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MRI-Guided stereotactic laser ablation for epilepsy surgery: Promising preliminary results for cognitive outcome

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ABSTRACT

Cognitive outcome data are reviewed with respect to the use of magnetic-resonance guided stereotactic laser ablation (SLA) as an epilepsy surgical procedure, with comparisons drawn to traditional open resection procedures. Cognitive outcome with stereotactic laser amygdalohippocampotomy (SLAH) appears better than open resection for several functions dependent on extra-mesial temporal lobe (TL) structures, including category-related naming, verbal fluency, and object/familiar person recognition. Preliminary data suggests episodic, declarative verbal memory can decline following SLAH in the language dominant hemisphere, although early findings suggest comparable or even superior outcomes compared with open resection. The hippocampus has long been considered a central structure supporting episodic, declarative memory, with epilepsy surgical teams attempting to spare it whenever possible. However, ample data from animal and human neuroscience research suggests declarative memory deficits are greater following broader mesial TL lesions that include parahippocampal gyrus and lateral TL inputs. Therefore, employing a neurosurgical technique that restricts the surgical lesion zone holds promise for achieving a better cognitive outcome. Focal SLA lesions outside of the amygdalohippocampal complex may impair select cognitive functions, although few data have been published in such patients to date. SLA is being effectively employed with adults and children with TL or lesional epilepsies across several U.S. epilepsy centers, which may simultaneously optimize cognitive outcome while providing a curative treatment for seizures.

1. Introduction

Whether smaller surgical resections improve cognitive and functional outcome compared to more traditional anterior temporal lobectomies is a major topic of debate in the field of epilepsy surgery (Helmstaedter, 2013). While standard anterior temporal lobectomy (ATL) retains a small advantage over selective open resection approaches for seizure control (Wiebe et al., 2001), research has been mixed and generally inconclusive regarding differences in cognitive outcome (Helmstaedter, 2013; Gleissner et al., 2002). The difficulty involved in sorting out this question is related to significant variability in the functions studied and the tests used to evaluate these abilities. However, another critical variable is that most open resection approaches result in significant "collateral" damage while accessing the mesial TL structures. For example, many of these approaches disturb the temporal stem, which is traversed by critical white matter tracts, including the uncinate fasciculus (UF) and the inferior fronto-occipital fasciculus (IFOF) (Sarubbo et al., 2013). Most also affect other extra-temporal structures, such as the fusiform gyrus, basal temporal language area, temporal pole, and additional white matter tracts. The emergence of a novel laser ablation technology holds promise for a minimally invasive approach that could reduce this secondary collateral damage.

2. Search criteria for current review

While (Fig. 1) laser interstitial thermal therapy (LiTT) has been available for several years (see Hoppe et al. for an excellent review article on this topic) (Hoppe et al., 2017), the current review is focused on cognitive outcome observed using the more recent use of magnetic resonance-guided stereotactic laser ablation (SLA) systems (Visualase®, Neuroblate®). *Pubmed* was searched using the terms LiTT, SLA, or laser ablation in conjunction with several permutations of cognitive function (i.e., cognitive function, memory, language, verbal fluency, executive

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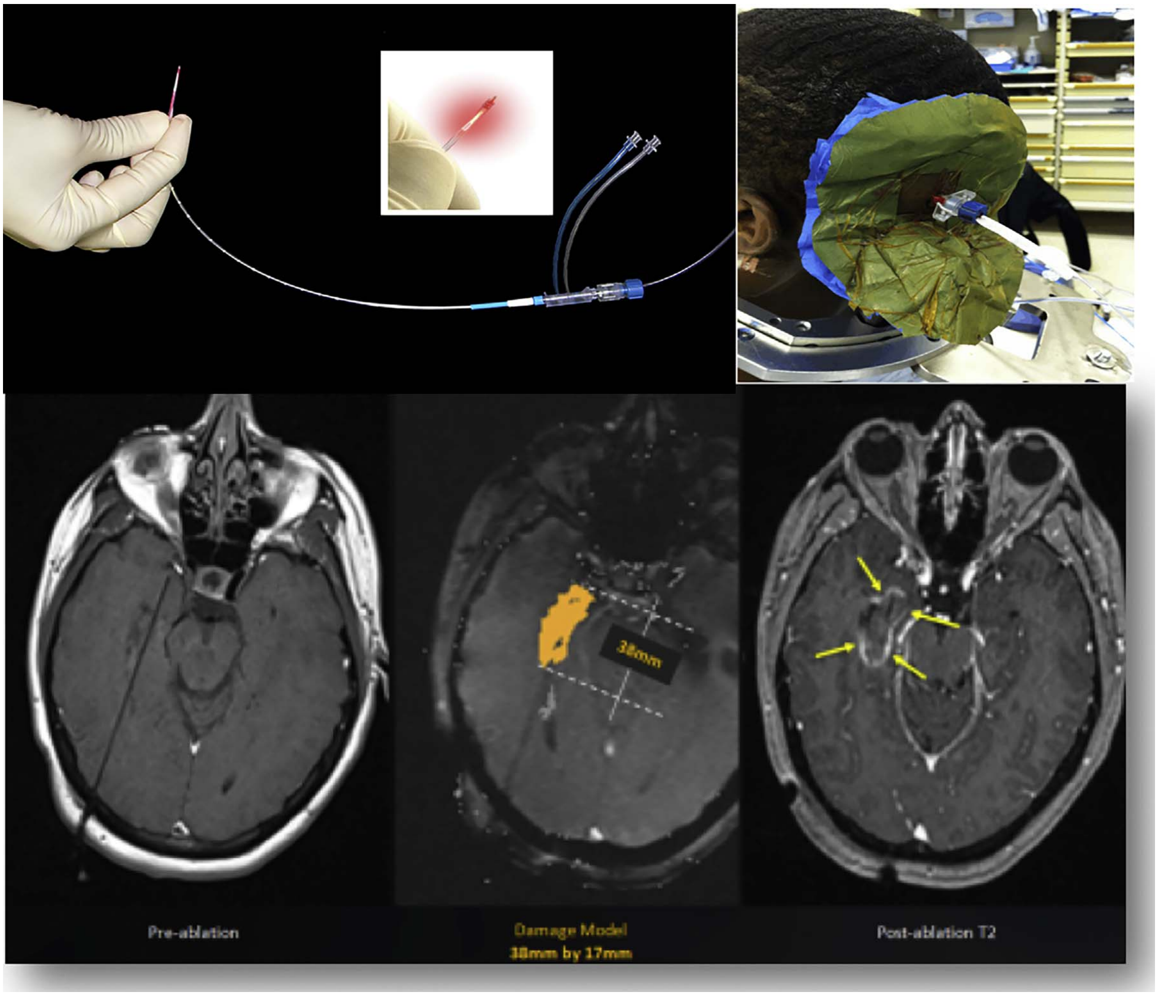

Fig. 1. Depiction of the Optical Fiber, the Ablation Process, and Pre- and Post-Ablation MRI Images in an Axial Plane Demonstrating the Focal Nature of the Damage Zone.

function) between November 2016 and July 2017. Only articles with original cognitive outcome data following epilepsy surgery were examined (including case studies). This resulted in only six publications, three of which were case studies. One additional publication[6] was added that was not identified by *Pubmed* search terms. This article was referenced in one of the other six publications. In addition, four SLA review articles were identified.

The case studies included hypothalamic hamartoma ablation in a patient who had previously undergone a right ATL (Zubkov et al., 2015), a SLA procedure involving the insular cortex of a patient with post-stroke epilepsy (Hawasli et al., 2014), and two TLE patients with normal neuroimaging who underwent SLAH (Dredla et al., 2016). The four SLA publications with group data included only one study that was prospective in nature (Drane et al., 2015). This study compared TLE patients undergoing SLAH (n = 19) with those undergoing open resection procedures (n = 39) on naming and object recognition tasks. One additional study compared TLE patients undergoing SLAH (n = 7) to a selective amygdalohippocampectomy procedure (n = 7) on a variety of clinical measures, but only had post-surgical data available for three to four patients from each patient group (Waseem et al., 2015). The remaining two group level studies retrospectively examined clinical memory measures for a subset of patients who returned for follow-up evaluation and both lacked any comparison control group. Kang et al. (2016) presented verbal memory data available on six of 20 SLAH patients, while Jermakowicz et al. (2017) reported verbal and visual memory data for 20 of 23 SLAH patients. The latter study also reported on some other clinical measures as available for analysis as well. As can be seen, there remains a dearth of publications related to the cognitive outcome of SLA. Additionaly, prospective, well-controlled studies are lacking in this area.

Because no studies with children came up in *Pubmed* with the specified search terms, this search was redone with specific terms for children. This combination of terms led to an additional four publications involving children, although none of these included formal cognitive data. Therefore, this review does not cover cognitive outcome of SLA in children, apart from a brief mention of the successful application of SLA to treat hypothalamic hamartoma.

3. Potential for improved cognitive outcome with laser ablation

3.1. Object recognition and naming outcome

Drane and colleagues (Drane et al., 2015) have demonstrated superior cognitive outcome for select functions with SLAH when prospectively compared to a variety of open resection approaches, including both standard and selective procedures. Naming of man-made objects and/or famous persons declined in 21 of 22 TLE patients undergoing language dominant open resection, while no significant decline on these tasks was experienced by any dominant SLAH patient (n = 10). Similarly, 11 of 17 TLE patients undergoing right (non-dominant) open resection experienced significant decline in their ability to recognize famous persons, while no TLE patients undergoing SLAH experienced any decline on this task (n = 9). Duffau and colleagues demonstrated in a series of tumor resection patients that even a