The Role of Preoperative Scalp Video-Electroencephalography and Intraoperative Electrocorticography in Mapping of Epileptogenic Zone in Temporal Lobe Epilepsy Surgery

Dina Sebaei[1], Ali M. Salah Eldin[2], Samar M. Hussein[1], Noha M. Abogresha[1], Amani El-Baz[1]
Departments of [1]Medical Physiology, and [2]Neurosurgery, Faculty of Medicine,
Suez Canal University Hospitals, Ismailia, Egypt
***Corresponding author:** Dina Sebaei,**Email:** dina.sebaei@med.suez.edu.eg**, Mobile:** 01023720605

ABSTRACT
Background: Temporal lobe epilepsy (TLE) is the most common type of epilepsy characterized by recurrent seizures. Resection surgery demonstrated efficacy in controlling seizures recently, and the success of epilepsy surgery is correlated with mapping of epileptogenic zone (EZ). This is achieved through pre-operative video-electroencephalography (video EEG) and intraoperative Electrocorticography (ECoG).
Aim of the study: To investigate role of preoperative scalp video EEG and intraoperative pre-resection electrocorticography in identifying the epileptogenic zone in temporal lobe epilepsy surgery.
Subjects and methods: Anterior temporal lobectomy (ATL), assisted by intraoperative ECoG, was performed on thirteen drug-resistant patients with TLE. Preoperative evaluations involved clinical semiology, scalp video EEG, MRI brain epilepsy protocol, and pre-resection and post-resection ECoG spike frequency (/min) was analyzed. After a year of follow-up, patients were divided into two categories: favorable seizure outcome (Engel class I) and non-favorable seizure outcome (Engel class II).
Results: Nine patients (69.2%) had intraoperative ECoG data that agreed with video EEG in mapping EZ. Intraoperative ECoG demonstrated epileptic discharges in all studied patients, which were in agreement with clinical semiology and MRI. There was no statistically significant difference in the pre-resection and post-resection spike frequencies between interictal and ictal video EEG recordings with and without epileptiform discharge. In all patients with a favorable postoperative seizure outcome, there was no post-resection ECoG residual epileptic discharge.
Conclusions: When video EEG is unable to localize the EZ in drug-resistant TLE patients undergoing ATL, mapping EZ using ECoG spike frequency can be utilized as a predictive method for postoperative seizure outcomes.
Keywords: Video EEG; Electrocorticography (ECoG); Epileptogenic zone; Pre-resection spike frequency; Temporal lobe epilepsy surgery.

INTRODUCTION

Epilepsy is a chronic neurological disorder marked by frequent seizures caused due to atypical electrical discharges in the brain. Almost 50 million individuals globally are affected by it. Eighty percent of epileptic sufferers live in developing countries. Individuals with epilepsy face a decreased quality of life and an increased chance of unexpected death **[(1,2)]**.

The most prevalent type of epilepsy is TLE. Typically, it is linked to memory loss, language difficulties, and temporal lesions like hippocampal sclerosis. Resection surgery has emerged as a successful treatment for controlling seizures in around one-third of TLE patients who are resistant to antiepileptic medications (AEDs) **[(3)]**. Resection surgery resulted in seizure-free outcomes for 40–90% of TLE patients **[(4)]**.

The mapping of EZ, the minimum cortical region that must be fully removed without causing a new neurological loss in order to successfully control seizures, is correlated with the success of resection surgery. This is made possible via intraoperative ECoG **[(5)]**.

Since many EEG abnormalities might be missed during standard EEG recording, a normal routine EEG recording does not rule out epilepsy. Thus, prior to epilepsy surgery, scalp video EEG monitoring is crucial for lateralizing and localizing seizures as well as to determine if EZ and neuroimaging results are consistent **[(6)]**.

The gold standard for locating the EZ is seizure onset zone (SOZ) identification. It is described as the visually recognized area in a video EEG recording that is involved in the initiation of spontaneous seizures. However, the spatial resolution of normal EEG is restricted. According to a previous study, conventional EEG in TLE patients was unable to predict the likelihood of seizures returning **[(7)]**.

During the video EEG recording time, it's possible that ictal events were missed. The interictal spike frequency in video EEG was not a good indicator of the postoperative seizure outcome in TLE patients **[(8,9)]**. However, long-term video EEG monitoring is highly advised as part of the preoperative evaluation according to new guidelines from the worldwide federation of clinical neurophysiology and the international league against epilepsy (ILEA) **[(10)]**.

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ECoG recordings show the electrophysiological correlates of brain activity in greater detail than non-invasive scalp EEG recordings. The ECoG recordings have better spatial resolution, sensitivity and signal-to-noise ratio due to proximity of electrodes to cortical surface [11]. During TLE surgery, intraoperative ECoG is essential for determining the limits of the suggested resected EZ area [2]. It's debatable if post-resection ECoG residual interictal epileptiform discharges (IEDs) have any predictive significance [12].

Due to this controversy, this study assessed the role of preoperative scalp video EEG and intraoperative pre-resection ECoG in identifying the EZ in TLE surgery.

PATIENTS AND METHODS

A prospective interventional study was conducted in the neurosurgical operating rooms at Suez Canal and Zagazig University Hospitals in Egypt, between July 2021 and January 2024. Thirteen drug-resistant TLE patients who had ECoG-guided resective epilepsy surgery were included in the study. Patients who experienced technical difficulties during their ECoG recordings were not included in the research.

Clinical history, MRI brain epilepsy protocol, scalps video EEG and neurocognitive assessment were all part of the preoperative assessment. The clinical history included information on age, gender, duration of epilepsy, frequency of seizures per week, and number of AEDs.

MRI brain epilepsy protocol

It included three-dimension (3D) T1-weighted sequence, 3D axial T1-weighted sagittal, 2D coronal and sagittal T2-weighted perpendicular to the longitudinal axis of the hippocampi, fluid-attenuated inversion recovery (FLAIR) axial, volumetric study, arterial spin labeling, and hippocampal asymmetry index. Patients were categorized as positive MRI HS and those without HS [13].

Preoperative scalp video EEG

Using the international 10-20 system, a neurophysiologist blind to the study's purpose performed non-invasive video EEG recordings of all patients during wakefulness and sleep over a period of 4 to 24 hours. Additional electrodes were placed at T1/T2 positions for EEG recording, as well as ECG recording. Provocative techniques included hyperventilation and intermittent photic stimulation. The electrodes had an impedance of less than 5kΩ. The EEG was recorded using a band-pass filter set to 0.53–400 Hz and a sampling rate of 1024 Hz. A neurophysiologist who was blinded to the study's objectives assessed the video EEG in order to identify and lateralize the seizure onset during the recording, as well as to validate the existence of IEDs [14].

Neurocognitive assessment

An Arabic neurocognitive assessment battery covering the cognitive domains of attention, verbal and visual memory, executive function, language, and social cognition was used to test patients with epilepsy preoperatively by a single neuropsychologist who was blind to aim of the study [15].

Surgical procedure

Based on the agreement of the MRI results, the neurocognitive evaluation, and the video EEG recording, the same neurosurgeon conducted all of the procedures. The surgical technique known as standard ATL involved removing the amygdala, anterior hippocampus, temporal pole, and anterolateral temporal cortex [16]. For surgical localization, most patients employed the neuronavigation system.

Anesthesia protocol

Under general anesthesia, the patients were given 2-4 mg/kg of propofol, 1 μg/kg of dexmedetomidine (Precedex) during a 20-minute period, and 1 μg/kg of fentanyl. During the maintenance phase, dexmedetomidine (0.2–0.7 μg/kg/hour) and propofol (4–12 mg/kg/hour) were utilized. The anesthesia was lowered at the time of the intraoperative ECoG recording by continuing to administer dexmedetomidine (0.2 mg/kg/min) while discontinuing the propofol infusion. A dose of 1 μg/kg of fentanyl was administered to induce interictal epileptogenic discharges [17].

Intraoperative scalp EEG monitoring

The Intraoperative Neurophysiological Monitoring (IONM) Portable system (Medtronic NIM- Eclipse E4, U.S.A.) was used to collect data throughout the entire procedure. Before the electrode was positioned, the skin was cleansed using a cotton alcohol swab. The worldwide 10-20 protocol for placing EEG electrodes was used while placing the recording corkscrew electrodes. At least three electrodes; one frontal, one centroparietal, and one temporal were symmetrically positioned on either side of the skull in bipolar and referential montages. To make sure the anesthetic was lowered before ECoG recording, power spectrum density was assessed using scalp EEG electrodes [18,19].

Intraoperative ECoG recording

Four or six contact strip electrodes were placed directly on the cortical surface by the neurosurgeon and left there for five to ten minutes in order to record ECoG. Every patient had a unique strip electrode placement determined by MRI and video EEG [20]. Three stages of

ECoG monitoring were recorded: pre-resection, post-resection, and post-resection of the lateral temporal lobe (mesial ECoG).

The strip electrode was positioned on the resection margins and then along the hippocampus's longitudinal surface after the epileptogenic tissue was removed. The recording strip electrode was positioned on the resection bed at three different locations following the excision of the mesial structures in order to search for any more epileptogenic foci. ECoG recordings were repeated on the resection bed until the ECoG recordings returned to normal. The same surgical neurophysiologist recorded and evaluated every recording [21,22].

The Medtronic NIM eclipse E4, U.S.A., Intraoperative Neurophysiological Monitoring (IONM) Portable system was utilized to collect data. The filters have a 1-70 Hz setting. Bipolar and referential montages were used while recording. The inter-electrode differences were below 2,000 Ω, indicating that the electrode impedances were reasonably equivalent or balanced, with less than 5000 Ω. Over the contralateral mastoid, the reference electrode was positioned [23].

Ethical consideration:

The study protocol was approved by the Ethics Committee of Faculty of Medicine, Suez Canal University, Egypt. Written informed consent was obtained from all the participants or their caregivers if they were children, and all patients and their families were counseled regarding the significance of intraoperative ECoG recording. The Helsinki Declaration was followed throughout the study's conduct.

Statistical analysis

SPSS statistical software, version 27, was used to examine the data. Continuous variables were presented as mean and standard deviation (SD) and were compared by the Student t test or the Mann Whitney U test. Categorical variables were presented as frequency and percentage and were compared by Fisher's exact test. P value < 0.05 was used to determine a significant difference.

RESULTS

Socio-demographic characteristics and clinical profile

Temporal lobectomy aided by intraoperative ECoG monitoring (9 left, 4 right) was performed on 13 patients (10 females and 3 males). **Table 1** provides a summary of socio-demographic variables. Patients ranged in age from 5 to 30 years (mean ± SD: 14.69 ± 9.013 years) at the time of TLE surgery. Every patient had a positive temporal lobe lesion on MRI. Using MRI hippocampal sclerosis, 84.6% of subjects had mesial TLE, and 15.4% of patients had lateral TLE.

Table 1: Socio-demographic characteristics and clinical profile (n=13 subjects)

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

*: Significant

Localization and lateralization value of video EEG

Video EEG recordings were able to localize the epileptogenic zone in 10 patients (76.9%) **(Figure 1)**. In 10 patients (76.9%), video EEG recordings were able to record the ictal event **(Figure 2)**. Interictal recordings from 7 patients (53.8%) revealed epileptiform discharge. Video EEG was able to lateralize the epileptogenic zone in 9 patients (69.2%). Clinical semiology was concordant with MRI brain lesions in all patients and concordant with video EEG in 9 patients (69.2%).

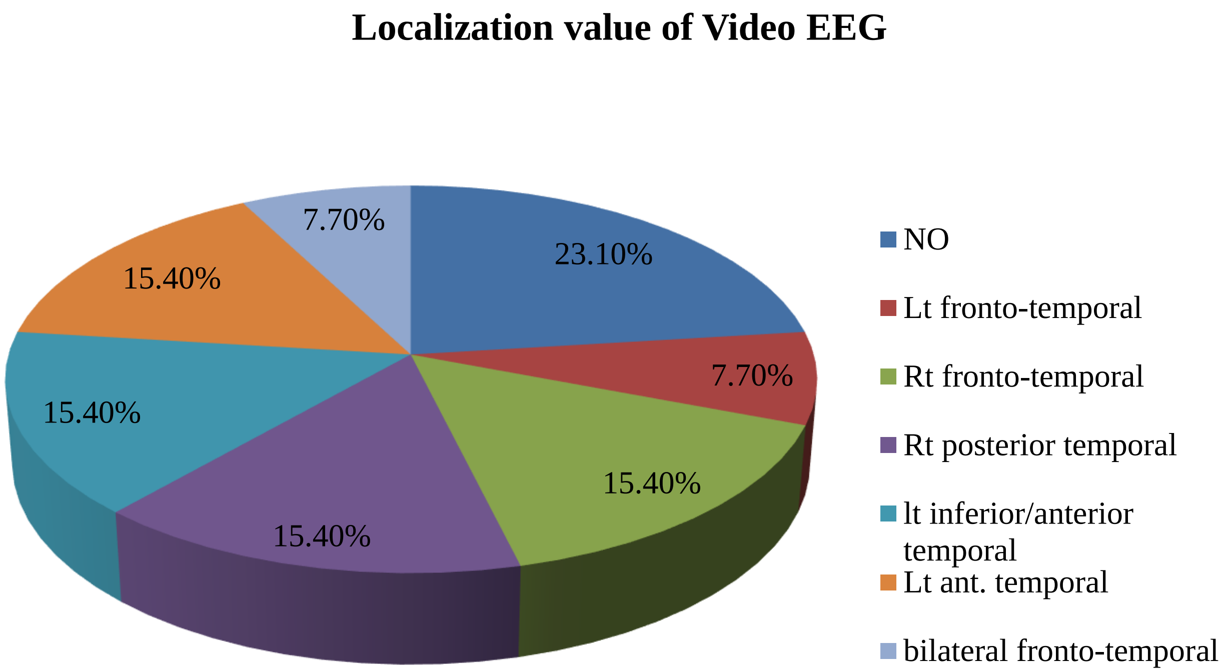

Figure 1: Localization value of video EEG.

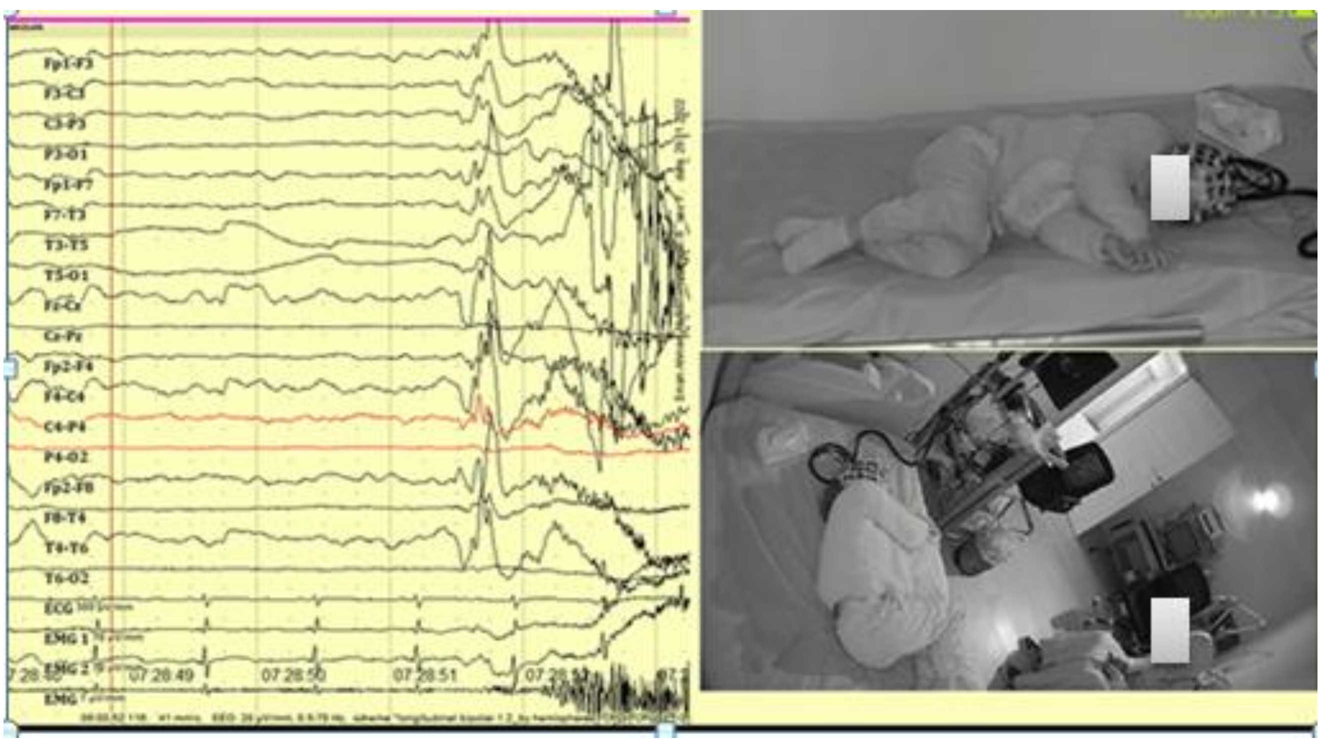

Figure 2: Video-electroencephalography (video EEG) in case of 5 years old female child revealed bilateral epileptogenic discharge. Despite clinical semiology and MRI being lateralized to the left temporal, there was no lateralization in video EEG. MRI revealed left temporal focal cortical dysplasia with left hippocampus sclerosis.

Preoperative Neurocognitive assessment

Only 10 patients (8 right-handed, 2 left-handed) underwent preoperative neurocognitive assessment. The most affected cognitive domain was memory. Forty percent had abnormal episodic verbal memory and visual memory, 90% had normal figurative language comprehension, 50% had normal executive function and 70% had normal social recognition **(Figure 3).**

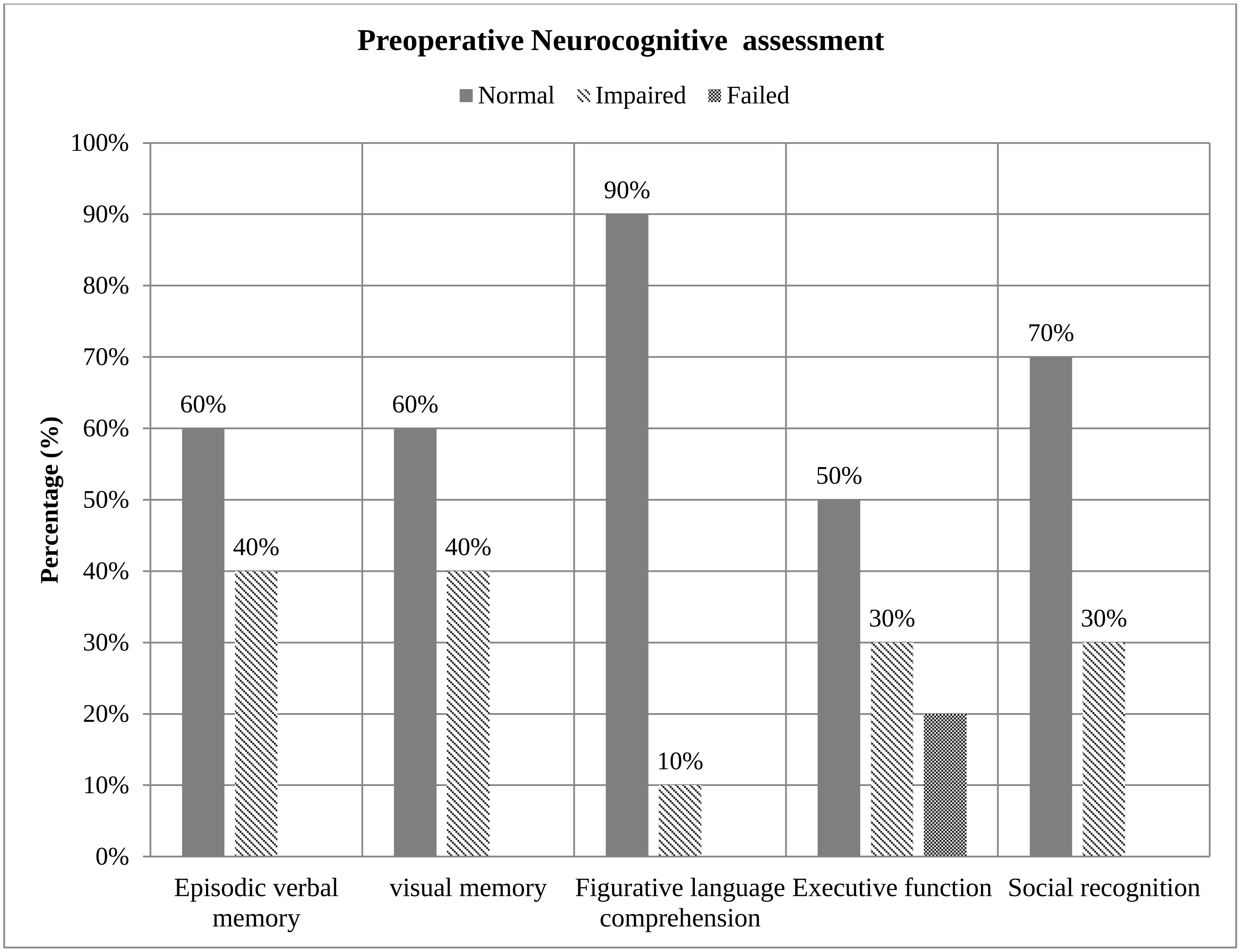

Figure 3: Preoperative neurocognitive assessment in patients with drug resistant temporal lobe epilepsy.

Intraoperative scalp EEG monitoring and power spectrum density

When anesthesia was induced, the lowest frequency that was more likely to be seen at the scalp EEG was 0–4 Hz. After anesthesia was induced, the intraoperative scalp EEG backdrop was delta waves.

The overall intraoperative scalp EEG power increased as frequency increased up to more than 5 Hz during intraoperative ECoG recording following propofol stopping. Alpha and theta coherence was observed during ECoG recordings in all patients, although beta and alpha coherence was not observed.

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

Eleven patients (84.6 %) had no post-resection ECoG residual discharge **(Figure 4)** and favorable postoperative seizure outcome (Engel class I). Two patients (15.4 %) had non-favorable seizure outcome one year postoperative and one of them had post-resection ECoG residual epileptic discharge.

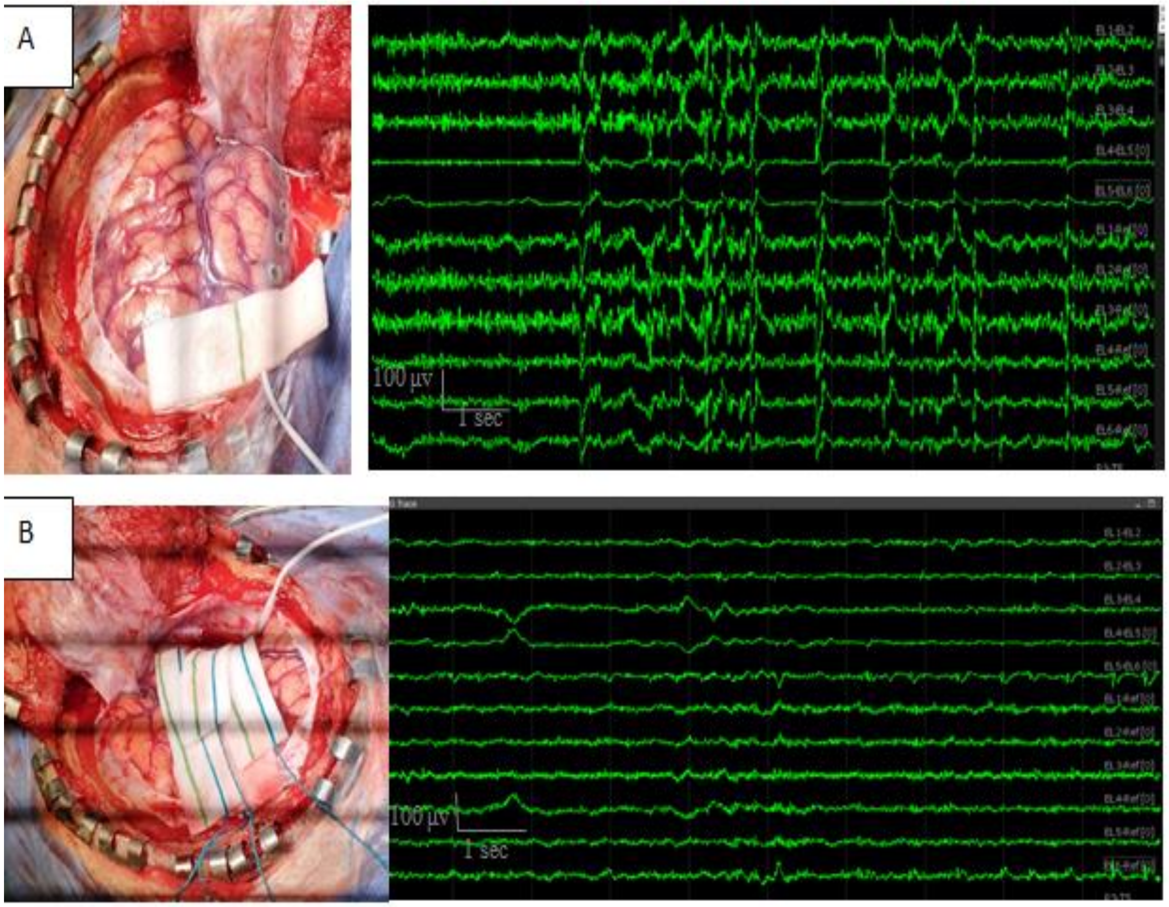

Figure 4: Intraoperative ECoG monitoring in case of 24 years old female patient with right temporal lobe epilepsy, MRI reported mesial temporal sclerosis. (**A**): Pre-resection ECoG showed spike slow wave epileptogenic activity in the six contact electrodes, **(B)**: Post-resection ECoG recording showed no epileptogenic activity.

There was significant difference between patients with postoperative favorable seizure outcome (seizure-free) and those with non-favorable seizure outcome (residual seizure) regarding pre-resection ECoG spike frequency and post-resection ECoG spike frequency (p value =0.008, p value =0.018 respectively, **Figure 5).**

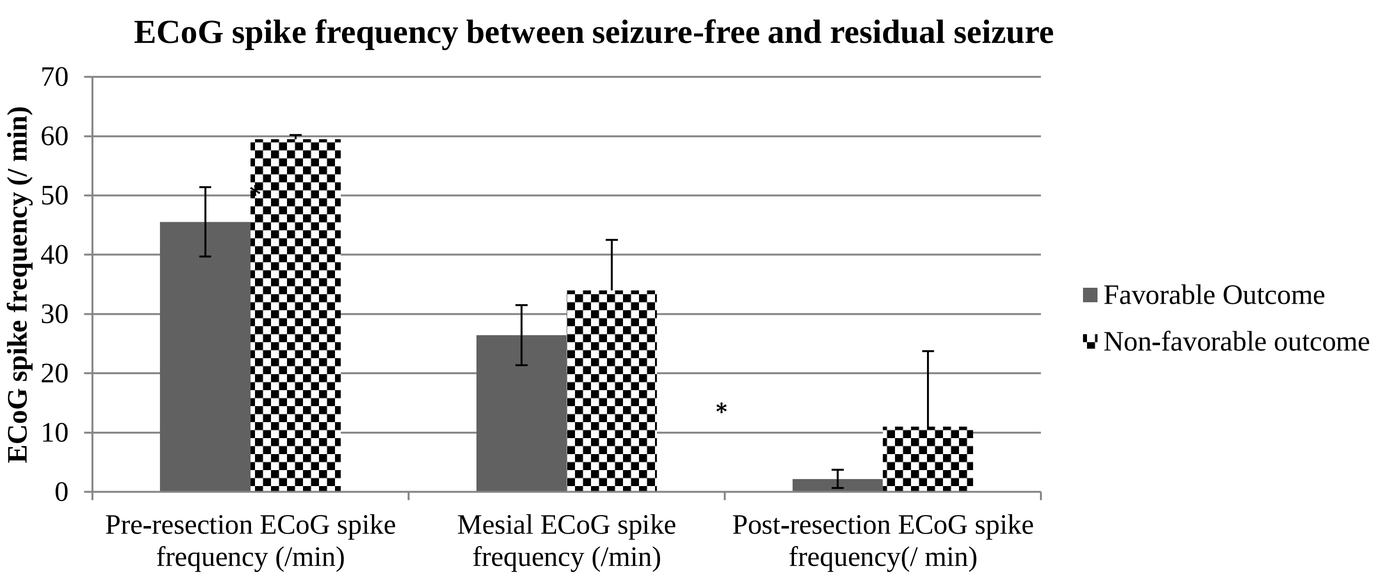

Figure 5: The relation between ECoG spike frequency (/min) and postoperative seizure outcome. *: Significant when compared to non-favorable outcome (residual seizure).

ECoG spike frequency in relation to video-EEG recording

The intraoperative ECoG results agreed with the video EEG recordings in nine patients (69.2%). In all studied individuals, intraoperative ECoG showed epileptic discharges that matched MRI and clinical semiology. There was no statistically significant difference in the pre-resection ECoG spike frequency between patients who were able to capture ictal video EEG and those who did not (**Table 2**).

Table 2: ECoG spike frequency in relation to ictal video EEG recording

Characteristics (n=13)	**Ictal video EEG (Mean ± SD)**		**P value**
	Yes N=10	No N=3	
Pre-resection ECoG spike frequency (/ min)	47.8 ± 8.404	47.33 ± 4.163	0.929
Post-resection ECoG spike frequency (/ min)	4.1 ± 5.763	1.67 ± 1.528	0.496

There was no statistically significant difference in the pre-resection ECoG spike frequencies comparing interictal video EEGs with and without epileptiform discharge (**Table 3**).

Table 3: ECoG spike frequency in relation to interictal video EEG recording

Characteristics (n=13)		**Interictal video EEG epileptiform discharge recording**		**P value**
		Yes N=7	No N=6	
Pre-resection ECoG spike frequency (/ min)	**Mean ± SD**	49.57 ± 8.423	45.5 ± 6.189	0.35
Post-resection ECoG spike frequency (/ min)	**Mean ± SD**	4.68 ± 6.793	2 ± 1.673	0.339

Based on post-resection residual epileptic discharge, there was no statistically significant difference between interictal video EEGs exhibiting epileptiform discharge and those that did not **(Table 4)**.

Table 4: Association between post-resection ECoG residual epileptic discharge and interictal video EEG recording

Characteristics (n=13)		**Interictal video EEG epileptiform discharge recording**		**P value**
		Yes N=7	No N=6	
Post- resection ECoG residual epileptic discharge	No, n (%)	6 (85.7)	6 (100)	1
	Yes, n (%)	1 (14.3)	0	

DISCUSSION

The current study investigated the role of intraoperative pre-resection ECoG and preoperative scalp video-EEG in locating the EZ. In thirteen patients with drug-resistant TLE, the current study examined the clinical utility of intraoperative ECoG during ATL.

In patients with TLE undergoing epilepsy surgery, the predictive value of the ECoG is controversial. The results of our investigation demonstrated the importance of ECoG guidance for EZ identification and surgical outcome prediction. Our study revealed a significant difference in the pre-resection and post-resection ECoG spike frequencies. Post-resection ECoG residual epileptic discharge was absent in all patients who were free of seizures after surgery.

The current study showed that in 69.2% of patients, video EEG was consistent with clinical semiology and MRI brain. All of the patients under investigation had intraoperative ECoG discharges that were consistent with MRI and clinical semiology. In terms of pre-resection ECoG spike frequency, we also found no difference between interictal and ictal video EEG recordings exhibiting epileptiform discharge and those that did not.

These results were in agreement with the study conducted by **Tatum *et al.*** [10], which revealed that 20% to 30% of patients never had an ictal event while having long-term video EEG recordings. Additionally, ictal video EEG was able to lateralize the epileptogenic zone in 60% of patients with drug-resistant extra temporal lobe epilepsy, and 31% of patients exhibited no interictal epileptiform discharge [24]. According to **Kobulashvili *et al.*** [24], long-term video EEG recordings showed a low specificity and a moderate sensitivity when it was used for EZ identification.

In contrast to our results, **Peng *et al.*** [25] found that in 85.3% of 34 patients, clinical semiology and video EEG were concordant. The different methods lead to this variation. We conducted short-term video EEG over a period of four to twenty-four hours. In some focal seizures, long-term video EEG may not identify a visible scalp ictal rhythm or IEDs in epileptic patients, leading to a false non-epileptic diagnosis [10,24]**.**

These results were in agreement with those of **Grewal *et al.*** [26], who showed that in drug-resistant MRI-n egative TLE patients undergoing a temporal lobectomy, the use of intraoperative ECoG decreased the risk of seizure recurrence. Additionally, a different study found that using intraoperative ECoG improved postoperative outcomes for children undergoing epilepsy surgery [27].

In contrast to previous findings, the **Goel *et al.*** [27] study found no statistically significant difference, independent of pathology, in postoperative seizure freedom between the surgical groups guided by ECoG and those not. It has been demonstrated that in various populations, the age at the time of surgery, the duration of epilepsy, and the type of pathology all directly affect the outcome of seizures after epilepsy surgery and affect the value of ECoG [28,29]. Despite being used for more than 60 years, the usefulness of intraoperative ECoG during temporal lobe surgery is still debatable, according to a review research by **Parameswaran** [30]**.**

After a year of follow-up, our results showed that 84.6% of patients were seizure-free (Engel Class I) on tapering doses of AEDs. The gold standard for treating patients with drug-resistant TLE is believed to be ATL. After ATL, 53 to 84% of patients with mesial temporal lobe sclerosis obtain seizure freedom for at least a year, according to various studies done over the previous 20 years [28,29]

. A recent retrospective analysis of patients with focal epilepsy who had resective surgery revealed that, after a mean follow-up of 5.2 years, 67.3% of patients remained seizure-free, 24.4% of patients showed improvement in their seizures, and 8.3% of patients showed no improvement at all [31].

The EZ must be identified and completely removed for epilepsy surgery to be successful. Important clues regarding their localization can be obtained throughout seizure semiology and preoperative video EEG. The preoperative scalp EEG epileptic discharges have been demonstrated to correlate well with seizure-onset zones and to give useful localization data. However, it is not an indication that the epileptogenic area is the same cortical structure that generated the scalp-visible potential. Even at high amplitudes, scalp EEG typically does not show hippocampal spikes [32].

The inadequate disruption of the pathogenic connection in an epileptogenic network, dual pathology, or inadequate excision of the EZ are among the reasons for unfavorable outcomes following epilepsy surgery. It is thought that the abnormal network includes numerous extra temporal connections, such as the lateral temporal, insular, and frontal areas. Previous research has shown that mesial TLE mostly affects the temporal lobe**s** [33].

Based on MRI hippocampal sclerosis, our study found that 84.6% of participants had mesial TLE and 15.4% had lateral TLE. Frequently, the inferiomesial surfaces of the temporal tip and the structures of the hippocampal regions were proposed as the locations of the epileptiform discharges [30]. Mesial structures are probably the source of the spikes seen in pre-resection ECoG in patients with mesial TLE, as shown by **Parameswaran**[30]**,** and removing these structures would greatly remove the spikes.

Our results revealed that memory was the most affected cognitive domain in patients with drug-resistant TLE. These results were consistent with **Yu *et al.*** [34] results that showed that drug-resistant TLE impaired prospective memory. Previous experimental study has advanced our understanding that seizures in animal model of epilepsy cause cellular and metabolic changes that result in neuronal loss in the hippocampus, neoneurogenesis, and synaptic reorganization, leading to cognitive impairments [34].

Achieving postoperative seizure freedom in children with epilepsy may be beneficial for their developing brains because frequent seizures might cause cognitive decline [27].

According to **Joudi Mashhad *et al.*** [35] systematic review, epilepsy surgery, particularly temporal lobectomy, is safe as the total risk of complications from epilepsy surgery was very low (5%). The likelihood of doing epilepsy surgery on appropriate patients is over 58%, despite the fact that surgical procedures are helpful for treating drug-resistant epilepsy.

The small sample size, lack of quantitative analysis of video EEG recordings, and short duration of video EEG recording, which is more expensive and less available than normal EEG, are some of the main limitations.

CONCLUSION

Finally, mapping of the EZ using ECoG spike frequency can be used as a prediction tool for postoperative seizure outcomes when video EEG fails to locate the EZ in drug-resistant TLE patients undergoing ATL.

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REFERENCES

1. **Espinosa-Jovel C, Toledano R, Aledo-Serrano Á *et al.* (2018):** Epidemiological profile of epilepsy in low income populations. Seizure, 56:67–72.
2. **Demuru M, Kalitzin S, Zweiphenning W *et al.* (2020):** The value of intra-operative electrographic biomarkers for tailoring during epilepsy surgery: from group-level to patient-level analysis. Sci Rep., 10(1):1–18.
3. **Damasceno B (2020):** Temporal lobe epilepsy. In: Research on Cognition Disorders. Springer, pp. 207–14.
4. **He X, Zhou J, Guan Y *et al.* (2020):** Prognostic factors of postoperative seizure outcomes in older patients with temporal lobe epilepsy. Neurosurg Focus, 48(4):1–6.
5. **Kuroda N, Sonoda M, Miyakoshi M *et al.* (2021):** Objective interictal electrophysiology biomarkers optimize prediction of epilepsy surgery outcome. Brain Communications, 3(2):fcab042.
6. **Kannan L, Jain P, Nayak D (2021):** Role of video-EEG in children. Indian J Pediatr, 88: 1007–1016.
7. **Asadollahi M, Noorbakhsh M, Salehifar V *et al.* (2020):** The significance of interictal spike frequency in temporal lobe epilepsy. Clin EEG Neurosci., 51(3):180–4.
8. **Wang S, Wang I, Tang Y *et al.* (2019):** Localization value of subclinical seizures on scalp video-EEG in epilepsy presurgical evaluation. Epilepsia, 60(12):2477–85.
9. **Ngo L, Sperling R, Skidmore C *et al.* (2017):** Absolute spike frequency as a predictor of surgical outcome in temporal lobe epilepsy. Seizure, 47:83–6.
10. **Tatum W, Mani J, Jin K *et al.* (2022):** Minimum standards for inpatient long-term video-electroencephalographic monitoring: A clinical practice guideline of the International League Against Epilepsy and International Federation of Clinical Neurophysiology. Epilepsia, 63(2):290–315.
11. **Archila-Meléndez E, Valente G, Gommer D *et al.* (2020):** Combining gamma with alpha and beta power modulation for enhanced cortical mapping in patients with focal epilepsy. Fron. Hum. Neurosci.. 14:555054.
12. **Roessler K, Heynold E, Buchfelder M *et al.* (2019):** Current value of intraoperative electrocorticography (iopECoG). Epilepsy Behav., 91:20–4.
13. **Ponnatapura J, Vemanna S, Ballal S *et al.* (2018):** Utility of magnetic resonance imaging brain epilepsy protocol in new-onset seizures: how is it different in developing countries? J Clin Imaging Sci. 15; 8:43.
14. **Rikir E, Maillard G, Abdallah C *et al.* (2020):** Respective contribution of ictal and inter-ictal electrical source imaging to epileptogenic zone localization. Brain Topogr., 33(3):384–402.
15. **Kishk A, Farghaly M, Nawito A *et al.* (2022):** Neuropsychological performance in patients with focal drug - resistant epilepsy and different factors that affect their performance. Egypt J Neurol Psychiatry Neurosurg, 58: 89
16. **Goldstein L, Dehghan Harati M, Devlin K *et al.* (2021):** Consequences of mesial temporal sparing temporal lobe surgery in medically refractory epilepsy. Epilepsy Behav., 115:107642.
17. **Ravat S, Iyer V, Panchal K *et al.* (2016):** Surgical outcomes in patients with intraoperative Electrocorticography (EcoG) guided epilepsy surgery-experiences of a tertiary care centre in India. Int J Surg., 36:420–8.

18. **Li T, Ying T (2016):** Intraoperative monitoring. In: Microvascular decompression surgery. Springer, pp. 151–70.
19. **Zouridakis G, Papanicolaou C (2000):** A concise guide to intraoperative monitoring. CRC Press. https://doi.org/10.1201/9781420041538
20. **Hussain A, Mathern W, Hung P *et al.* (2017):** Intraoperative fast ripples independently predict postsurgical epilepsy outcome: Comparison with other electrocorticographic phenomena. Epilepsy Res., 135:79–86.
21. **El Tahry R, Ferrao Santos S, de Tourtchaninoff M *et al.* (2016):** Post-resection electrocorticography has no added value in epilepsy surgery. Acta Neurol Belg., 116(3):279–85.
22. **Boran E, Sarnthein J, Krayenbühl N *et al.* (2019):** High-frequency oscillations in scalp EEG mirror seizure frequency in pediatric focal epilepsy. Sci Rep., 9(1):16560.
23. **Isley R, Edmonds L, Stecker M (2009):** Guidelines for intraoperative neuromonitoring using raw (analog or digital waveforms) and quantitative electroencephalography: A position statement by the American Society of Neurophysiological Monitoring. J Clin Monit Comput., 23(6):369–90.
24. **Noe K, Sulc V, Wong-Kisiel L *et al.* (2013):** Long-term outcomes after nonlesional extratemporal lobe epilepsy surgery. JAMA Neurol., 70(8):1003–8.
25. **Kobulashvili T, Kuchukhidze G, Brigo F *et al.* (2018):** Diagnostic and prognostic value of noninvasive long-term video-electroencephalographic monitoring in epilepsy surgery: A systematic review and meta-analysis from the E-PILEPSY consortium. Epilepsia, 59(12):2272–83.
26. **Grewal S, Alvi A, Perkins J *et al.* (2019):** Reassessing the impact of intraoperative electrocorticography on postoperative outcome of patients undergoing standard temporal lobectomy for MRI-negative temporal lobe epilepsy. ,
27. **Peng J, Wong T, Huang C *et al.* (2021):** Quantitative analysis of intraoperative electrocorticography mirrors histopathology and seizure outcome after epileptic surgery in children. J Formos Med Assoc., 120(7):1500–11.
28. **Goel K, Pek V, Shlobin A *et al.* (2023):** Clinical utility of intraoperative electrocorticography for epilepsy surgery: A systematic review and meta-analysis. Epilepsia, 64(2):253–65.
29. **Radhakrishnan A, Menon R, Abraham M *et al.* (2018):** Predictors of outcome after surgery in 134 children with drug-resistant TLE. Epilepsy Res., 139:150–6.
30. **Parameswaran S (2018):** Acute electrocorticography (EcoG) during mesial temporal lobe epilepsy surgery-review. Open Access J Neurol Neurosurg., 7(5):5–8.
31. **Meng Q, Liu Y, Ren Y *et al.* (2023):** Multivariate analysis of seizure outcomes after resective surgery for focal epilepsy: a single-center study on 833 patients. Neurosurg Rev., 46(1):89.
32. **Yu Y, Hsu C, Lin F *et al.* (2017):** Prognostic significance of postoperative spikes varied in different surgical procedures for mesial temporal sclerosis. Seizure, 52(201):71–5.
33. **Tripathi M, Garg A, Gaikwad S *et al.* (2010):** Intra-operative electrocorticography in lesional epilepsy. Epilepsy Res., 89(1):133–41.
34. **Yu H, Gao J, Chang K *et al.* (2023):** Inhibitory dysfunction may cause prospective memory impairment in temporal lobe epilepsy (TLE) patients: an event-related potential study. Front. Hum. Neurosci., 17:1006744.
35. **Joudi Mashhad M, Harati H, Parooie F *et al.* (2020):** Epilepsy surgery for refractory seizures: a systematic review and meta-analysis in different complications. Egypt J Neurol Psychiatry Neurosurg., 56:1–12.