Awake Craniotomy, Electrophysiologic Mapping, and Tumor Resection With High-Field Intraoperative MRI

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BACKGROUND: Awake craniotomy and electrophysiologic mapping (EPM) is an established technique to facilitate the resection of near eloquent cortex. Intraoperative magnetic resonance imaging (iMRI) is increasingly used to aid in the resection of intracranial lesions. Standard draping protocols in high-field iMRI units make awake craniotomies challenging, and only two groups have previously reported combined EPM and high-field iMRI.

METHODS: We present an illustrative case describing a simple technique for combining awake craniotomy and EPM with high-field iMRI. A movable platter is used to transfer the patient from the operating table to a transport trolley and into the adjacent MRI and still maintaining the patient's surgical position. This system allows excess drapes to be removed, facilitating awake craniotomy.

RESULTS: A 57-year-old right-handed man presented with new onset seizures. Magnetic resonance imaging demonstrated a large left temporal mass. The patient underwent an awake, left frontotemporal craniotomy. The EPM demonstrated a single critical area for speech in his inferior frontal gyrus. After an initial tumor debulking, the scalp flap was loosely approximated, the wound was covered with additional drapes, and the excess surrounding drapes were trimmed. An iMRI was obtained. The image-guidance system was re-registered and the patient was redraped. Additional resection was performed, allowing extensive removal of what proved to be an anaplastic astrocytoma. The patient tolerated this well without any new neurological deficits.

CONCLUSIONS: Standard protocols for positioning and draping in high-field iMRI units make awake craniotomies problematic. This straightforward technique for combined awake EPM and iMRI may facilitate safe removal of large lesions in eloquent cortex.

INTRODUCTION

Awake craniotomy and electrophysiologic mapping (EPM) are established techniques to facilitate safe resection of lesions near eloquent cortex (14, 15). High-field (≥1.5 T) intraoperative magnetic resonance imaging (iMRI) is an attractive strategy to enable extensive glioma resection (2, 11). Combining EPM and iMRI would be a potent technique to facilitate safe, extensive glioma resection near eloquent cortex. This was first reported more than 10 years ago using low-field iMRI (3). However, techniques for combining EPM and high-field iMRI have only recently been described (7, 18). The delay in applying EPM to high-field iMRI may reflect the draping required to maintain a sterile field during intra-dissection imaging. In many high-field iMRI systems, patients’ heads and upper bodies are essentially “cocooned” in sterile drapes during intra-dissection imaging (17). This is problematic for awake craniotomies due to issues with both patient comfort (claustrophobia for alert patients) and safety (airway protection for sedated patients). In this report, we describe a simple minimal draping technique that enables intra-dissection imaging to be performed easily and safely in a high-field iMRI and still maintaining sterility. This has allowed us to combine awake craniotomy and electrophysiologic mapping with high-field iMRI.

TECHNIQUE

Repeat MRI at our institution showed a similar tumor, although new edema was seen at the biopsy site (Figure 1A). A functional MRI showed bilateral activation for speech in both the frontal and temporal lobes, suggesting some language reorganization (data not shown). The patient was taken to a dedicated operating room for iMRI adjacent to a standard 1.5-T MRI scanner (General Electric, Fairfield, CT, USA) (Figure 2A). This system allows standard ferromagnetic tools to be used in the operating room (with the exception of the head holder, which must be non-ferromagnetic). A mobile patient transfer platter attached to the operating table allows
the patient to be moved to a transport trolley in pinions without any change in positioning. They are transferred approximately 20 feet to the adjacent multipurpose MRI scanner for imaging before returning to the operating room. The scanning room is separated from the operating room by retractable doors.

After moderate intravenous sedation (dexmedetomidine) and generous local anesthesia (bupivacaine), he was positioned supine with a role placed under the left shoulder and the head turned slightly to the left. The head was held in place with nonferromagnetic three-point pin fixation. The preoperative MRI was registered to the patient using a STEALTH image guidance system (StealthStation, Medtronic, Minneapolis, MN, USA). This included functional MRI sequences for expressive speech. The operative field was prepped and draped in the standard fashion and a left frontotemporal craniotomy was performed. After opening the dura, the patient’s sedation was lightened and electrophysiologic stimulation motor and speech mapping was performed using a 5-mm bipolar electrode as described elsewhere (14, 15). A single, critical area for speech where stimulation caused naming and counting arrest was seen in the posterior inferior frontal gyrus and marked with a sterile letter “E” (“English”;

An anterior temporal lobectomy extending 5 cm from the temporal pole and initial tumor debulking was performed. At the end of this procedure, a large resection cavity was created but the tumor was still present superomedially and posteriorly. The sylvian fissure had shifted 1 cm inferiorly from its position identified by STEALTH using the preoperative MRI, suggesting that image guidance was no longer accurate. Accordingly, we choose to obtain an interdissection MRI and re-register the STEALTH system. This was done to iden-
tify the exact location and extent of residual tumor and facilitate further safe image-guided resection. The scalp flap was loosely reapproximated. Sterile sponges were placed over the wound and an approximately 60 × 60-cm sterile drape was placed over the sponges and secured with a large adhesive plastic drape. The excess drapes were trimmed to allow the patient to be transferred to the MRI table (Figure 2D). The patient was kept in position with three-point pin fixation and brought into the adjacent MRI scanner using the transfer platter and transport trolley. An interdissection MRI was obtained, showing the expected residual tumor superomedially and posteromedially (Figure 1B). The patient was removed from the scanner and returned to the adjacent operating room where he was transferred back to the operating table, still maintaining his position with three-point pin fixation. He remained alert.
and comfortable throughout this imaging process. The interdissection MRI was registered to the patient using the STEALTH system. This entire process (partial closure, draping, imaging, redraping, re-registering the STEALTH system) took approximately 40 minutes.

The patient was redraped and additional resection was performed with the aid of the updated image-guidance system. Some tumor was deliberately not resected superomedially next to the middle cerebral artery and in the posterior aspect of the parahippocampal gyrus where the patient became mildly confused when we began to work in this area. Nevertheless, an extensive resection (~90%) was performed. The patient’s wound was closed, he was removed from pin fixation, and a full head dressing was applied. A final postoperative MRI was obtained confirming the extent of the resection (Figure 10). The patient had an unremarkable postoperative course with no new neurological deficits. The final pathological diagnosis was anaplastic astrocytoma (World Health Organization grade 3), confirming the results of his earlier biopsy sample. He has subsequently received adjuvant external beam radiation and temozolomide chemotherapy.

DISCUSSION

Penfield and Boldrey (13) first described awake craniotomy and electrophysiologic mapping more than 70 years ago. In the past 20 years, this technique has become increasingly applied for glioma resection near eloquent cortex (14, 15). Although motor mapping can be performed with patients receiving general anesthetic, speech mapping must be performed awake. Image guidance using frameless stereotaxy based on preoperative imaging is another established technique to facilitate extensive resection of intracranial lesions. This is helpful for planning craniotomies, finding lesions, and determining the extent of resection intraoperatively. Determining the extent of resection is potentially the most valuable, but is also the most challenging. As the tumor is removed, the brain shifts (6), causing significant inaccuracies to develop in image-guidance systems. This is most likely to occur in patients with large tumors (>3 cm in diameter) or tumors adjacent to the ventricles (1).

Intraoperative MRI has been proposed to help address this issue. Unlike most clinical diagnostic MRI scanners that use high-field magnets (1.5 T), the first generation of iMRI scanners used low-field magnets (0.2 to 0.5 T) (4, 8). Although useful, the image quality was reduced compared with standard MRI. As an alternative, high-field (>1.5 T) iMRI systems have been developed that produce quality images (9, 17). Importantly, re-registering image-guidance systems with high-field iMRI appears to facilitate more extensive but safe resection compared with low-field iMRI and image guidance (2). Functional imaging, such as diffusion tensor imaging and functional MRI, can be incorporated into image-guidance systems, but brain shift makes interpretation difficult as resection proceeds and questions remain about how closely these modalities replicate EPM (the accepted gold standard) (11, 10). This was demonstrated in our patient, when the critical area for speech identified by EPM was shown to be approximately 1 cm away from any speech areas identified on functional MRI. Diffusion tensor imaging could be obtained intraoperatively to address this issue (12). It may be possible to incorporate intraoperative functional MRI for awake patients in the future as well, but this would clearly need to be balanced against the amount of time required during craniotomy.

Thus, combined EPM, image guidance, and high-field iMRI may be an ideal technique to facilitate safe extensive resection of lesions in eloquent cortex. Despite the availability of high-field iMRI for more than a decade, to our knowledge no reports combining high-field iMRI with EPM appeared in the literature until 2009 (7, 18). There may be several reasons for this, but it may reflect standard draining protocols for interdissection imaging in a high-field iMRI environment. To keep the sterile field from contamination, the patient’s entire head and upper body are essentially wrapped in sterile drapes (17). This creates an environment that is either extremely claustrophobic for alert patients or potentially suffocating for sedated patients without definitive airway protection. Our simple draining technique for interdissection imaging is much less restrictive and makes awake craniotomy much less challenging. This technique is facilitated by the transfer platter and trolley that allow the patient to be transferred to and from the adjacent MRI scanner in pinions without changing the surgical position. The two earlier reports of combined EPM and high-field iMRI do not describe the draining protocols for interdissection imaging in detail, although Nabavi et al. (7) suggest uncovering the patient’s face and Weingarten et al. (18) describe trimming drapes hanging below the operating table.

Additional experience with more patients and longer follow-up is necessary to definitively address outcomes for patients undergoing awake craniotomy, EPM, and glioma resection aided by high-field iMRI. The role of cytoreductive surgery in surviving patients with gliomas still remains somewhat controversial as only level 2 evidence is available at present (5, 16). Nevertheless, most neurosurgeons and neuro-oncologist agree that maximal safe resection is appropriate for newly diagnosed patients. We believe that simple techniques like ours for combining awake craniotomy, EPM, and high-field iMRI may be an important step in facilitating maximal safe resection for large gliomas in eloquent cortex.

REFERENCES


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Sydney Opera House, Sydney, New South Wales, Australia. Photo by David Hoff.