of this procedure.

2. Methods

From our epilepsy program database, we identified all intractable epilepsy patients who had undergone phase III evaluation (intracranial EEG monitoring with subdural electrodes, depth electrodes, or both) over the past 10 years. These patients' radiology reports were then reviewed to determine whether they had had magnetic resonance (MR) imaging while the intracranial electrodes were in place. Finally, we retrospectively reviewed the medical records of the patients who had an MR imaging scan while the electrodes were in place to determine if any complications occurred during the scan which were attributable to the presence of the electrodes.

Two types of depth electrodes (Ad-Tech Corporation, Racine, WI) were implanted stereotactically during the course of this study. Prior to February 18, 1996, all depth electrodes were made of nichrome except for 12 which were platinum. After this date, platinum probes were employed. The subdural electrodes (Ad-Tech Corporation, Racine, WI) consisted of either strips or grids. Both types of electrodes were composed of type 316 stainless steel contacts and type 316L stainless steel wires except for 18 strips which had platinum contacts.

After surgical placement of the probes, special care was taken when bandaging the head to keep each electrode wire straight so as not to form loops which could potentially induce electrical currents. MR pulse sequences included a sagittal spin echo T1 localizer with parameters of 350/11/1/5/0 (repetition time/echo time/excitations/thickness/skip), coronal T1-weighted images at 400/20/1/3/0, axial T2-weighted images at 2500/14,84/1/5/2.5, and/or 3-D axial and coronal spoiled gradient echo images at 25/5/2/45°/3 (repetition time/echo time/excitations/flip angle/thickness). All scans were performed on a 1.5-T MR unit (Signa, GE Medical Systems, Milwaukee, WI) with a transmit-receive head coil.

3. Results

Between January 1990 and October 1996, 95 patients underwent 108 MR scans with intracranial electrodes in place; 11 patients had two phase III evaluations and one subject had three phase III evaluations. The medical records were available for 86 patients who had undergone 98 procedures; ten patients had two procedures and one patient had three procedures. The number of depth electrodes implanted per procedure varied from zero to eight, the number of subdural strips from zero to 19, and the number of subdural grids from zero to four. A total of 143 depth electrodes (116 nichrome and 27 platinum), 688 subdural strips (670 with stainless steel contacts and 18 with platinum contacts), and 38 subdural grids were implanted in the 98 procedures reviewed.

There were no documented complications related to MR scanning with the electrodes in place. No neurologic events occurred during or immediately after the MR scans. A total of six patients had focal neurologic deficits following electrode placement, but prior to MR scanning.

4. Discussion

Of all available imaging modalities, MR provides the best anatomic information, and can frequently identify an epileptogenic lesion within the brain (Jack, 1995). However, there are times when a lesion cannot be identified non-invasively, and intracranial electrophysiologic monitoring is required (Risinger and Gumnit, 1995). Just as MR can provide a precise anatomic location for intrinsic brain lesions, it also can localize the position of surgically implanted depth and subdural electrodes (Meiners et al., 1996). However, placing patients into an MR scanner with implanted metallic devices within the brain raises concerns regarding the safety of this procedure. Three potential complications can occur when a metallic device is placed in the strong magnetic field of an MR scanner (Shellock et al., 1996). The primary concern is movement or dislodgment of the device. This concern is supported by two reported complications related to metallic objects. In the first case, a ferromagnetic cerebral aneurysm clip dislodged while a patient was in the MR scanner resulting in death (Shellock et al., 1996). In a second case, an intraocular metallic foreign body resulted in a vitreous hemorrhage and blindness (Kelly et al., 1986). Secondary concerns include induction of electrical current and heating. Brooks et al. suspended stainless steel depth electrodes in the magnetic field of an MR scanner and showed that there was no deflection; thus no movement should occur when the electrodes were implanted, and indeed they had no complications (Brooks et al., 1992). Meiners et al. similarly found no deflection of nichrome electrodes (Meiners et al., 1996). In our cohort of patients, either platinum or nichrome depth electrodes were used. Platinum is non-ferromagnetic and thus will not be deflected by a magnetic field.

With regard to current induction and temperature elevation, Zhang et al. studied the temperature change in a nichrome electrode placed in a 1.5-T MR scanner (Zhang et al., 1993). They found that the temperature within the electrode bundle increased by 0.07°C after 3 min of scanning, which is less than the body's normal temperature variation. Thus, thermal effects should not be a concern.

A review of the literature reveals 84 cases in which patients have undergone MR imaging with depth electrodes in place (Duckwiler et al., 1990; Brooks et al., 1992; Meiners et al., 1996; Ross et al., 1996). Stainless steel electrodes were used in 30 cases, nichrome electrodes in three cases, and platinum alloy (79% platinum and 21% rhodium/ruthenium alloy) electrodes in 51 cases. Some of the patients with implanted stainless steel depth electrodes also had stainless steel subdural electrodes implanted, although the exact number is not mentioned in the report. None of these patients had an adverse outcome from MR scanning. In the present study, 86 patients who had undergone 98 intracranial electrophysiologic evaluations were scanned by MR without any documented complications from the MR scan. However, there is a limitation to our study. We did not specifically examine and question the patients immediately prior to and following the MR scan to determine if any subtle change in neurologic function had occurred. Despite this limitation, we feel that the literature and the present study support the safe use of MR to localize the types of intracranial electrodes employed in these various studies.

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