Percutaneous Selective Laser Hippocampectomy for Treatment of Mesial Temporal Lobe Epilepsy within an Interventional MRI Suite

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Introduction & Purpose: Patients with intractable seizures due to mesial temporal lobe epilepsy are typically left only with the surgical option. The scope of surgical procedures includes anterior temporal lobectomy and selective amygdalo-hippocampetomy (SAH) that targets the seizure onset zone within the mesial aspect of the temporal lobe. Selective approaches may be associated with more favorable cognitive outcomes [1]. Targeting selected deep brain anatomy via open surgical procedures is, however, complicated by potential collateral damage that renders the approach, and subsequently the outcome, less selective than desired [2]. The aims of this study are to: (1) test the feasibility of performing selective hippocampetomy via targeted percutaneous placement of a laser fiber followed by controlled ablation under real-time MR monitoring; (2) examine the short- and intermediate-term safety of the procedure; and (3) report the MR imaging appearance of laser-mediated thermal ablation zones within the hippocampal complex.

Patients & Methods:
10 percutaneous hippocampal laser ablations were performed under MRI in 4 patients (2 males & 2 females, age= 22-45 y, mean= 31.5y) diagnosed with intractable complex partial seizures originating in the mesial temporal lobe. A laser fiber with a 10-mm-long diffusing tip constructed on a 400 micron based fiber was inserted in a 1.65-mm-diameter cooling catheter (Visualase, Inc., Houston, TX). The laser fiber/cooling catheter combination was inserted stereotactically in the operating room. The patients were then moved to an interventional MRI suite equipped with a wide (70cm), short (125 cm) bore 1.5T MRI scanner (Siemens Espree, Germany). MR imaging with MP-RAGE (TR/TE/TI/FA=1900/3.5/1100/15°) was used to locate, adjust, and confirm the laser fiber tip position (Fig. 1A, B). When the fiber position was deemed satisfactory on MR imaging, further confirmation was added by applying a test dose of laser energy (30 seconds at 4.5W) to verify the actual location of the ablation nidus on real-time temperature and cumulative damage estimate mapping (TE/TE/FA = 24/10/30°) using the Visualase® workstation. Subsequently, 980nm diode laser energy was delivered at the target location with the treatment endpoint based on actual on-line thermal monitoring and damage estimates of the growing ablation zone (Fig. 1C). Laser fiber repositioning for additional ablation was conducted once in two patients and twice in two patients in order to encompass the entire area of the hippocampal head and anterior body. Post-ablation scans consisted of TSE-T2, GRE-T2, FLAIR, DWI/ADC, and pre- and post-gadolinium MP-RAGE. These were evaluated for the location, size and MRI characteristics of thermal lesions and for immediate post-operative complications including intra- or extra-axial hemorrhage. The patients were observed for 1-2 nights for any neurological deficits including motor weakness, sensory loss, or visual field or speech disturbances.

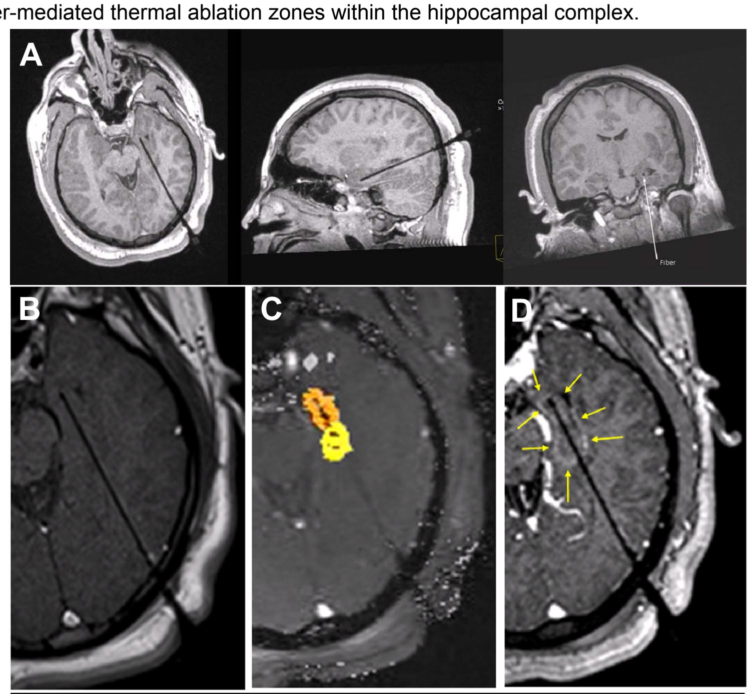

Fig. 1. **(A) Axial, sagittal, and coronal MP-RAGE scans confirming laser fiber placement within the left hippocampal complex prior to the commencement of treatment. (B) Magnified axial MP-RAGE of pre-treatment area. (C) Cumulative damage estimate map showing predictions of the extent of necrosis resulting from the first (orange) and second (yellow) ablation cycles. (D) Post-treatment gadolinium-enhanced MP-RAGE axial scan showing rim enhancement marginating the extent of necrosis and matching the lesion topography predicted on the damage estimate map.**

Results:
The 10 thermal ablation zones included 5 right-sided and 5 left-sided ablations and were generated during a total of 4 treatment sessions (one session per patient). The duration of each ablation cycle, the associated deployed laser power and energy, and the resultant thermal ablation zone size are listed in table 1. Ablation zones in all but one patient were properly positioned at the targeted anatomy on post-ablation scans. In one patient, laser fiber positioning was 3 mm off the hippocampus. Thermal ablation zones demonstrated hypointense signal on T2-weighted imaging sequences, traversed by linear hyperintense signal at the site of laser fiber track, and surrounded by a thin hyperintense rim. This rim demonstrated bright signal of restricted diffusion on the DWIs and dark signal on the ADC maps. Pre-contrast T1-weighted sequences demonstrated hyperintense signal of acute blood products at the laser fiber track. Following gadolinium administration, a thin rim of enhancement marginated the ablation zone (Fig. 1D) corresponding to the changes seen on T2WIs and DWIs. No intra- or extra-axial hemorrhage was detected on any of the post-ablation scans. Follow-up durations ranged between 7 and 21 weeks. No neurological deficits were observed on short and intermediate-term follow-up. Seizures were eliminated in 3 patients while one patient experienced recurrent seizure activity.

		Duration (seconds)	Power (Watts)	Energy (Joules)	Individual ablation zone size (mm)	Total ablation zone size (mm)
Subject 1	Ablation cycle 1	111	10	1110	18 x 12	25 x 12
	Ablation cycle 2	56	10	560	14 x 12	
	Ablation cycle 3	185	10	1850	11 x 9	
Subject 2	Ablation cycle 4	180	12	2160	18 x 12	40 x 15
	Ablation cycle 5	196	12	2352	18 x 15	
	Ablation cycle 6	196	12	2352	17 x 14	
Subject 3	Ablation cycle 7	290	12	3480	12 x 10	20 x 12
	Ablation cycle 8	195	12	2340	17 x 12	
Subject 4	Ablation cycle 9	90	12	1080	21 x 11	35 x 14
	Ablation cycle 10	174	12	2088	19 x 14	

Table 1. **Number of ablation cycles per treatment session, duration, power, energy, and resultant ablation size per cycle, and total achieved ablation size per treatment session.**

Discussion & Conclusion:
This report introduces a minimally invasive alternative to surgical amygdalo-hippocampectomy via percutaneous insertion of a cooled diode laser applicator followed by temperature-controlled targeted energy deposition under real-time MRI monitoring within a dedicated "interventional MRI" suite. The online feedback of the ablation progress allows a gradual build-up of the ablation zone while avoiding inadvertent injury to adjacent structures. In addition to the demonstrated feasibility, short and intermediate-term safety has been shown on both imaging and neurological functional assessments. The previously reported MR imaging features of thermal ablation zones in other organs do apply to hippocampal imaging following laser ablation. Despite the demonstrated promising efficacy for seizure control, such evaluation awaits long-term follow-up results on a larger cohort of patients.

References: [1] Helmstaedter C, et al. Epilepsia. 2008;49(1):88-97. [2] Gleissner U, et al. Epilepsia. 2002;43(1):87-95.