

Magnetic resonance imaging–guided laser interstitial thermal therapy for refractory focal epilepsy in a patient with a fully implanted RNS system: illustrative case

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BACKGROUND The resective surgery plus responsive neurostimulation (RNS) system is an effective treatment for patients with refractory focal epilepsy. Furthermore, the long-term intracranial electroencephalography data provided by the system can inform a future resection or ablation procedure. RNS patients may undergo 1.5-T magnetic resonance imaging (MRI) under the conditions specified in the RNS system MRI guidelines; however, it was unknown if the MRI artifact would limit intraoperative laser interstitial thermal therapy (LITT) in a patient with a fully implanted RNS system.

OBSERVATIONS The authors were able to complete a successful awake LITT of epileptogenic tissue in a 1.5-T MRI scanner on the ipsilateral side to an implanted RNS system.

LESSONS If a future LITT procedure is probable, the neurostimulator should be placed contralateral to the side of the potential ablation. Using twist drill holes versus burr holes for depth lead placement may assist in future laser bone anchor seating. Before a LITT procedure in a patient with the neurostimulator ipsilateral to the ablation, 1.5-T MRI thermography scanning should be scheduled preoperatively to assess artifact in the proposed ablation zone. Per the RNS system MRI guidelines, the patient must be positioned supine and awake, with no more than 30 minutes of active scan time before a 30-minute pause.

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KEYWORDS laser ablation; LITT; RNS system; focal epilepsy

Responsive neurostimulation (RNS) system (RNS System, NeuroPace Inc.) is an effective treatment for patients with refractory focal epilepsy. Clinical studies have demonstrated a median seizure frequency reduction of 58% at year 3 and 75% at year 9.¹ Post-trial real-world studies report similar median seizure frequency reductions in a much shorter time frame: 75% at 2 years and 82% at 3 or more years.² In addition to seizure reductions, the epilepsy community has been able to gain insights into seizure activity from the long-term intracranial electroencephalography (iEEG) data that were not possible to obtain in the past. The iEEG data have enabled long-term seizure lateralization and eventual resective procedures to be performed in cohorts of patients with mesial temporal lobe epilepsy.^{3,4} The long-

term iEEG data have also allowed the continuous monitoring of recurrent seizure activity at prior resection borders,⁵ as was the case in our patient described here.

Laser interstitial thermal therapy (LITT) of seizure foci can be an alternative or supplement to resective surgery. LITT has been demonstrated to be nearly as effective as resection for treating epileptogenic tissue in some brain areas, such as the mesial temporal lobe.^{6,7} LITT is sometimes preferred over resection because it is less invasive and it may cause fewer postoperative cognitive deficits.⁸ LITT is also a preferred approach when a surgical target resides deep in the brain, which may be more difficult to reach with open resective techniques.

ABBREVIATIONS ATL = anterior temporal lobectomy; ECT = electroconvulsive therapy; iEEG = intracranial electroencephalography; LITT = laser interstitial thermal therapy; MRI = magnetic resonance imaging; RNS = resective surgery plus responsive neurostimulation.

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Previous magnetic resonance imaging (MRI) limitations of the RNS System did not allow LITT procedures to be performed with the neurostimulator and leads remaining in place. However, the latest RNS System neurostimulator model (RNS-320) has received approval for 1.5-T MRI. MRI artifacts on structural imaging extend below the neurostimulator and around the implanted leads, per the RNS System labeling;⁹ therefore, it was unknown if it would be possible to successfully perform an LITT procedure on the ipsilateral side to the system implant. Here we describe the first adult patient to successfully undergo an awake LITT procedure with a fully implanted ipsilateral RNS System at Stanford University.

Illustrative Case

The patient was a 26-year-old right-handed female who presented with a complex epilepsy history. She has a past medical history of post-traumatic stress disorder and depression ultimately requiring electroconvulsive therapy (ECT). She experienced her first seizure after her fourth ECT session with leftward head turn progressing to a bilateral tonic-clonic seizure. This episode resulted in status epilepticus, requiring a prolonged hospitalization. After recovery from this acute episode, she continued to have frequent seizures despite discontinuation of ECT. Her seizures started an aura of déjà vu, some de-realization, followed by alterations in sound perception (as if in a tunnel or in a barrel) and awareness, some with secondary generalization to a tonic-clonic seizure. Subsequent evaluation including iEEG ultimately showed primarily right temporal seizure onsets. At the time, the patient preferred not to have a resection and underwent implantation with an RNS System with the neurostimulator seated in the right parietal bone and a right mesial temporal depth lead, and cortical strip leads covering the right anterior and lateral temporal regions. Data from this procedure subsequently led to an anterior temporal lobectomy (ATL) with two cortical strip leads repositioned to cover the posterior margin of the ATL. She continued to have 5–12 auras of déjà vu, sometimes in daily clusters, some with loss of awareness.

Postresection imaging revealed residual amygdala and piriform cortex. Her case was presented at an epilepsy surgical conference 11 months after the resection, and we elected to use laser ablation to ablate the remaining amygdala and piriform cortex, with the RNS neurostimulator and leads remaining in place.

The procedure entailed bone anchor and image-guided laser catheter stereotactic placement in the operating room under general anesthesia (Fig. 1A and B). An intraoperative O-arm was acquired to confirm laser accuracy. The patient was then woken up and extubated, and transported to the MRI suite where an awake LITT (Visualase, Medtronic) would be performed. She was positioned supine with her head turned, and padding was placed inside the head coil to help maintain her head position. The laser catheter was supported to ensure there was no pressure or tension on the anchor bolt or sheath. The patient reported being comfortable in her final position prior to going into the MRI. Once inside the MRI, we confirmed that two-way communication was effective prior to proceeding. The NeuroPace MRI guidelines were adhered to by limiting the total scan time to less than 30 minutes, positioning the patient supine with head turned, and verbally monitoring during the scan (patient awake).

MRI-guided laser thermal ablation of remnant amygdala/piriform cortex was performed. The distance between the RNS System lead and the laser target was 5.5 cm. Real-time thermography was limited due to ipsilateral neurostimulator artifact (Fig. 1C and D),

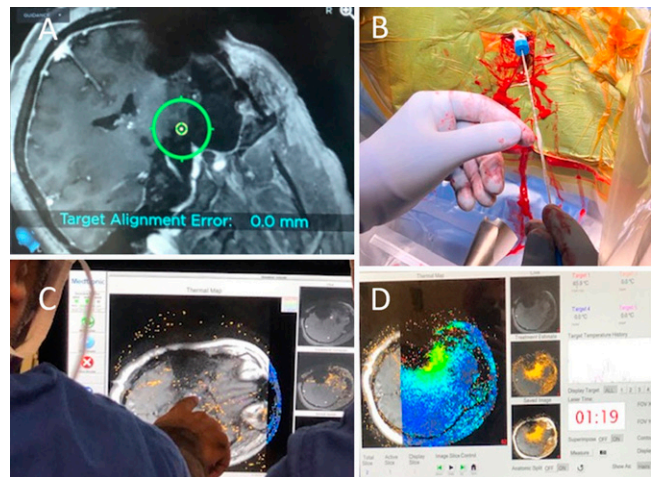


FIG. 1. Operative workflow. **A and B:** Image-guided placement of laser using Medtronic Precision Aiming Device. **C and D:** Thermography artifact caused by ipsilateral stimulator affected the lateral border of the region of interest.

but, interestingly, during test dosing (30% energy) and initial ablation (50% energy), the patient had a typical aura. This resolved with completion of the ablation. Postoperative imaging showed a good ablation zone within the mesial temporal remnant with extension to the piriform cortex (Fig. 2). The total scan time was approximately 25 minutes, including imaging setup time and ablation time. The patient remained neurologically intact, and, at the 6-week post-LITT follow-up, she reported a significant reduction in seizure burden and auras.

Discussion

To our knowledge, this is the first published experience of an LITT procedure performed in an adult patient with an RNS neurostimulator and leads remaining in place. There were no complications, with resultant improvement in seizures and quality of life. The alternative is an additional surgical procedure to remove the RNS neurostimulator and leads before ablation, which carries a higher risk for surgical morbidity with two procedures and increases the time to provide the ultimate treatment. Also, by leaving the RNS neurostimulator and leads in place, ongoing intracranial EEG data are available, and responsive stimulation can be provided. Our approach supports new surgical possibilities for RNS System patients, in whom ablative therapy can be performed while still maintaining RNS therapy.

In this particular procedure, the trajectory of the laser fiber was distinct from the active leads connected to the RNS System. The operative procedure therefore was simply focused on placement of the laser catheter through a separate entry point. In the event of a desired laser trajectory being along the trajectory of an implanted RNS lead (such as a long-axis amygdalohippocampectomy with bitemporal RNS leads), the procedure would require the removal of the RNS lead along the desired ablation trajectory, followed by placement of a laser catheter. This could still be done as a single procedure with the patient under general anesthesia, which would be followed by ablation in the MRI suite. Another ipsilateral RNS lead at the posterior margin of the ablation, or in another location,

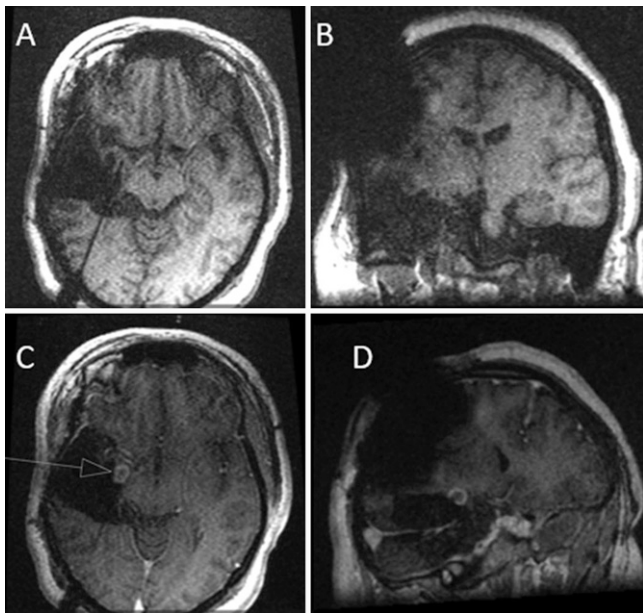


FIG. 2. Pre- and postablation imaging. **A and B:** Laser trajectory showing good position of fiber in axial and coronal planes in the amygdala and piriform cortex remnant. **C and D:** Postablation imaging showing lesion of remnant tissue (Panel C, white arrow).

could then be replaced if needed, depending on the clinical situation. This should likely be done after a minimum of 4–6 weeks of recovery from the ablation, but in certain situations it could be considered immediately by going back to the operating room after the ablation and placing a new lead.

Our initial experience underscores (1) the importance of considering the location of a potential future LITT when placing the neurostimulator to minimize MRI artifact in the region of interest and (2) the utility of awake LITT for confirming that the ablation is within the epileptogenic network.

Observations

We were able to complete a successful LITT ablation of epileptogenic tissue on the ipsilateral side to an implanted RNS System, using the conditions outlined in the NeuroPace-provided MRI guidelines. This experience, and lessons learned from it, will expand the possibilities of doing future ablative procedures guided by the long-term iEEG data collected from the RNS System, especially in cases that are not amenable to an open resective procedure.

Lessons

If a future LITT procedure may be possible, the RNS System neurostimulator should be placed contralateral to the side of the predicted ablation. For example, in a patient with bilateral mesial temporal lobe epilepsy, the neurostimulator should be placed on the side with fewest seizure onsets observed during epilepsy evaluation procedures.

The Visualase bone anchor must be screwed into a 3.2-mm twist drill hole. If the RNS depth electrode is placed via a 14-mm burr hole, there will not be sufficient bone remaining to secure the bone anchor along the trajectory of the existing lead.

In this scenario, either a new trajectory must be planned for ablation such that an anchor bolt can be seated in the skull, or, alternatively, the ClearPoint Neuro Navigation Platform (Clear-Point Neuro) can be used to place the laser fiber within a prior burr hole.

Before an LITT procedure in an RNS System patient, a 1.5-T MRI thermography image sequence should be scheduled. This will show where the implant artifact is causing instability in the thermography and will allow the surgeon to assess whether the artifact will impact the ability to estimate the damage zone in the subsequent LITT procedure.

The RNS System 1.5-T MRI labeling requires that a patient be positioned in supine position and monitored visually and audibly during the scan. The total scan time cannot exceed 30 minutes without a pause of 30 minutes. We achieved our ablation by turning the patient's head and fixing the head within the bore of the MRI with pillows to avoid head movement. The Visualase system allowed us to track total scan time.

If planning an ablation and new RNS System lead implantation on the same day, the lead placement must occur after the ablation procedure due to the labeling restriction requiring the lead(s) to be implanted for a minimum of 10 days before any MRI.

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Disclosures

Mrs. Mirro reported equity ownership/stock options with NeuroPace and is an employee of NeuroPace. Ms. Wilmer-Fierro reported equity ownership/stock options with NeuroPace and is an employee of NeuroPace. Dr. Razavi reported grants from NeuroPace outside the submitted work. Dr. Buch has served as a consultant for NeuroPace. No other disclosures were reported.

Author Contributions

Conception and design: Buch, Purger, Razavi, Halpern. Acquisition of data: Buch, Mirro, Purger, Wilmer-Fierro, Razavi. Analysis and interpretation of data: Buch, Mirro, Purger, Zeineh, Razavi, Halpern. Drafting the article: Buch, Mirro, Razavi. Critically revising the article: Mirro, Purger, Zeineh, Razavi, Halpern. Reviewed submitted version of manuscript: Mirro, Purger, Zeineh, Razavi, Halpern. Approved the final version of the manuscript on behalf of all authors: Buch. Administrative/technical/material support: Mirro, Zeineh, Razavi. Study supervision: Razavi, Halpern.

Supplemental Information

Previous Presentations

A portion of this content was presented at the American Epilepsy Society Meeting held in Chicago, Illinois, December 3–6, 2021.

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