FULL-LENGTH ORIGINAL RESEARCH

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Intracranial monitoring contributes to seizure freedom for temporal lobectomy patients with nonconcordant preoperative data

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Abstract

Objective: The question of whether a patient with presumed temporal lobe seizures should proceed directly to temporal lobectomy surgery versus undergo intracranial monitoring arises commonly. We evaluate the effect of intracranial monitoring on seizure outcome in a retrospective cohort of consecutive subjects who specifically underwent an anterior temporal lobectomy (ATL) for refractory temporal lobe epilepsy (TLE).

Methods: We performed a retrospective analysis of 85 patients with focal refractory TLE who underwent ATL following: (a) intracranial monitoring via craniotomy and subdural/depth electrodes (SDE/DE), (b) intracranial monitoring via stereotactic electroencephalography (sEEG), or (c) no intracranial monitoring (direct ATL—dATL). For each subject, the presurgical primary hypothesis for epileptogenic zone localization was characterized as unilateral TLE, unilateral TLE plus (TLE+), or TLE with bilateral/poor lateralization.

Results: At one-year and most recent follow-up, Engel Class I and combined I/II outcomes did not differ significantly between the groups. Outcomes were better in the dATL group compared to the intracranial monitoring groups for lesional cases but were similar in nonlesional cases. Those requiring intracranial monitoring for a hypothesis of TLE+had similar outcomes with either intracranial monitoring approach. sEEG was the only approach used in patients with bilateral or poorly lateralized TLE, resulting in 77.8% of patients seizure-free at last follow-up. Importantly, for 85% of patients undergoing SEEG, recommendation for ATL resulted from modifying the primary hypothesis based on iEEG data.

Significance: Our study highlights the value of intracranial monitoring in equalizing seizure outcomes in difficult-to-treat TLE patients undergoing ATL.

KEYWORDS

anterior temporal lobectomy, epilepsy surgery, stereotactic electroencephalography, subdural electrodes, temporal lobe epilepsy

1 | INTRODUCTION

Patients diagnosed with focal epilepsy refractory to antiepileptic medication comprise an estimated 30% of the adult epilepsy patient population.[1] Patients with this condition are at high risk of physical injury secondary to seizures,[2] sudden unexpected death (SUDEP),[3] and status epilepticus.[4,5] Although surgical treatment has been reliably shown to provide high odds for seizure control improvement,[6-8] surgery often is viewed as a "last resort" in the United States, after extensive antiepileptic medication trials.[9,10] The reasons for this are multiple and include procedural and preprocedural expertise.[11-14] Despite the difficulties in performing randomized control trials in this setting, it has been demonstrated that in temporal lobe epilepsy (TLE), surgery is superior to prolonged treatment with antiepileptic medication.[15-17]

The delineation of the epileptogenic zone and guidance of subsequent therapeutic surgery in patients with refractory focal epilepsy is greatly facilitated by diagnostic intracranial monitoring,[18] that is, invasive electrical recordings obtained via either subdural electrodes with or without depth electrodes (SDE/DE)[19] or stereotactic electroencephalography (sEEG).[20] sEEG is a minimally invasive approach that enables electrical recording from deep brain structures and sulci in a way that SDE/DE does not. The sEEG approach also enables bilateral studies[19,21] that are uncommon and challenging with SDE/DE and is often reported to take less surgical time and conferring a lower risk of surgical complications.[22,23] Conversely SDE/DE procedures, although they include craniotomy and cannot access deep brain structures or the inner sulcal parts of the cortex, are superior for assessing more lateral brain regions and cover a greater superficial cortical area.[24] Although each intracranial monitoring approach has its own advantages and disadvantages, ultimately the choice in an individual patient is driven by the hypothesis for the epileptogenic zone and lateralization.[25,26]

Whether a patient with presumed temporal lobe seizures, with concordant semiology, neuroimaging, and scalp EEG findings, should proceed directly to temporal lobectomy surgery versus undergo intracranial monitoring is a question that arises commonly during the surgical evaluation process in the United States. Previous studies have utilized intracranial monitoring in this group and reported higher seizure freedom rates with sEEG (64.7%-76.0%) compared to the SDE/DE (54.6%-55.9%).[22,27] However, these patient populations were comprised of diverse syndromes, complicating the assessment of the relative benefit of intracranial investigations in specific focal epilepsy syndromes. In this study, we evaluated the effect of intracranial monitoring on surgical outcome in a retrospective cohort of consecutive patients with refractory TLE, all of whom underwent an anterior temporal lobectomy (ATL). We investigated whether postsurgical seizure control was differentially associated with having undergone intracranial monitoring, or with the type of intracranial monitoring used.

Key point

- Intracranial monitoring in TLE resulted in noninferior outcomes compared to direct ATL.

- Outcomes in patients with a TLE+hypothesis were similar following either intracranial monitoring technique.

- Outcomes in patients with bilateral and/or poor lateralization, addressed uniquely with sEEG, were equivalent to outcomes in unilateral TLE treated by direct ATL.

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2 | METHODS

2.1 | Study design

An IRB-approved database of consecutive adult epilepsy surgeries completed between October 2011 and June 2019 was retrospectively queried for subjects who underwent ATL. Patient demographics, age at time of surgery, handedness, duration of epilepsy, type of implantation or procedure (sEEG, SDE/DE, or dATL), lateralization of temporal lobectomy, electroencephalogram (EEG) findings, imaging reports, multidisciplinary conference summaries, and Engel scale-classified postoperative outcomes, were obtained.

2.2 | Patients

From a pool of 253 patients who underwent diagnostic and/or resection surgery for epilepsy between November 2011 and June 2019 at the University of Pittsburgh Comprehensive Epilepsy Center, a total of 155 patients were diagnosed with TLE. Of these patients, 85 patients were surgically treated

by ATL, 37 were offered less invasive targeted treatments (laser ablation or closed-loop neurostimulation), and 20 did not proceed to further treatment. In the ATL-treated patient group selected for this study, 40/85 were females (47.1%), mean age at the time of evaluation was 47.9 ± 14.2 years, and mean duration of epilepsy was 20.8 ± 15.6 years. All ATL-treated patients underwent the standard presurgical evaluation phase that included long-term monitoring with video-EEG, epilepsy-specific structural MRI protocol (3T), and at least one other modality from a constellation of functional neuroimaging modalities: positron emission tomography (PET), ictal single photon emission computer tomography (SPECT), and magnetoelectroencephalography (MEG). All ATL-treated patients were categorized based on the epilepsy localization primary hypothesis determined during a multidisciplinary epilepsy patient management conference: unilateral TLE (uTLE), unilateral TLE plus (TLE+), and TLE with bilateral or poor lateralization (bTLE). Subsequently, the selected patients were implanted with either sEEG or SDE/DE or proceeded to dATL without intracranial monitoring. Written informed consent was obtained for data collection from all patients. The study was approved by the Institutional Review Board (IRB).

2.3 | Hypothesis formation

The hypothesis for surgical treatment was based on presurgical noninvasive data from three modalities: scalp EEG (ictal), imaging (structural and functional combined), and ictal semiology (for which only strong lateralizing features were considered: eg, unilateral hand dystonia as an isolated semiological sign or combined with contralateral automatisms, unilateral tonic and/or clinic signs, asymmetric ending of secondarily generalized seizures, postictal aphasia[28]). All patients had a diagnosis of TLE. Decision-making regarding the necessity of intracranial investigation, the implantation modality, and the brain areas covered by the electrodes was based on the epileptogenic zone hypothesis, weighting of data by the multidisciplinary team, and patient input.[29,30]

2.4 | Surgical techniques

Standard en bloc resection was used to perform ATLs.[31] A temporal craniotomy was performed exposing the Sylvian fissure. In dominant hemisphere ATLs, the overall posterior neocortical extent of resection did not exceed 4.5 cm from the pole, modified up to 2 cm from the pole on the superior temporal gyrus and up to 3 cm on the middle temporal gyrus. In nondominant hemisphere ATLs, the overall posterior neocortical extent of resection did not exceed 5.5 cm from the pole.

SDE/DE implantations were performed via a craniotomy.[32] A skull clamp was used to allow access to large areas of the head and a large C-shaped craniotomy flap was made with preservation of vascularity to the flap by protection of the superficial temporal artery. The strip and/or grid electrodes were slid underneath the craniotomy edges while irrigation fluid was injected over the brain surface. Typically, an 8 × 8 grid would be placed over the lateral brain surfaces, with at least four rows below the Sylvian fissure and the rest of them above. The grid was accompanied by three six-contact strips covering the subtemporal area from the level of the pole to the temporo-occipital region. Grids were trimmed in some cases to adapt to the cortical surface and avoid bridging veins. Neuro-navigation was employed in cases with concomitant placement of depth electrodes, typically involving one each in the amygdala and hippocampus.

The sEEG implantations were carried out using the Leksell stereotactic frame (Elekta AB, Stockholm, Sweden) or with robotic assistance (ROSA®, Zimmer-Biomet, Warsaw, IN).[33,34] Intracranial electrode implantation planning (electrode trajectories by definition of the cortical entry and the target points) was performed with iPlan® Stereotaxy (Brainlab AG, Munich, Germany) and ROSA® software, respectively, after fusion of preoperative T1 MR images with and without contrast agent. Typical temporal sEEG coverage included orthogonal trajectories targeting the pole, the amygdala, the head, and the tail of the hippocampus, and the posterior basal temporal area. Bilateral investigations were typically symmetric, implementing the same coverage. In cases where extratemporal involvement was suspected (TLE+), the plan was complemented by orthogonal electrodes targeting the insula through the superior temporal gyrus, the frontal and parietal operculum, and an orbitofrontal electrode entering through the anterior part of the inferior frontal gyrus.

2.5 | Surgical outcomes

Evaluation of postoperative seizure control was performed by retrospective review of electronic medical records. The documentation of quantitative (frequency and duration of seizures) and qualitative (severity of seizures) features was used to formulate outcome assessments. Postoperative seizure control assessments were in turn scored using the Engel outcome scale.

2.6 | Statistical analysis

Statistical tests included Pearson χ^2 test and ANOVA single-factor tests chosen to compare binary (categorical)

and continuous numerical outcomes, respectively, between surgical groups. In the case of contingency tables with expected counts in violation of Pearson χ^2 assumptions, the *P*-value was simulated using Monte-Carlo simulation with 100 000 replicates. All tests were two-sided, with an a priori level of significance set to .05 and performed using R 3.1.6 (R Foundation for Statistical Computing, Vienna, Austria) on Microsoft SQL Server 2012 R2 (Microsoft Corporation, Redmond, Washington, USA). Kaplan-Meier survival analysis was performed to determine the probability of seizure freedom (Engel Class I) among surgical approaches and surgical hypotheses.

3 | RESULTS

3.1 | Cohort

Out of the 85 patients of our cohort, 40 patients underwent intracranial monitoring before ATL, 23 of whom underwent sEEG. Other than the sEEG group having a significantly greater proportion of left-hand dominant cases (40.9% in the sEEG group, 5.6% in the SDE/DE group, and 0% in the dATL group; $P = <0.001$), the three surgical subgroups of our cohort were not significantly different in demographics (Appendix S1 and Table S1). No permanent adverse effects from ATL occurred in this patient cohort.

Patients in the uTLE hypothesis group (57/85) had concordant noninvasive data supporting a unilateral temporal SOZ from at least two modalities in all cases; an additional modality exhibited discordant nonlateralizing or discordant findings, in 77.2% and 12.3% of these patients, respectively. TLE+hypothesized patients (19/85) had data from at least one modality consistent with unilateral lateralization (100%), no findings indicating bilateral onset, and semiology that included prominent extratemporal features. 50% of these patients had concordant data from a second modality, and 15.8% had data from all modalities concordant. bTLE hypothesized patients (9/85) had data from at most one modality with unilateral findings (2 patients had none), and data from the remaining modalities that were either discordant, nonlocalizable, or bilateral.

Seizure outcomes were reviewed at one year postoperatively, or at the nearest appointment ≥1 year up to two years (15.11 ± 4.25 months). Additionally, all patients were evaluated at their most recent follow-up, with a mean duration of 37.8 ± 20.3 months postoperatively. All patients had a most recent follow-up at a time-point more than one year postoperative.

The Pearson χ^2 test and ANOVA single-factor tests achieved an effect size of 0.3 for all results given the a priori significance of 0.05 and power of 0.80.

3.2 | Seizure outcomes

At one year post-ATL, the total number of Engel Class I patients was 57 (67.0%) and the total number of combined Engel Class I/II patients was 71 (83.5%). At most recent follow-up, the total number of Engel Class I patients was 55 (64.7%) and the total number of combined Engel Class I/II patients was 68 (80.0%). At one year postoperatively, as well as at most recent follow-up, no statistical differences in the number of patients achieving Engel Class I or combined I/II outcome (Table 1) were observed between the three surgical groups. When considering the SDE/DE and sEEG groups together as an intracranial monitoring group compared to the dATL group, there also was no significant difference between groups, either at one year or at most recent follow-up (Table 1). Kaplan-Meier analysis of the probability of seizure freedom (Engel Class I) among the three surgical groups showed identical profiles for all surgical groups over the course of a 5-year interval (Figure 1A).

As the presence of an MRI lesion in the temporal lobe highly influences decision-making in TLE, we investigated its relation to outcomes across the three surgical groups. Overall, 48/85 cases involved an MRI-visible lesion, 28 of which were consistent with hippocampal sclerosis. The dATL group had a temporal MRI lesion in 73.3% of cases, compared to 56.5% in the sEEG group and 11.8% in the SDE/DE group ($P < .01$), as well MRI findings suggestive of hippocampal sclerosis in 80% of cases, compared to 60.9% in the sEEG group and 29.4% in the SDE/DE group ($P < .01$). In the subgroup of patients with a temporal lobe MRI lesion, both at one year follow-up and at most recent follow-up, there was no significant difference in Engel Class I or combined I/II outcomes between the surgical groups, even when considering sEEG and SDE/DE as a combined intracranial monitoring group (Table 1). Within the dATL group, the highest proportion of combined Engel Class I/II outcomes occurred in subjects with an MRI-visible lesion. No significant differences between the surgical groups were found for subjects without an MRI-visible lesion (Table 1). It is notable, however, that the proportion of patients with successful outcomes who underwent intracranial monitoring was as high as those whose data were concordant enough to undergo ATL directly. We also accounted for the presence or absence of an MRI lesion anywhere else in the brain and found no significant differences between groups (Table S2).

Finally, we investigated the effect of hypothesis-driven surgical decisions in this ATL cohort. All dATL cases were offered ATL based on a primary hypothesis of uTLE. In 47.1% of the SDE/DE cases, intracranial monitoring was offered based on a primary hypothesis of TLE+, with a uTLE hypothesis accounting for the remainder. Thus, in

TABLE 1 Engel Class outcomes at one year and at most recent follow-up for each surgically treated group and MRI lesion-related subgroups

Study group and subgroups	Study group (N = 85)				Subgroup with temporal MRI lesion (N = 48)				Subgroup without temporal MRI lesion (N = 37)			
Surgical group	sEEG (N = 23)	SDE/DE (N = 17)	dATL (N = 45)	P[b]	sEEG (N = 13)	SDE/DE (N = 2)	dATL (N = 33)	P	sEEG (N = 10)	SDE/DE (N = 15)	dATL (N = 12)	P
Outcomes[a] at 1 year postoperative (N, %, 95% confidence interval)[c]												
Engel Class I	14 60.9% (40.8-77.8)	12 70.6% (46.9-86.7)	31 68.9% (54.3-80.5)	.75	9 69.2% (42.4-87.3)	1 50.0% (9.5-90.5)	23 69.7% (52.7-82.6)	1.00	5 50.0% (23.7-76.3)	11 73.3% (48.0-89.1)	8 66.7% (39.1-86.2)	.57
	26 65.0%[d] (49.5-77.9)			.70	10 66.7% (41.7-84.8)			1.00	16 64% (44.5-79.8)			1.00
Engel Class I/II	17 73.9% (53.5-87.5)	15 88.2% (65.7-96.7)	39 86.7% (73.8-93.7)	.37	10 76.9% (49.7-91.8)	1 50.0% (9.5-90.5)	29 87.9% (72.7-95.2)	.29	7 70.0% (39.7-89.2)	14 93.3% (70.2-98.8)	10 83.3% (55.2-95.3)	.33
	32 80.0% (65.2-89.5)			.41	11 73.3% (48.0-89.1)			.21	21 84.0% (65.3-93.6)			1.00
Outcomes at most recent follow-up (N, %, 95% confidence interval)[e]												
Engel Class I	17 73.9% (53.5-87.5)	9 52.9% (31.0-73.8)	29 64.4% (49.8-76.8)	.39	10 76.9% (49.7-91.8)	0 0.0% (0.0-65.8)	21 63.6% (46.6-77.8)	.11	7 70.0% (39.7-89.2)	9 60.0% (35.7-80.2)	8 66.7% (39.1-86.2)	.91
	26 65.0% (49.5-77.9)			.96	10 66.7% (41.7-84.8)			.84	16 64% (44.5-79.8)			1.00
Engel Class I/II	18 78.3% (58.1-90.3)	13 76.5% (52.7-90.4)	37 82.2% (68.7-90.7)	.82	10 76.9% (49.7-91.8)	1 50.0% (9.5-90.5)	28 84.8% (69.1-93.3)	.51	8 80.0% (49.0-94.3)	12 80.0% (54.8-93.0)	9 75.0% (46.8-91.1)	1.00
	31 77.5% (62.5-87.7)			.59	11 73.3% (48.0-89.1)			.43	20 80.0% (60.9-91.1)			1.00

Abbreviation: dATL, direct anterior temporal lobectomy; sEEG, stereoelectroencephalography; SDE/DE, subdural electrodes/Depth electrodes.

[a]Measured using the Engel Epilepsy Surgery Outcome Scale.

[b]Calculated using Pearson χ^2 test. P <.05 indicates significance.

[c]Follow-up appointment at ≥1 year and <2 years.

[d]Intracranial investigation prior to ATL by sEEG or SDE/DE.

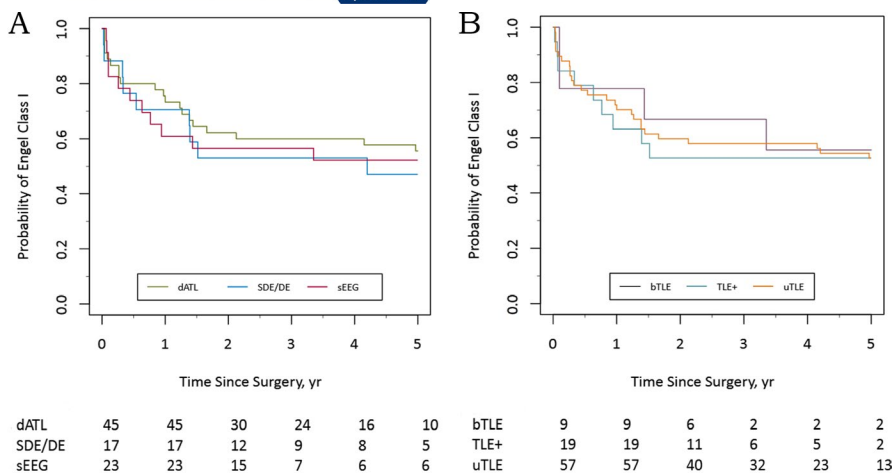[e]Most recent follow-up postoperatively at ≥2 years.

FIGURE 1 Kaplan-Meier survival analysis charts. A, Evaluation of the probability of seizure freedom (Engel Class I) for all three surgical groups of our study (sEEG, SDE/DE and dATL). B, Evaluation of the probability of seizure freedom for the three TLE hypothesis groups (uTLE, TLE+, and bTLE)

dATL	45	45	30	24	16	10
SDE/DE	17	17	12	9	8	5
sEEG	23	23	15	7	6	6

bTLE	9	9	6	2	2	2
TLE+	19	19	11	6	5	2
uTLE	57	57	40	32	23	13

nearly half of patients undergoing SDE/DE, recommendation for ATL resulted from modifying the primary hypothesis based on intracranial EEG (iEEG) data. Only 13.0% of the sEEG group had a uTLE hypothesis; 47.8% had a TLE+hypothesis and 39.1% had a bTLE hypothesis. Thus, in over 85% of patients undergoing SEEG, recommendation for ATL resulted from modifying the primary hypothesis based on iEEG data. There was no significant difference in outcomes between surgical groups treated for uTLE, at one year follow-up or at most recent follow-up (Table 2), although uTLE patients treated by dATL demonstrated higher percentages with Engel Class I/II outcome at most recent follow-up. There was also no significant difference between the two surgical groups (sEEG and SDE/DE) that were investigated for TLE+, although the SDE/DE group had higher percentages with combined Engel Class I/II outcome at both follow-up time-points (Table 2). sEEG was the only surgical technique used to address TLE patients with poorly lateralized or bilateral noninvasive data, and patients achieved high levels of seizure control both at one year and most recent follow-up that were overall comparable to the rest of the surgical groups for uTLE and TLE+ (even trending higher at most recent follow-up; Table 2). A Kaplan-Meier analysis evaluating the probability of seizure freedom (Engel Class I) among the three hypothesis-driven groups demonstrated equivalent profiles over the course of a five-year interval (Figure 1B). Of note, multivariate logistic regression for up to three variables, as well as univariate analyses of all individual variables, yielded no significant results.

4 | DISCUSSION

The benefit of performing intracranial monitoring in the context of epilepsy surgery has been demonstrated previously, in series of patients whose ultimate therapeutic surgical treatments varied significantly with regard to type and approach.[22,27] These surgically treated patient cohorts were not controlled for factors that highly impact the surgical outcome, such as the localization of any resection and its extent. On the other hand, ATL is a well-established procedure with specific standardized anatomical boundaries.[31,35] ATL is established as the gold-standard treatment for drug-refractory TLE patients, where it has been shown to provide seizure freedom in approximately two-thirds of patients at one year and nearly half at 10 years.[15,36] Therefore, our rationale in using a cohort that underwent the same surgical treatment was to address the validity of prior intracranial investigations without introducing confounds related to the type of temporal lobe surgery or anatomical extent of the resection. In this study, we evaluated the benefit of intracranial sEEG and SDE/DE investigations in achieving seizure control specifically in patients who ultimately underwent ATL, standardized by a single neurosurgeon's surgical approach.[31]

Overall, the results of our retrospective study suggest that sEEG and SDE/DE implantation in refractory TLE epilepsy cases results in outcomes that are not inferior to those in patients whose presurgical data were concordant enough to allow ATL without prior intracranial investigation. These outcomes appear at least as favorable as those reported in a major prospective cohort study.[15] Kaplan-Meier analysis demonstrated no major differences among the sEEG and SDE/DE surgical groups regarding the probability of maintaining their post-ATL level of seizure control. These findings suggest that previous results regarding the superiority of sEEG over SDE/DE may be driven by the data from extratemporal cases.[22,27,37,38] To the best of our knowledge, our study is the first to investigate the efficiency of intracranial monitoring approaches in a focused and uniform manner, in terms of patient population (TLE) and surgical treatment (ATL).

Furthermore, our retrospective study confirms the nonsignificant effect of the presence of MRI-appreciable lesions on surgical outcomes across all surgical groups.[39] Although completeness of resection is the most predictive factor for

TABLE 2 Hypothesis-based Engel Class outcomes at one year and at most recent follow-up for each surgically treated group

Hypothesis-driven subgroups	Unilateral TLE (N = 57)				TLE+ (N = 19)				Bilateral or poorly lateralized TLE (N = 9)			
Surgical group	sEEG (N = 3)	SDE/DE (N = 9)	dATL (N = 45)	P	sEEG (N = 11)	SDE/DE (N = 8)	dATL (N = 0)	P	sEEG (N = 9)	SDE/DE (N = 0)	dATL (N = 0)	P
Outcomes at 1 year postoperative (N, %, 95% confidence interval)												
Engel Class I	2	5	31	1.00	6	6	–	.63	6	–	–	–
	66.7%	55.6%	68.9%		54.5%	75.0%			66.7%			
	(20.8-93.9)	(26.7-81.1)	(54.3-80.5)		(28.0-78.8)	(40.9-92.9)			(35.4-87.9)			
Engel Class I/II	2	8	39	.76	8	7	–	.60	7	–	–	–
	66.7%	88.9%	86.7%		72.7%	87.5%			77.8%			
	(20.8-93.9)	(56.5-98.0)	(73.8-93.7)		(43.4-90.3)	(52.9-97.8)			(45.3-93.7)			
Outcomes at most recent follow-up (N, %, 95% confidence interval)												
Engel Class I	2	5	29	.87	8	4	–	.38	7	–	–	–
	66.7%	55.6%	64.6%		72.7%	50.0%			77.8%			
	(20.8-93.9)	(26.7-81.1)	(49.8-76.8)		(43.4-90.3)	(21.5-78.5)			(45.3-93.7)			
Engel Class I/II	2	6	37	.58	8	7	–	.60	8	–	–	–
	66.7%	66.7%	82.2%		72.7%	87.5%			88.9%			
	(20.8-93.9)	(35.4-87.9)	(68.7-90.7)		(43.4-90.3)	(52.9-97.8)			(56.5-98.0)			

Note: Abbreviations as in Table 1.

postoperative seizure freedom,[40-42] MRI findings can sometimes be misleading when considered as markers of epileptogenic zone localization for resection, particularly in the face of discordant electro-clinical data that can lead to hypothesis bias and inferior outcomes.[43,44] For example, selective amygdalohippocampectomy with MRI-appreciable sclerosis has been shown to result in inferior postsurgical seizure control contrary to expectations based on the imaging finding.[45] When the SDE/DE approach is considered, clear discrimination between epileptogenic, irritative, symptomatogenic, functional deficit, and epileptogenic lesion zones must be performed to determine electrode coverage.[46] When a sEEG approach is considered, MRI-appreciable lesions should be incorporated in the anatomo-electro-clinical hypothesis as an integral part.[47] Nevertheless, the presence of an MRI lesion alone has not been shown to predict a favorable outcome.[42]

Importantly, this retrospective study relates that the benefit of each surgical technique to the presurgical hypothesis. We showed that patients whose presurgical data converge to uTLE can be treated in a satisfactory manner by all surgical approaches. With two concordant modalities, dATL can be immediately considered, which spares a costly and lengthy intracranial intervention.[48] Our data also suggest that patients with a TLE+hypothesis can be assessed equally by either intracranial monitoring technique, which allows TLE+patients to reach posttreatment outcomes comparable to those of the more straight-forward group of uTLE patients treated by dATL. In addition, and in agreement with the notion of sEEG being most beneficial in complicated cases,[22,49] our study highlights the unique ability of sEEG to address cases with bilateral and/or poor lateralization evidence and contribute to postsurgical seizure control outcomes equivalent to that of the uTLE/dATL group. In the absence of sEEG, these patients may not have been offered surgical treatment, or may have been subjected to a therapy with a higher risk of failure.[50] There is increasing use of sEEG in the United States,[51,52] and these results suggest that using sEEG increases the probabilities of achieving optimal seizure control, in cases in which temporal lobe involvement is suspected but there are no data sufficiently concordant to generate a uTLE hypothesis.

In summary, we evaluated the effect of intracranial monitoring on postsurgical seizure control outcomes in a retrospective cohort of consecutive patients with refractory TLE that underwent ATL. The retrospective nature of our study is an objective limitation, partially counterbalanced by restricting the analysis to subjects receiving one uniform treatment in a large cohort. Our data highlight the value of intracranial monitoring in equalizing the surgical outcomes in these patients, across the range of complexity in generating a presurgical hypothesis for the seizure onset zone.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.