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The impact of stereotactic laser ablation at a typical epilepsy center☆

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ABSTRACT

Purpose: Stereotactic laser ablation (SLA) is a novel form of epilepsy surgery for patients with drug-resistant focal epilepsy. We evaluated one hundred consecutive surgeries performed for patients with epilepsy to address the impact of SLA on our therapeutic approach, as well as patient outcomes.

Methods: A retrospective, single center analysis of the last one hundred neurosurgeries for epilepsy was performed from 2013 to 2015. Demographics, surgical procedures, and postoperative measures were assessed up to 5 years to compare the effect of SLA on outcome. Confidence intervals (CI) and comparative tests of proportions compared outcomes for SLA and resective surgery. Procedural categorical comparison used Chi-square and Kaplan–Meier curves. Student *t*-test was utilized for single variables such as age at procedure and seizure onset.

Results: One hundred surgeries for epilepsy yielded thirty-three SLAs and twenty-one resections with a mean of 21.7-month and 21.3-month follow-up, respectively. The temporal lobe was the most common target for SLA (92.6%) and resection (75%). A discrete lesion was present on brain magnetic resonance imaging (MRI) in 27/32 (84.4%) of SLA patients compared with 7/20 (35%) of resection patients with a normal MRI. Overall, 55–60% of patients became seizure-free (SF). Four of five patients with initial failure to SLA became SF with subsequent resection surgery. Complications were more frequent with resection although SF outcomes did not differ (Chi square; $p = 0.79$). Stereotactic laser ablation patients were older than those with resections (47.0 years vs. 35.4 years, $p = 0.001$). The mean length of hospitalization prior to discharge was shorter for SLA (1.18 days) compared with open resection (3.43 days; SD: 3.16 days) ($p = 0.0002$).

Conclusion: We now use SLA as a first line therapy at our center in patients with lesional temporal lobe epilepsy (TLE) before resection. Seizure-free outcome with SLA and resection was similar but with a shorter length of stay. Long-term follow-up is recommended to determine sustained SF status from SLA.

1. Introduction

Seizures have negative consequences that are life-limiting for a person's transportation, employment, overall quality of life, health, and survival [1,2]. Surgery is a successful treatment option in patients with drug-resistant focal epilepsy when compared with the best medical therapy [3]. Temporal lobectomy has been considered the "gold standard" for most patients with drug-resistant temporal lobe epilepsy (TLE) [1,4]. A randomized controlled trial demonstrated that 58% of those treated with surgery were free of seizures impairing awareness (vs. 8% in the medical group) with 10% of those operated experiencing side effects from surgery [3]. Despite the significant rate of seizure freedom from surgical intervention, higher cost, prolonged hospitalization, and the perception of surgery as a last resort hamper surgical referrals to full-service epilepsy centers for evaluation [5]. Surgical safety registries have reported major complication rates from standard resection ranging from 1.6% to 6.6% and minor complication rates ranging from 5% to 17.5% [6].

In addition to open resection, other neurological procedures performed for patients with epilepsy include the vagus nerve stimulator (VNS) for poor surgical candidates [7] and invasive electroencephalogram (EEG) implantation for complex cases [8]. New treatments include novel neurosurgical procedures for epilepsy including stereotactic laser ablation (SLA) and the responsive neurostimulator (RNS). Benefits of minimally invasive epilepsy surgery with SLA include a focused approach to distant subcortical structures [9], patient attraction, and quick recovery times though trends at a typical epilepsy center are lacking in addition to small number of patients with short-term follow-up. Prior reports of smaller resections, including super-selective SLA, suggest similar seizure-free (SF) outcomes compared with larger resections and relative

Abbreviations: ASD, antiseizure drug; iEEG, intracranial EEG; mTLE, mesial temporal lobe epilepsy; MTS, mesial temporal sclerosis; PET, positron emission tomography; RNS, responsive neurostimulator; SF, seizure-free; NSF, not seizure-free; SLA, stereotactic laser ablation; VNS, vagus nerve stimulator; MRI, magnetic resonance imaging; EEG, electroencephalogram; SD, standard deviation.

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improvements in neuropsychological outcomes [9]. The RNS (Neuropace, Blue Mountain, CA) is another novel surgical technique used for treatment of epilepsy [10]. Both techniques are increasingly used at full service epilepsy centers, though limited information is available to assess their overall impact within a typical epilepsy surgical center. Therefore, we assessed the overall outcomes and treatment trends for all neurological surgeries performed at our center for patients with drug-resistant epilepsy over 3 years, with particular attention to SLA.

2. Material and methods

We performed a retrospective chart review at a single tertiary care epilepsy center (National Association of Epilepsy Centers, level 4) from February 2013 through December 2015.

The last one hundred neurological surgeries performed for epilepsy were identified with an average of 21.7 months (range 12–42 months) of follow-up for patients undergoing SLA and an average of 21.3 months of follow-up for patients undergoing resection. All investigations and surgeries were performed at Mayo Clinic in Florida. The study was approved by the Institutional Review Board of Mayo Clinic.

2.1. Patient selection

The demographics of patients undergoing SLA included age, gender, age at seizure onset, and number of previously failed antiseizure drugs (ASDs), in addition to a comprehensive presurgical evaluation. Inclusion criteria included a minimum age of 18 years, drug-resistant focal epilepsy, neurosurgery for epilepsy performed at Mayo Clinic, and follow-up >6 months. Exclusion criteria were age less than 18 years, pregnant, operation performed elsewhere, or follow-up less than 6 months. All patients underwent an initial standard noninvasive, presurgical protocol. Anatomic neuroimaging used a high-resolution (3.0 or 1.5 T) brain magnetic resonance imaging (MRI) (Siemens, Erlangen, Germany) with a dedicated epilepsy protocol [11]. Interictal and ictal video-EEG monitoring and flourodeoxyglucose positron emission tomography (PET) were performed in 27/32 patients. Technetium-labeled ictal single photon emission computed tomography (SPECT) was obtained in three patients; PET and SPECT was not obtained in two patients (one with bilateral lesions). Neuropsychological testing (Wada in selected cases) was performed in each patient preoperatively. Postoperative neuropsychological testing was performed in selected cases, guided primarily by patient complaint. The final selection of the surgical procedure was decided at a multidisciplinary surgical epilepsy conference [12]. Patients with a nonlocalized or discordant preoperative evaluation were implanted with stereotactic intracortical electrodes and/or subdural strips/grids for intracranial EEG (iEEG) monitoring when a single seizure-onset zone was anticipated, and referred for neuromodulation when more than 1 seizure focus were present, or the seizure onset zone was within eloquent cortex [12].

2.2. Surgery

Surgery performed for drug-resistant epilepsy included SLA and open resection using a traditional craniotomy for cortical resection. Surgery was performed by a single neurosurgeon (RW). A total of thirty-three surgeries using SLA were performed. Thirty patients were treated with the Visualase® (Medtronic Inc., US) and two with the NeuroBlate® (Monteris Medical, Plymouth, MN). Stereotactic laser ablation was performed according to the technique described by Willie et al. [13]. Ablation was typically performed as a first-line approach when a small (i.e., <2 cm) lesion (i.e., hippocampal sclerosis) amenable to stereotactic ablation was present and if it was concordant with electrophysiological localization [14,15]. Resection was performed using standard surgical technique [1] when lesions were large and not amenable to ablation (typically >2 cm), prior ablation failed, biopsy was required, or surgery near eloquent cortex was present.

Surgery for placement of intracranial electrodes was patient-specific. Intracranial EEG was utilized when a noninvasive evaluation was discordant, ambiguous, or more than 1 seizure onset zone were present. Intracranial EEG used 4–8, 4 cm stainless steel or platinum–iridium contacts embedded within a silastic subdural strip, grid (16–64 contacts) separated by 10 mm, and eight contact depths with stainless steel electrodes (Ad-Tech Medical Instrument Corporation, Racine, WI, USA) using a common approach [16]. The configuration, location of the electrodes, and duration of the recording were guided by the anticipated localization of the seizure-onset zone [17].

Implantation of neurostimulators was performed according to standard practice [9]. The RNS system was implanted if patients were not amenable to ablation/resection and 1–2 well-defined seizure foci were identified [10] guided by iEEG monitoring for electrode lateralization and localization [8]. The VNS (LivaNova (Cyberonics), Houston, TX) was implanted when prior procedures were undesirable or deemed unlikely to be successful [7].

2.3. Postoperative care

The time from the initial evaluation to the day of surgery, length of hospital stay, follow-up duration, outcome at the last visit (clinic or telephone contact), and the presence of any perioperative complications were noted. Follow-up evaluation was extended in SLA patients by telephone contact in August 2016 (mean 21.7 months, range 12–42 months). Reoperations were evaluated from the second surgery carried forward. Postoperative wound care, neurosurgical, and neurological evaluation were performed at 2 weeks, 3 months, and every 3–6 months thereafter. Neuropsychological testing at 1 year was routinely offered to patients who underwent surgery, however, patients with complaints are more willing to undergo the rigorous full day of testing, while improved patients are not.

2.4. Seizure outcome assessment

Seizure outcome was determined at the last follow-up contact with classification according to the Engel classification system [17]. A spontaneous unprovoked seizure recorded following surgery was included as a NSF outcome. Immediate perioperative seizures (<1 week) and patients with auras only were included in the SF outcome assessment when patients remained SF for the duration of the study period. Non-SF patients were stratified by Engel classification for resection/ablation. The preoperative seizure frequency was extrapolated from monthly seizure calendars for 3 months prior to surgery.

2.5. Statistical analysis

Because of the sample sizes, we used 95% confidence intervals (CI) of proportion for SF rates from SLA and resection. The categorical outcome for SF patients compared SLA with resection using Chi square analysis. The time intervals spent in the hospital following surgery, age at seizure onset, and age at procedure for SLA and resection were assessed with an unpaired Student *t*-test with a p-value $<0.05\%$ reaching clinical significance. The SF outcome was graphically displayed to the time of first seizure breakthrough according to a Kaplan–Meier curve generated over the 3 years of study for SLA and resection.

3. Results

3.1. Demographics

One hundred neurological surgeries that were performed on patients with drug-resistant focal epilepsy are summarized in Fig. 1. A trend analysis of all surgeries for epilepsy was performed over a 5-year period (Figs. 2 and 3).