Value of Quantitative Intraoperative Electrocorticography During Anterior Temporal Lobectomy in Temporal Lobe Epilepsy Patients

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KEYWORDS

Electrocorticography (ECoG); pre-resection spike frequency; anterior temporal lobectomy (ATL); temporal lobe epilepsy

ABSTRACT

Introduction: There is debate on the predictive usefulness of electrocorticography (ECoG) during anterior temporal lobectomy (ATL) in temporal lobe epilepsy (TLE) patients. The purpose of this study was to determine the usefulness of quantitative intraoperative ECoG monitoring for postoperative seizure outcomes after ATL in TLE patients.

Methods: The study enrolled thirteen TLE patients who underwent ECoG-assisted ATL. Pre- and post-resection ECoG spike frequency (/min) and spike amplitude (µv/mm) were analyzed with histopathological and preoperative video-electroencephalography (EEG) data. After one year of follow-up, patients were classified as seizure-free (Engel Class I) or with residual seizure outcomes using the Engel Seizure Outcome Classification Scheme.

Results: The pre-resection and post-resection ECoG showed significant differences in spike frequency (/min) and amplitude (µv/mm) (P-value < 0.001). Patients with residual seizures (15.4%) showed significantly greater pre- and post-resection ECoG spike frequency and amplitude, as well as significantly higher seizure frequency before surgery, compared to patients with postoperative seizure freedom (84.6%). The pre-resection ECoG spike frequency was significantly greater in TLE patients with histopathology focal cortical dysplasia (FCD) than in those with non-FCD. The post-resection ECoG revealed a sensitivity of 100%, a specificity of 50%, a negative predictive value of 100%, and a positive predictive value of 91.67%.

Conclusions: Pre-resection ECoG spike frequency and amplitude can be used as a predictive tool for postoperative seizure outcomes, particularly when video-EEG can't identify the epileptogenic zone (EZ) in TLE patients undergoing ATL.

1. Introduction

Epilepsy is a chronic neurological disease characterized by recurrent seizures caused by abnormal electrical discharges in the brain. About 80 percent of patients with epilepsy live in the developing world. Patients with epilepsy have a low quality of life and are at risk of sudden death. It accounts for 0.5% of all disability-adjusted life years worldwide [1].

Temporal lobe epilepsy (TLE) is the most frequent type of epilepsy. It is usually associated with language impairment and memory decline. With 70% of cases being mesial TLE, it is the most frequent subtype of TLE [2]. Focal cortical dysplasia (FCD), hippocampal sclerosis (HS), gliosis, and dysembryoplastic neuroepithelial tumor (DNET) are the most prevalent underlying causative abnormalities [3].

About a third of TLE patients have seizures that are resistant to antiepileptic drugs (AEDs); currently, resection surgery has been established as an effective treatment for seizures. After resection surgery, approximately 40–90% of TLE patients were seizure-free [4]. Early epilepsy surgery offers the highest chance of achieving postoperative seizure freedom, eliminating unfavorable social and psychological outcomes and early mortality [5].

An anterior temporal lobectomy (ATL) with or without amygdalohippocampectomy is the surgical procedure recommended for drug-resistant TLE patients. Surgical, neurological, and neurocognitive complications may arise after TLE resection surgery. Consequently, to achieve a better postoperative outcome, epilepsy surgery should control seizures and reduce neurological impairment [6].

The effectiveness of resection surgery is dependent on the mapping of the epileptogenic zone (EZ), which is the minimal cortical area that must be completely resected without creating a new neurological deficit to achieve successful seizure management. This is achieved through intraoperative electrocorticography (ECoG). The EZ is identified via ECoG as interictal epileptiform discharges (IEDs) generated from a certain brain area. It frequently extends beyond the magnetic resonance imaging (MRI) lesion [7].

Many EEG abnormalities, including epilepsy, can be missed during routine EEG recordings. So, scalp video-EEG monitoring has an important role in the lateralization and localization of seizures, as well as assessing concordance between EZ and neuroimaging findings before epilepsy surgery [8].

A previous study reported that the standard EEG in patients with TLE was unable to predict the probability of seizure recurrence [9]. The area of interictal spiking, also known as the irritative zone, is often larger than the seizure onset zone (SOZ) [10].

Intraoperative ECoG plays a vital role in determining the borders of the planned resected EZ area during TLE surgery. Continuous intraoperative ECoG monitoring is used to map out areas of the eloquent cortex and define the EZ [11]. Insufficient data exists to determine the overall efficiency of the intraoperative ECoG, despite its frequent use during epilepsy surgery [12].

The observed interictal spikes in ECoG are the primary determinant for identifying the resection area. The prognostic value of post-resection ECoG residual IEDs is controversial [13]. Previous studies reported no correlation between post-resection ECoG residual discharges and postoperative seizure outcome [12], [14]. In contrast, Tripathi *et al.* [10] reported a correlation between post-resection ECoG findings and a good postoperative seizure outcome. Due to this controversy, this study evaluated the impact of quantitative intraoperative ECoG on postoperative seizure outcomes in TLE patients after ATL.

2. Methodology

A prospective interventional study included thirteen drug-resistant TLE patients undergoing ECoG-guided ATL between September 2021 and December 2023. Patients with failed ECoG recordings due to technical causes were excluded from the analysis.

Preoperative assessment included clinical history, MRI brain epilepsy protocol [15]., video-EEG, and neurocognitive assessment. Clinical history included age, gender, age of onset of epilepsy, duration of epilepsy, seizure frequency per week, and number of antiepileptic drugs. An Arabic neurocognitive assessment battery was used to test patients with epilepsy preoperatively by a neuropsychologist who was blind to the aim of the study [16]**.**

Preoperative Video-EEG

The non-invasive video-EEG recording was done in all patients during wakefulness and sleep in the period range of 4 hours to 24 hours using the international 10-20 system for placement of EEG electrodes with additional electrodes at T1/T2 positions as well as for ECG recording. Hyperventilation and intermittent photic stimulation were performed as provocative techniques. Video-EEG was evaluated by a neurophysiologist who was blind to the aim of the study. Video-EEG was used to localize and lateralize IEDs if present and localize and lateralize seizure onset during ictal recording [17].

Surgical Procedure

The same neurosurgeon performed all the operations based on the concordance of video-EEG recording, MRI data, and neurocognitive assessment. ATL was used as the surgical procedure, which included or did not include resection of mesial structures based on intraoperative ECoG findings [18]. All patients and their relatives were counseled about the importance of intraoperative ECoG recording, and written informed consent was obtained. Anesthesia protocol

The patients were operated on under general anesthesia induced with propofol (2-4 mg/kg), dexmedetomidine (Precedex) (1 µg/kg over 20 minutes), and fentanyl (1 µg/kg). Propofol (4–12 mg/kg/hour) and dexmedetomidine (0.2–0.7 µg/kg/hour) were used in the maintenance phase. At the time of intraoperative ECoG recording, the anesthesia was lightened by stopping the propofol infusion at least 20 minutes before recording and continuing dexmedetomidine (0.2 mg/kg/min). Fentanyl (1 µg/kg) was given to provoke IEDs [19]. Intraoperative scalp EEG monitoring

The data was recorded during the surgery using the Intraoperative Neurophysiological Monitoring (IONM) Portable System (Medtronic NIM-Eclipse E4, U.S.A.). Bipolar and referential montages were used, with at least three electrodes placed symmetrically on each side of the head: one frontal, one centroparietal, and one temporal. To ensure that the anesthesia was lightened before ECoG recording, power spectrum density was measured through scalp EEG electrodes [20], [21].

Intraoperative ECoG Recording

ECoG recording was done using six contact strip electrodes that were applied directly to the cortical surface by a neurosurgeon for 5–10 minutes. The placement of strip electrodes was selected individually for each patient, based on video-EEG and MRI findings. Electrodes were sequentially repositioned over the EZ as needed [22].

ECoG monitoring was recorded in three stages; pre-resection ECoG, after resection of the lateral temporal lobe (mesial ECoG), and post-resection. After excision of the epileptogenic tissue, the strip electrode was placed on the resection margins and subsequently along the longitudinal surface of the hippocampus. Post-resection of mesial structures, the recording strip electrode was placed on the resection bed at three sites to look for any additional epileptogenic focus. In cases of persistent abnormalities, the tissue underneath the recording electrodes was resected, and the ECoG recording was repeated on the resection bed until the ECoG recording became normal [23]. All recordings were recorded and interpreted by the same surgical neurophysiologist.

For data acquisition, the IONM Portable System (Medtronic NIM-Eclipse E4, U.S.A.) was used. Filters were set at 1–70 Hz. Recordings were performed using both referential and bipolar montages. Electrode impedances were less than 5000 Ω and relatively equal or balanced (i.e., the inter-electrode differences did not exceed 2,000 Ω). The reference electrode was placed over the contralateral mastoid [24]**.**

Quantitative ECoG recording parameters

They included spike frequency (/min), spike amplitude (µv/mm), and ECoG patterns. Pre-resection ECoG recordings of epileptiform discharges were classified according to the morphology of the discharges into the following four patterns: 1. ECoG pattern type I: intermittent isolated spikes or sharp waves followed by focal slowing, 2. ECoG pattern type II: High-frequency spikes were defined as trains of high-frequency spikes that exceed 30 Hz. 3. ECoG pattern type III: Continuous epileptiform discharges were defined as periodic discharges lasting longer than 10 seconds. 4. ECoG pattern type IV: Combination of isolated spike discharges and high-frequency spikes in the same ECoG recording. The pre-resection ECoG recording of epileptiform discharges was subsequently divided into the following categories based on the dominating topography (predominance of more than 70%): lateral temporal, medial temporal (mesial), or both lateral and mesial [7], [25].

Postoperative Seizure Outcome

It was assessed one year after surgery and classified into seizure-free outcome (Engel Class 1) and non-favorable residual seizure outcome (Engel Class II) according to the Engel Seizure Outcome Classification Scheme [7], [22]**.** Patients were categorized into FCD and non-FCD (gliosis and DNET) according to the histopathology of the resected tissues [7], [26]**.**

Statistical analysis

The data were analyzed with SPSS statistical software version 27. The Student t-test, or Mann-Whitney U test, was used to compare continuous variables, which were given as mean and standard deviation (SD). Fisher's exact test was used to compare categorical variables that were given as frequency and percentage. A significant difference was defined as a P-value < 0.05.

3. Results and Discussion

Socio-demographic characteristics and clinical profile

Thirteen patients (10 females and 3 males) underwent ATL (9 left, 4 right) guided by intraoperative ECoG monitoring. Socio-demographic characteristics are summarized in **Table 1.** At the time of TLE surgery, patients were aged from 5 to 30 years old (mean ± SD: 14.69 ± 9.013 years old). All patients had a positive MRI temporal lobe lesion. 84.6 per cent of subjects were identified as having mesial TLE through MRI hippocampus sclerosis, and 15.4% of patients had lateral TLE. The most affected cognitive domain was memory. Forty percent had abnormal episodic verbal memory and visual memory.

The histopathological characteristics of the studied patients were: 9 patients exhibited FCD, 2 patients exhibited DNET, and 2 patients exhibited gliosis. Eleven patients (84.6%) had no post-resection ECoG residual discharge and were seizure-free (Engel Class I) with tapered doses of AEDs after one year of follow-up, while two patients (15.4%) had a non-favorable postoperative seizure outcome (Engel Class II).

The relation between preoperative clinical profile and postoperative seizure outcome

Patients with residual seizure had a significantly higher seizure frequency/week than patients with postoperative favorable outcomes **(mean±SD: 15.5±7.778, 6.36± 4.675; respectively; p-value < 0.05, Table 1).** All patients who had postoperative non-favorable outcomes had MRI hippocampus sclerosis, and histopathology revealed FCD.

Table 1 Socio-demographic characteristics of studied subjects (n = 13 subjects)

Characteristics	All patients n = 13	Seizure-free n = 11	Residual seizure n = 2	P value
Age (years old)	14.69 ± 9.01	16.18 ± 9.031	6.5 ± 0.707	0.172
Age onset of seizure (years old)	6.69 ± 6.81	7.45 ± 7.174	2.5 ± 0.707	0.367
Duration of epilepsy (years)	8 ± 5.66	8.73 ± 5.867	4 ± 1.414	0.296
Seizure frequency/week	7.77 ± 5.92	6.36± 4.675	15.5 ± 7.778	**0.038***
Number of AEDs	3.23 ± 0.44	3.18 ± 0.405	3.5 ± 0.707	0.368

Student t-test, Mann-Whitney U test, *: Significant.

ECoG pattern

The most common recorded pre-resection ECoG pattern and mesial ECoG pattern was ECoG pattern type I (intermittent isolated spikes or sharp waves followed by focal slowing) (**Fig. 1**). Regarding the topographic distribution of pre-resection ECoG recordings of epileptiform discharges, eleven patients (84.6%) had lateral temporal and mesial discharges, and two patients (15.4%) had mesial ECoG discharges. All patients with postoperative non-favorable outcomes had lateral temporal and mesial discharges.

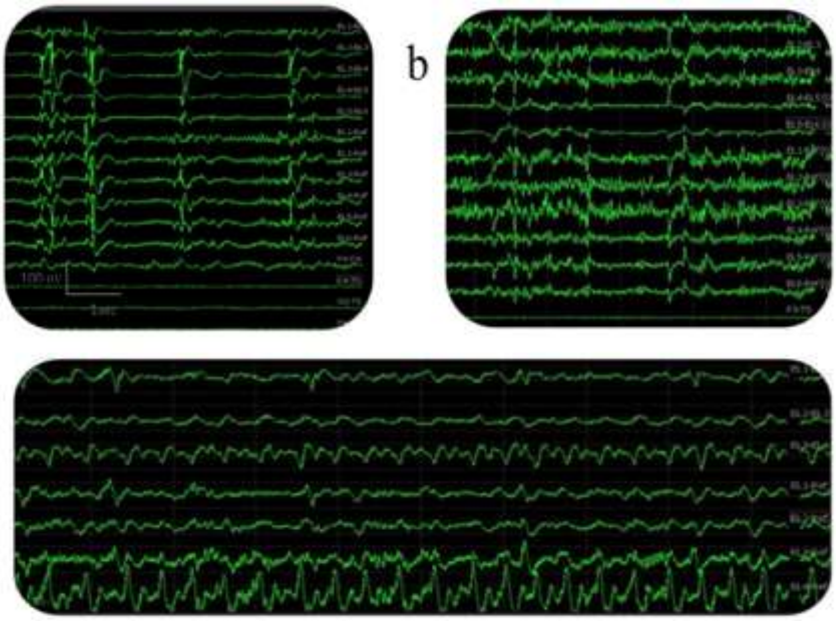

Fig. 1 Pre-resection ECoG patterns: (a) ECoG pattern type I (intermittent isolated spikes followed by focal slowing), (b) ECoG pattern type II (high-frequency spikes), and (c) ECoG pattern type III (continuous epileptiform discharges).

Quantification analysis of the pre-resection and post-resection ECoG and postoperative seizure outcomes

Pre-resection and post-resection ECoG spike frequency (/min) and spike amplitude (µv/mm) were significantly higher in patients with residual seizure than in patients with postoperative favorable seizure outcome (seizure-free) (p-value <0.05, **Table 2).** The surgical resection of the lateral temporal lobe and hippocampus caused a significant decrease in the pre-resection spikes **(Fig. 2)**. There was a highly significant difference between pre-resection and post-resection ECoG spike frequency (/min) (*P-value < 0.001*, **Table 3**).

Table 2 Quantification of ECoG data based on postoperative seizure outcomes

characteristics	**all patients N = 13**	**seizure-free N = 11**	**residual seizure N = 2**	**P value**
Pre-resection				
Pre-resection ECoG spike frequency (/min)	47.69 ± 7.476	45.55± 5.837	59.5 ± 0.707	**0.008***
Pre-resection ECoG spike amplitude (µv/mm)	377.38 ± 52.4	360.91± 36.774	468 ± 4.243	**0.002***
Mesial recording				
Mesial ECoG spike frequency (/min)	27.62± 5.95	26.45 ± 5.067	34 ± 8.485	0.1
Mesial ECoG spike amplitude (µv/mm)	124.54± 8.05	122.27 ± 6.405	137 ± .0	**0.009***
Post-resection				
Post-resection ECoG spike frequency (/min)	3.54 ± 5.14	2.18 ± 1.537	11 ± 12.728	**0.018***

Post-resection ECoG spike amplitude (µv/mm)	61.62 ± 38.63	55.36 ± 38.211	96 ± 22.627	0.182

Student t-test, Mann-Whitney U test, *: Significant

Table 3 ECoG spike frequency in relation to interictal and ictal video-EEG recording

	Pre-resection ECoG spike frequency (/min)	**P value**	**Post-resection ECoG spike frequency (/min)**	**P value**
ECoG in all patients (n = 13)				
	47.69 ± 7.476		3.54 ± 5.14	**< 0.001***
Interictal video-EEG epileptiform discharge recording				
Yes (N = 7)	49.57 ± 8.423	0.35	4.68 ± 6.793	0.339
No (N = 6)	45.5 ± 6.189		2 ± 1.673	
Ictal video-EEG recording				
Yes (N = 10)	47.8 ± 8.404	0.929	4.1 ± 5.763	0.496
No (N = 3)	47.33 ± 4.163		1.67 ± 1.528	

Paired t-test; Student t-test, Mann-Whitney U test, *: Significant.

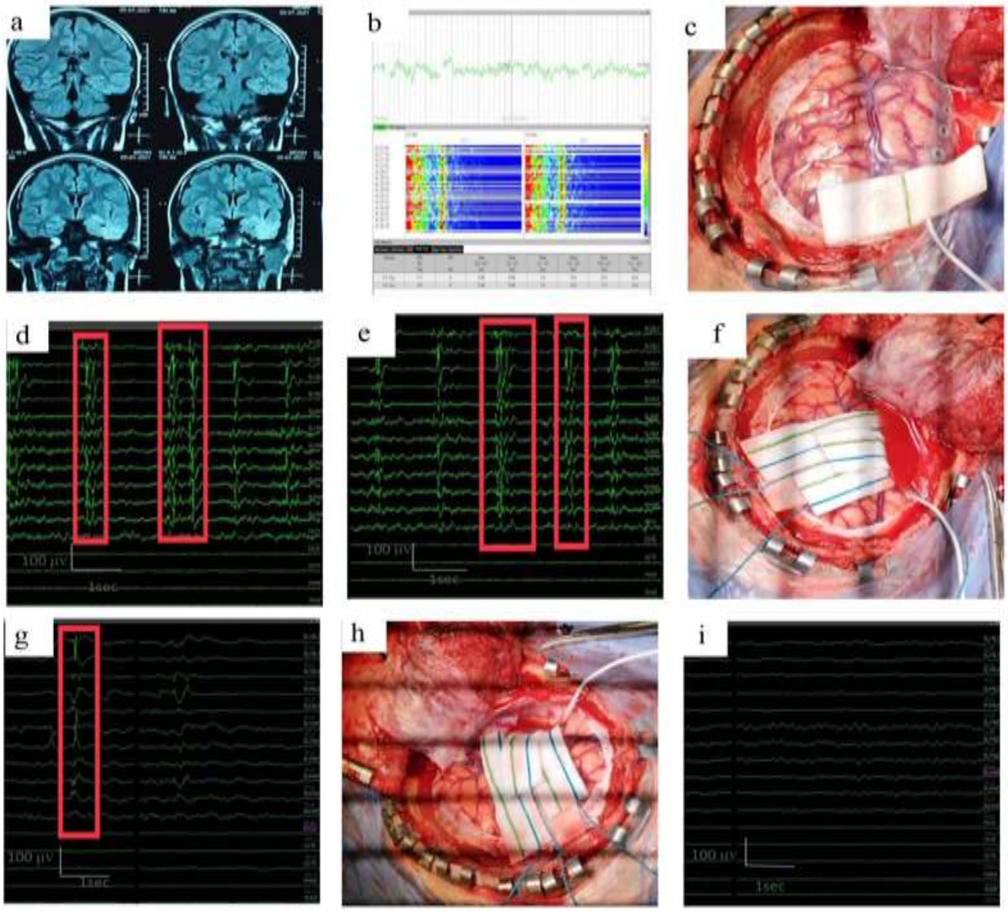

Fig. 2: Intraoperative ECoG during TLE surgery in a 13-year-old female patient with drug-resistant focal to bilateral tonic-clonic seizures with an age of onset of 5 years. Video-EEG showed bilateral temporal spike slow wave epileptogenic activity with left side predominance. a: MRI showed left temporal cortical dysplasia; b: power spectrum density via scalp EEG electrodes showed the start of awareness; C: recording six contact strip electrodes over the temporal lobe; d&e: pre-resection ECoG recording showed spike slow wave epileptogenic activity in the six electrodes; f: the recording strip electrode was placed after resection of the MRI lesion; g: ECoG recording after resection of the MRI lesion showed epileptogenic activity, so the neurosurgeon further resected the mesial structures; h&i: post-resection ECoG recording showed no epileptogenic activity.

ECoG spike frequency in relation to video-EEG recording

Intraoperative ECoG recordings were concordant with video EEG in 9 patients (69.2%). Video-EEG recordings were able to record the ictal event in 10 patients (76.9%). Interictal recordings from 7 patients (53.8%) revealed epileptiform discharge, whereas intraoperative ECoG revealed epileptic discharges in all studied subjects with concordant clinical semiology and MRI. There was no significant difference in pre-resection ECoG spike frequency between patients who could record video-EEG epileptiform discharge and those who couldn't (Table 3).

Correlation between ECoG characteristics and preoperative seizure frequency/week and **MRI HS**

There was a positive correlation with statistical significance ($P\ value < 0.05$) between pre-resection ECoG spike frequency and preoperative seizure frequency/week (Fig. 3a). The pre-resection ECoG spike frequency was greater in patients with MRI HS without significant correlation ($P\ value = 0.306$) (Fig. 3b).

ECoG characteristics according to different histopathology

TLE patients with histopathology FCD exhibited a greater pre-resection ECoG spike frequency than those with histopathology non-FCD (Gliosis and DNET), with a significant association (*P value = 0.009*) **(Fig. 3c).** There was no significant association between different histopathologies regarding pre-resection ECoG spike amplitude, pre-resection ECoG patterns, and post-resection ECoG residual epileptic discharge **(Table 4).**

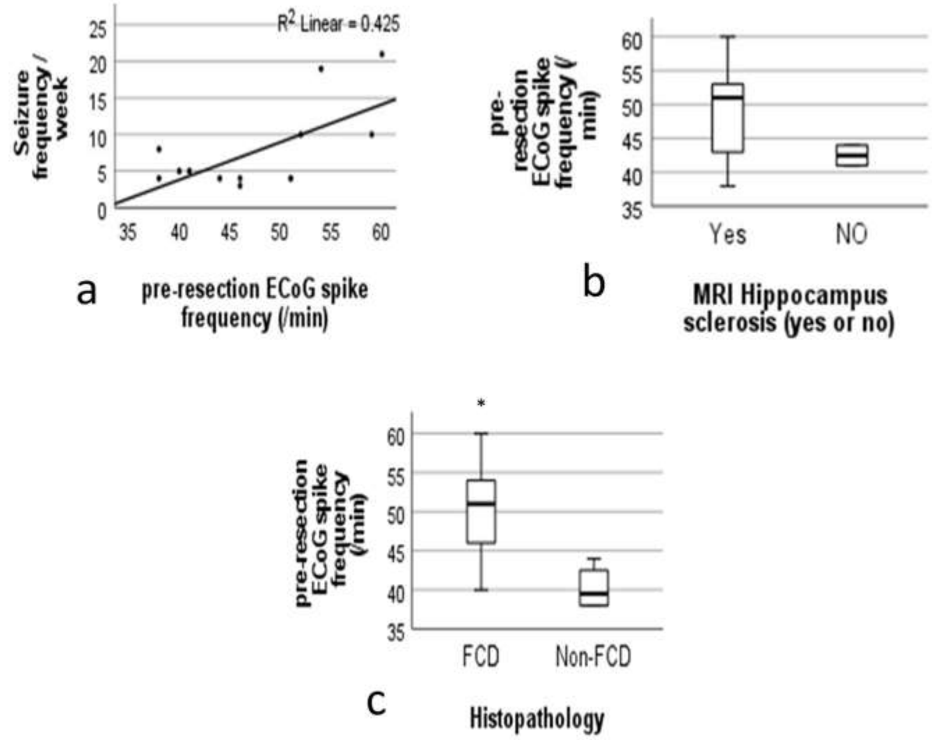

Fig. 3 a: The relation between pre-resection ECoG spike frequency and seizure frequency per week. N = 13, Pearson correlation r = 0.652, P value = 0.016; b: pre-resection ECoG spike frequency (min) in patients with MRI hippocampus sclerosis (HS) and those without HS; c: pre-resection ECoG spike frequency (/min) in temporal lobe epilepsy patients with FCD and those with histopathology other than FCD. FCD: focal cortical dysplasia; non-FCD includes gliosis and dysembryoplastic neuroepithelial tumor (DNET). *p is significant at <0.05.

Predictive value of post-resection ECoG residual epileptic discharge for postoperative seizure outcome

The negative predictive value of post-resection ECoG was 100%. The positive predictive value of post-resection ECoG was 91.67%. The specificity of post-resection ECoG was 50%, and the sensitivity was 100% **(Table 5)**.

Table 4 ECoG characteristics according to different histopathology

characteristics (n = 13)		**All patients n = 13 n (%)**	**FCD n = 9 n (%)**	**Non-FCD n = 4 n (%)**	**P value**
Pre-resection ECoG pattern	ECoG type I, n (%)	6 (46.1)	5 (55.6)	1(25)	0.091
	ECoG type II, n (%)	2 (15.4)	1 (11.1)	1 (25)	
	ECoG type III, n (%)	2 (15.4)	0	2 (50)	
	ECoG type IV, n (%)	3 (23.1)	3 (33.3)	0	

Post-resection ECoG residual epileptic discharge	No, n (%)	12 (92.3)	8 (88.9)	4 (100)	>0.999
	Yes, n (%)	1(7.7)	1 (11.1)	0	

Fisher Exact test, * p is significant at <0.05.

Table 5 Predictive value of post-resection ECoG for postoperative seizure outcome

characteristics (n = 13)		**seizure-free**	**residual seizure**	**P value**
Post-resection ECoG residual epileptic discharge	No, n (%)	11 (84.3)	1 (7.7)	0.154
	Yes, n (%)	0	1 (7.7)	

Fisher Exact test, *p is significant at <0.05.

Discussion

The current study tested the clinical importance of performing intraoperative ECoG during ATL in thirteen drug-resistant TLE patients. The accuracy of intraoperative ECoG in predicting postoperative seizure outcomes and its ability to determine postoperative prognosis were assessed in this study.

The main findings of the current study are that patients classified as having residual seizures (Engel Class II) exhibited a significantly greater pre-resection ECoG spike frequency and amplitude, and a significantly greater frequency of seizures before surgery, in comparison to patients classified as having no seizures after surgery (Engel Class 1). Our results also showed that intermittent isolated spikes or sharp waves followed by localized slowing were the most common pre-resection ECoG pattern for determining the resection area.

Peng *et al.* [7] showed similar outcomes in children with epilepsy. **Yang, Hakimian, and Schwartz** [27] showed that epileptiform spikes are the most frequent intraoperative ECoG indicators for identifying EZ. On the contrary of our results, **Chen *et al.*** [28] found that pre-resection ECoG spike frequency was not associated with postoperative seizure outcome in a study of 22 epilepsy patients with unilateral HS undergoing selective amygdalohippocampectomy. In comparison to selective amygdalohippocampectomy, the ATL was linked with a better chance of being seizure-free. However, minimal surgical methods remain to be explored to preserve neurofunction and improve quality of life [29].

Our data revealed that 84.6% of patients were seizure-free (Engel Class I) with tapering AED doses after one year of follow-up. According to several studies conducted over the past 20 years, 53 to 84% of mesial temporal lobe sclerosis patients achieve seizure freedom for at least one year after ATL [12], [28], [30]. The causes behind non-favorable outcomes following epilepsy surgery can be partial excision of the EZ, insufficient disruption of the pathogenic connection in an epileptogenic network, or dual pathology [12].

There is a debate concerning the prognostic utility of the ECoG during epilepsy surgery in TLE patients. Our findings demonstrated a significant difference in pre- and post-resection ECoG spike frequency and amplitude. All patients who were seizure-free after surgery had no post-resection ECoG residual epileptic discharge.

These results were consistent with **Grewal *et al.*** [31] findings, which showed that using intraoperative ECoG reduced the likelihood of seizure recurrence in drug-resistant MRI-negative TLE patients undergoing ATL. Contrary to the prior findings, **Goel *et al.*** [12] findings revealed no statistically significant difference in postoperative seizure freedom between surgery groups guided by ECoG and those not guided by ECoG, independent of pathology [12].

We also reported that the pre-resection ECoG spike frequency was significantly greater in TLE patients with histopathology-based FCD than in those with non-FCD (gliosis and DNET). These findings were consistent with the findings of **Goel *et al.*** [12]**,** which demonstrated that the use of ECoG in patients with FCD is highly associated with better seizure outcomes. **Peng *et al.*** [7] reported that the pre-resection ECoG spike frequency was higher in epileptic children with cortical dysplasia (MCD) than in non-MCD children. Complex interactions between neurons and abnormalities in excitatory and inhibitory neurotransmitters are among the reasons for epileptogenesis in FCD, although they are not fully known [32].

Our investigation revealed that clinical semiology was in concordance with MRI brain lesions in all patients and with video-EEG in 69.2%. In terms of pre- and post-resection ECoG spike frequency, there was no difference between interictal and ictal video-EEG recordings that showed epileptiform discharge and those that did not.

These findings were consistent with **Tatum *et al.*** [33], which showed that 20% to 30% of patients never experience an ictal event during long-term video-EEG recordings. **Kobulashvili *et al.*** [34] concluded that long-term video-EEG recordings had moderate sensitivity and low specificity for identifying the EZ.

In contrast to our findings**, Peng *et al.*** [7] revealed that clinical semiology was concordant with video-EEG in 85.3% of 34 patients. This discrepancy is due to the differing methodology, as we used short-term video-EEG. Long-term video-EEG may fail to identify IEDs in epileptic patients, leading to an inaccurate non-epileptic diagnosis. However, the most recent guidelines from the International League Against Epilepsy (ILEA) strongly recommend performing long-term video-EEG recording in the preoperative evaluation of patients with drug-resistant epilepsy [33].

Our study found that post-resection ECoG had a sensitivity of 100%, a specificity of 50%, and a positive predictive value of 91.67%. These findings were consistent with those of **Tripathi *et al.*** [10], which reported that ECoG had 100% sensitivity, 68.3% specificity, and 89.9% positive predictive value. Our study focused only on TLE patients; however, the **Tripathi *et al.*** [10] study included patients with various types of epilepsy.

The predictive value of post-resection ECoG residual discharges for postoperative seizure outcomes is controversial. Our findings showed that post-resection ECoG spike frequency was significantly greater in patients with residual seizures than in those with postoperative seizure freedom. However, 84.6% of patients with no ECoG epileptic discharge after complete resection had a better seizure prognosis than patients with post-resection ECoG residual epileptic discharge (7.7%), while the difference was not statistically significant. This difference implies that, in a larger sample size, the post-resection ECoG residual epileptic discharge may be a significant predictor of non-favorable seizure outcomes. Perilesional tissue manipulation during surgery may result in temporary changes and "false positive" findings on the post-resection ECoG [27].

Consistent with our findings, **Greiner *et al.*,** [35] reported that 51% of patients with no ECoG epileptic discharge had a good outcome, and 35% of patients with continued post-resection ECoG pikes had a good outcome without significant difference. Additionally, other studies revealed no difference in postoperative seizure outcomes in patients with or without post-resection residual discharges [12], [14]. On the contrary, **McBride *et al.*** [36] reported that after temporal lobectomy, a poor outcome was associated with 50% or more of the pre-resection epileptiform discharges remaining in the post-resection ECoG.

According to our study, 84.6% of subjects had mesial TLE, as determined by MRI hippocampal sclerosis. Epileptiform discharges were more frequently proposed to originate from the inferiomesial surfaces of the temporal tip and the structures of the hippocampal regions [10]. Additionally, we showed that 69.2% of TLE patients with mesial and lateral temporal ECoG discharges had a favorable seizure outcome. We also demonstrated that all patients with mesial ECoG discharges had favorable seizure outcomes.

Consistent with our findings, **Yan *et al.*** [2] concluded that three-fifths of TLE patients had mesial TLE, and these patients had better postoperative seizure outcomes. On the contrary, **Yu *et al.*** [37] reported that 90% of patients who underwent lesionectomy in TLE with preserved mesial structures had a good prognosis and reported that ECoG did not add any significant data.

A major limitation includes the small sample size, lack of quantitative analysis of video-EEG recordings, and short time of video-EEG recording as it is more expensive and less available than routine EEG.

Finally, it is to be concluded that localization of EZ using ECoG spike frequency can be used as a predictive tool for postoperative seizure outcomes. Prolongation of periods of follow-up more than one year after ATL guided by ECoG may be needed for long-term assessment of postoperative seizure outcomes in the future.

Abbreviations

AEDs	Antiepileptic Drugs
ATL	Anterior Temporal Lobectomy
DNET	Dysembryoplastic Neuroepithelial Tumor
ECoG	Electrocorticography
EEG	Electroencephalography
EZ	Epileptogenic Zone
FCD	Focal Cortical Dysplasia
HS	Hippocampal Sclerosis
IEDs	Interictal Epileptiform Discharges
ILAE	International League Against Epilepsy
IONM	Intraoperative Neurophysiological Monitoring
MCD	Malformations of Cortical Dysplasia
MRI	Magnetic Resonance Imaging
SOZ	Seizure Onset Zone
TLE	Temporal Lobe Epilepsy

Declarations

Ethics approval

The study was performed in accordance with the Declaration of Helsinki and approved by the Ethics Committee at the Faculty of Medicine, Suez Canal University, Egypt (Code 4643#).

Informed consent

Informed consent was obtained from all participants or their parents or legal guardians in the case of children.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this manuscript.

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

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Author contributions

Conceptualization: AE, NA, SH, AS, and DS; methodology: SH, AS, and DS; formal analysis and investigation: SH and DS; writing—original draft preparation: DS; writing—review and editing: AE, NA, SH, and DS; supervision: AE, NA, SH, and AS. All authors read and approved the final manuscript.

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