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ABSTRACT

SUMMARY: We report on a 75-year-old woman with a history of right MCA aneurysm clipping and medically refractive right-hand tremor. We successfully performed focused ultrasound thalamotomy of the left ventral intermediate nucleus under MR imaging-guidance at 3T. A thorough pretreatment evaluation of MR thermometry was critical to ensure that adequate precision could be achieved at the intended target. The tremor showed a 75% decrease at 24 hours postprocedure and a 50% decrease at a 3-month follow-up. There were no immediate adverse events.

ABBREVIATIONS: MRgFUS = MR-guided focused ultrasound; MRT = MR thermometry; VIM = ventral intermediate nucleus

MR-guided focused ultrasound (MRgFUS) is a stereotactic technique that is increasingly being used for essential tremor and Parkinson-related tremor, in which high-intensity focused ultrasound is used to heat and ablate the thalamic target via precise intraprocedural target localization and the real-time monitoring of thermal dynamics with MR imaging.[1,2] Staged bilateral thalamotomy is a regulatory-approved procedure with a potential for adverse events, including ataxia, dysarthria, and dysphasia.[3-5] However, there is a paucity of literature for MRgFUS in the setting of an intracranial aneurysm clip, which can present challenges with magnetic field inhomogeneity that can render MR thermometry (MRT) unreliable. Here, we present a case of unilateral MRgFUS ventral intermediate nucleus (VIM) thalamotomy for medically refractory tremor in the setting of a contralateral MCA aneurysm clip on a 3T MR imaging scanner. It is shown that a pretreatment MRT study can both aid in evaluating patient-specific MRT performance and result in a safe and efficacious procedure.

Case

The patient is a 75-year-old, right-handed woman with a history of hypertension, seizure disorder, and aneurysmal subarachnoid hemorrhage treated by MCA clip (Yasargil FE784K, conditional $B_0 \leq 3T$) ligation. The patient presented for a medically refractory right-hand tremor that was diagnosed 10 years prior. The patient had a preprocedural diagnosis of poststroke parkinsonism. The tremor was characterized by a prominent resting and postural tremor (right upper extremity: Clinical Rating Scale for Tremor [CRST]-A 7 [rest 3, postural 3, kinetic 1], CRST-B 11, CRST-C 16). The symptoms, including imbalance, affected her activities of daily living. After discussing the results from the main randomized controlled trial of MRgFUS for essential tremor, including the expected 50% reduction in tremor[6] as well as the risks, benefits, and alternatives, the patient agreed to proceed with MRgFUS of the left VIM.

Before referral to our institution, the patient had a head CT scan done, according to the specifications of the MRgFUS vendor (Insightec). The day before the procedure, diagnostic MR imaging was performed for the structural evaluation and assessment of the degree of susceptibility artifact from the aneurysm clip in the right Sylvian fissure (CT shown in Online Supplemental Data). All MR imaging scans were performed at 3T (Skyra, Siemens). The MR imaging revealed extensive encephalomalacia and gliosis in the right MCA territory from aneurysmal subarachnoid hemorrhage and associated ischemic injury.

On the day of the treatment, the standard MRT protocols were tested with the patient in a focused ultrasonography transducer (Exablate Neuro, Insightec) without the coupling water bath. Before shaving her head or placing the stereotactic frame, the patient's head was stabilized with pads, and imaging was performed with the embedded 2-channel head coils (Insightec). To investigate the homogeneity of the magnetic field and its impact on the MRT in the region of the left VIM target, 30-second duration MRT scans were acquired (8 dynamics). Scans were acquired

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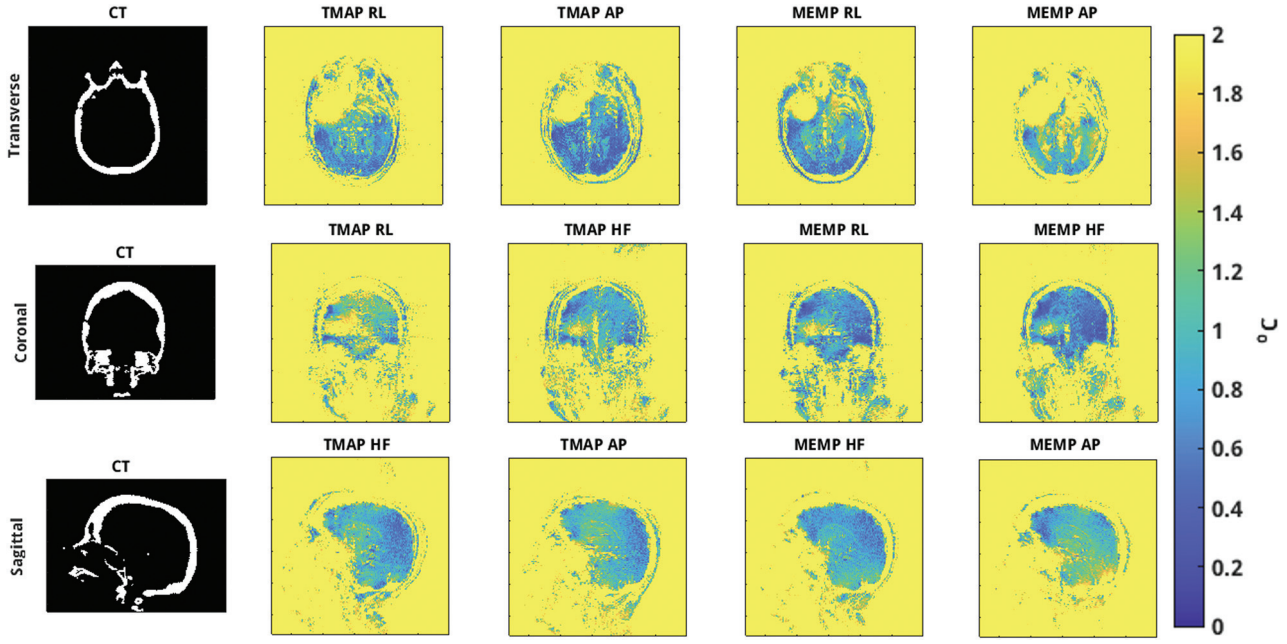

FIG 1. CT scan and precision of MRT scans. MRT precision is measured as the standard deviation through time. For all 3 orientations, both phase-encoding directions for both the single-echo and multi-echo MRT sequences are shown. The scans were performed in the Exablate transducer (without the coupling water bath) with a 2-channel radiofrequency receiver coil. The patient's head was stabilized with pads, but no stereotactic frame was used. The scans were performed before the patient's head was shaved.

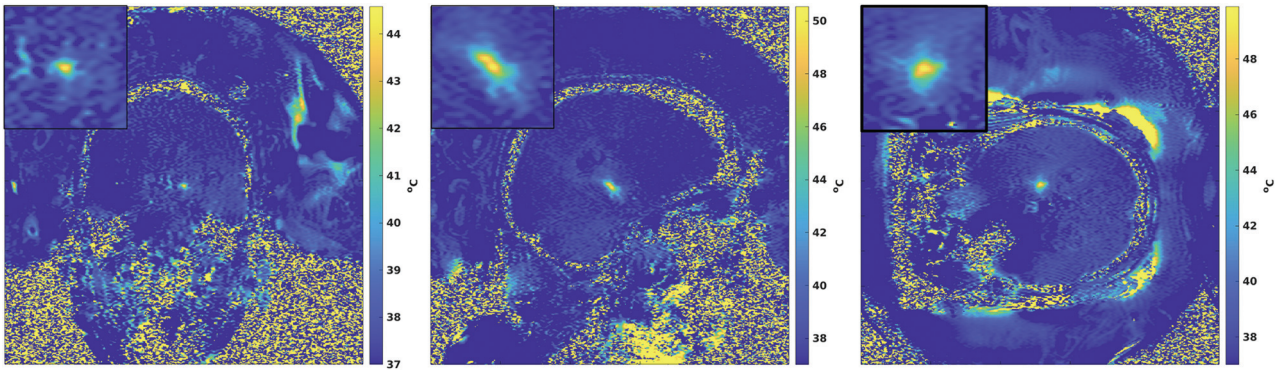

FIG 2. MRT of the hottest time point for one heating in each orientation (sonications 2, 7, and 11, respectively, are shown). The inlay in each panel zooms in on a 33 × 33-mm region around the focal spot.

in 3 orthogonal orientations, and for each orientation, both phase-encoding directions were acquired. Scans were performed with vendor-supplied single-echo (TMAP) and multi-echo (MEMP) protocols, for a total of 12 scans (Figure 1). TMAP has a frequency encoding bandwidth of 45 Hz/pixel, whereas MEMP has a bandwidth of 250 Hz/pixel, and hence, less susceptibility to off-resonance effects. For the multi-echo protocol, the echoes were optimally combined by weighting the signal by (TE_j*M_j), where TE is the echo time, M is the magnitude image, and j = 1: N for N echoes.[7] To investigate the precision of the measurement as a function of the spatial location, the standard deviation through time was calculated over each 30-second scan, as shown in Figure 1.

Following the verification of adequate MRT precision in the target area, the patient's head was shaved, secured in a stereotactic head frame, and placed in a cold bath of degassed water. The patient was placed and secured on the MR imaging scanner table within the Exablate Neuro System (Insightec). After turning off the transducer elements that were interacting with the aneurysm clip, calcifications, etc, 861 of 1024 elements were active (Online Supplemental Data), with a skull attenuation ratio of 0.60. Next, test doses of ultrasonography were delivered while monitoring side effects and tremor reduction (Online Supplemental Data). No side effects were observed during the alignment sonications. During the verification sonications, substantial tremor reduction was not observed in the initially targeted location. Therefore, the target was moved 1 mm posterior and, later, 1.5 mm lateral, given that the patient did not have any sensory changes. The target was moved a total of 4 times, until a tremor reduction was seen with sonications at a temperature of ~49–52°C. A total of 11 sonications with power ranging from 200–952 W, lasting between 11.5–31.4 seconds, and delivering between 2002–22202 J, were performed.

The last 3 sonications were stopped prematurely by the patient because of discomfort, but it was not believed to be related to the aneurysm clip. MRT was successfully acquired during all sonications (Figure 2 and Online Supplemental Data), with a maximum temperature rise of 53.0°C (Online Supplemental Data).

Posttreatment T2-weighted images (axial sampling perfection with application-optimized contrasts by using different flip angle evolution [SPACE sequence; Siemens]) that were acquired immediately posttreatment in 20-channel head coil (Siemens) showed a hyperintense signal at the treatment site (Online Supplemental Data).

DISCUSSION

Patient-specific factors complicate the MRgFUS treatment of drug refractory tremor. Understanding the technical basis through additional pretreatment scans can aid in the safe performance of the procedure. Successful MRgFUS VIM ablation was achieved with a 75% tremor reduction recorded at 24 hours postprocedure in a patient with an MCA aneurysm clip. A pretreatment MRT study was performed to ensure that satisfactory temperature map quality could be achieved at the intended target. MRT was subsequently successfully acquired in all 3 orthogonal scan planes during the treatment. The pretreatment investigation helped guide which MRT sequence, scan planes, and phase-encoding direction would ultimately be most successful during the treatment. As shown in Figure 1, multi-echo protocols (MEMP), in general, provided better precision than did the single-echo protocol (TMAP) and were therefore used throughout the treatment. The additional preprocedure experiments showed that MRT would be feasible in the thalamus contralateral to the clip, and it was also predicted that MRT would be unreliable in the ipsilateral thalamus. Based on this experience, a pretreatment scan using the treatment hardware and pulse sequences (especially thermometry) is recommended to evaluate the extent of artifact, based on patient-specific clip type and location.

CONCLUSIONS

This report demonstrates the feasibility of MRgFUS thalamotomy in a patient with an aneurysm clip. We showed accurate MRT on a 3T scanner by using the multi-echo MRT sequence.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

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