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Prognostic significance of serial postoperative EEG in extratemporal lobe epilepsy surgery

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H I G H L I G H T S

- The study evaluated the prognostic value of postoperative EEG in patients surgically treated for drug-resistant extra-temporal lobe (ET) epilepsy.
- The presence of interictal epileptiform discharges in early postoperative EEG may predict long-term seizure outcome.
- Serial postoperative EEGs including sleep recording may add further predictive power and help making decision about antiepileptic drug discontinuation.

A B S T R A C T

Objective: To assess the prognostic value of postoperative EEG in patients surgically treated for drug-resistant extra-temporal lobe (ET) epilepsy.
Methods: We studied 63 consecutive patients with ET epilepsy who underwent epilepsy surgery and were followed up for at least 2 years (mean duration of follow-up 6.2 ± 2.3 years, range 2–12). Follow-up evaluations were performed 2, 12, and 24 months after surgery, and included standard EEG (at 2 months) and long-term video-EEG monitoring during both wakefulness and sleep (at 12 and 24 months). Seizure outcome was determined at each follow-up evaluation, and then at yearly intervals. Patients who were in Engel Class I at the last contact were classified as having a good outcome.
Results: Seizure outcome was good in 39 patients (62%). The presence of interictal epileptiform discharges (IED) in postoperative EEG at each time point was found to be associated with poor outcome. The strength of this association was greater for awake plus sleep recording as compared with awake recording alone. In a multiple regression model including all pre- and post-operative factors identified as predictors of outcome in univariate analysis, the presence of early (2 months after surgery) EEG epileptiform abnormalities was found to be independently associated with poor seizure outcome.
Conclusions: Postoperative IED may predict long-term outcome in patients undergoing resective surgery for ET epilepsy.
Significance: The increase in risk of unfavourable outcome associated with EEG epileptiform abnormalities detected as early as two months after surgery may have substantial practical importance. Serial postoperative EEGs including sleep recording may add further predictive power and help making decision about antiepileptic drug discontinuation.
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1. Introduction

Correct prediction of postoperative seizure outcome is of great importance in selecting patients with drug-resistant focal epilepsy for surgery. Patients with extra-temporal lobe (ET) epilepsy need particular attention, given their relatively poor outcome after epilepsy surgery (Aykut-Bingol et al., 1998; Jeha et al., 2007; Beleza and Pinho, 2011). The identification of prognostic factors can also help counselling patients about postsurgical seizure recurrence and making decision about withdrawal of antiepileptic drug (AED) treatment.

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Recently, Rathore and Radhakrishnan (2010) reviewed the prognostic significance of the presence of interictal epileptiform discharges (IED) in postoperative EEG amongst patients with focal epilepsy undergoing resective surgery. They concluded that IED in postoperative EEG predicts seizure outcome with a fair degree of accuracy. Moreover, a recent study on patients with temporal lobe epilepsy (TLE) showed that IED in postoperative EEG performed before AED withdrawal predicts the risk of postsurgical seizure recurrence. Serial EEGs were found to have greater predictive value than a single one (Rathore et al., 2011). However, there are only few data from long-term longitudinal studies about the relationship between postoperative IED and seizure outcome in patients with ET epilepsy. Also, the usefulness of prolonging EEG duration in order to include sleep recording is still unclear.

In order to shed light on these issues, we tested the association between seizure outcome and IED in serial postoperative (2, 12, and 24 months) EEG in patients with drug-resistant ET epilepsy who underwent resective surgery and were followed up for at least 2 years.

2. Methods

2.1. Patient population

The study was carried out at the Epilepsy Surgery Unit (ESU) of the NEUROMED-IRCCS neurological institute, Pozzilli (IS), Italy. All patients affected by medically refractory ET epilepsy who underwent resective surgery and had at least 2 years of follow-up were included in the study.

All patients underwent a non-invasive pre-surgical protocol as previously described in detail (Quarato et al., 2005), which included: (1) detailed medical history and neurological examination; (2) continuous long-term intensive, diurnal and nocturnal video-EEG monitoring (Telefactor Corp., Conshohoken, PA, USA); (3) neuropsychological evaluation; (4) psychiatric assessment; (5) 1.5 or 3 Tesla magnetic resonance imaging (MRI) brain scan.

The video-EEG recording methodology was described in detail in a previous paper (Di Gennaro et al., 2012) and is only briefly summarised here. According to the 10–20 International System for scalp electrode placement, a total of 21 AgCl cup electrodes were placed on the scalp of each patient. Until the year 2003, the electrodes were attached to the scalp with collodion; from 2003 onwards, an electrode paste was used (EC2®, Grass Telefactor) (Falco et al., 2005). Scalp EEG analysis was done using bipolar longitudinal-transverse and referential montages.

When the non-invasive protocol did not allow to identify the epileptogenic zone, subdural electrodes (assembled in grids or strips) were implanted after craniotomy under general anaesthesia to further delineate the epileptogenic zone and/or to perform cortical mapping of eloquent areas.

2.2. Surgery

After localising the epileptogenic zone and performing functional brain mapping in selected cases, resective surgery was performed by a single epilepsy surgeon.

In lesional cases, surgery was classified as ''lesionectomy'', ''subtotal lesionectomy'', or ''lesionectomy plus cortectomy'' when the lesion was totally removed, partially removed, or removed together with apparently normal cortex, respectively. The latter subgroup was further subdivided in total (lesion plus all non-lesional cortex involved in the ictal onset zone) and subtotal resections. In cryptogenic cases, surgery was classified as ''total cortectomy'' or ''subtotal cortectomy'' when the ictal onset zone, as defined by intracranial EEG, was totally or partially removed, respectively.

Finally, two patient groups were identified according to the extent of resection, i.e., total and subtotal resection. Usually, the reason for subtotal resection was partial overlapping between the epileptogenic zone and eloquent cortical areas.

All patients had the bone flap replaced after surgery, with no craniotomy defect.

2.3. Aetiology

Based on histological examination of the resected brain tissue, three groups of patients were identified, i.e., ''low-grade tumours'', ''focal cortical dysplasia'', and ''other lesions'' (focal atrophy or gliosis or vascular malformations).

2.4. Outcome

Seizure outcome was determined according to Engel's classification (Engel, 1996) by the patient's report to the neurologist during follow-up visits performed about 2 months, 1 year, and then at yearly intervals after the operation. Favourable outcome was defined as being in Engel class 1 (complete freedom from seizures during the last 2 years of follow-up) at the last follow-up visit.

2.5. EEG

In each patient, postoperative EEG standard recording of approximately 30-min duration was performed about 2 months after surgery with 21 silver pad electrodes using the 10–20 International System (Nicolet, CareFusion, San Diego, CA, USA). The term ''standard'' refers to recording obtained after electrode maintenance during relaxed wakefulness, while the patient is lying down in bed with closed eyes in a quiet room.

About 1 and 2 years after surgery, patients were admitted in our Unit for MRI brain scan, neuropsychological testing, psychiatric assessment, and long-term continuous video-EEG monitoring (approximately 24 h of recording). The awake interictal recording under standard conditions of about 30-min duration and all the sleep recording period were considered for the study, whereas the remaining awake recording was not considered.

In patients who experienced seizures after surgery, seizures did not occur in the week before the scheduled follow-up evaluation, except for two occasions. Therefore, postictal activation effect of IED can be ruled out in all recordings except two (Gotman and Koffler, 1989).

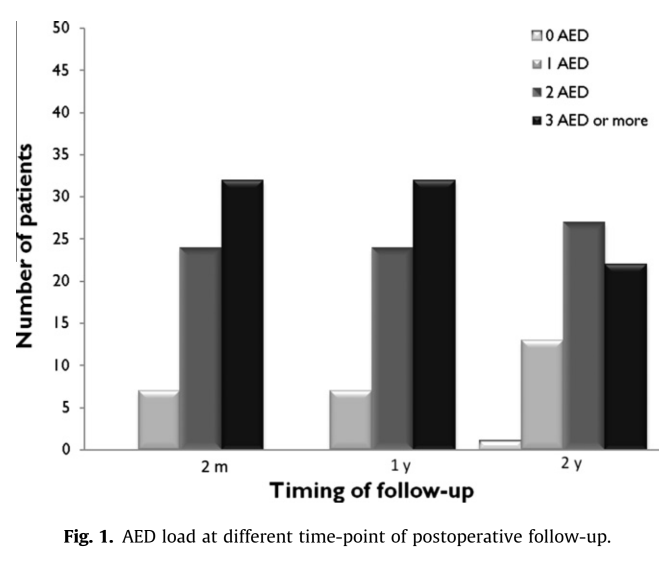

Fig. 1. AED load at different time-point of postoperative follow-up.

Hyperventilation was used to activate IED both in all postoperative EEG recordings, while photic stimulation was used only in the first postoperative EEG.

During the first year of follow up AEDs were kept constant in all patients; then, they were gradually tapered in patients who were free from both seizures and IEDs (Fig. 1).

All EEGs were reviewed by a neurologist (GDG) with over 20-year experience in electroencephalography, who was not masked to current clinical status. Post-operative EEGs performed 1 and 2 years after surgery were reviewed using a high-definition monitor (2024 × 1860 dpi) and two filter settings, LFF 1.3 and HFF 50 Hz. Post-operative EEGs carried out 2 months after surgery were reviewed on paper.

As in a previous study (Di Gennaro et al., 2004), we identified IEDs (sharp waves, spikes, polyspikes, spike-and-wave and polyspike-and-wave complexes) by criteria similar to those of Gloor (1975), i.e., isolated triangular paroxysmal waves lasting <80 ms (spikes) or 80–200 ms (sharp waves), with a rapidly increasing and a less rapidly decreasing phase, and with an amplitude at least twice the preceding 5 s of background activity.

IEDs were topographically classified into focal/regional (unilateral, bilateral or contralateral to the site of the resection) or generalised (Noachtar et al., 1999).

2.6. Statistical analysis

All statistical analyses were carried out using SPSS for Windows, version 17.0 (SPSS Inc., Chicago, IL). First, a descriptive analysis was performed. Then, we calculated the sensitivity, specificity, predictive values, and likelihood ratios for the presence of postoperative IED in either awake or awake plus sleep EEG with respect to outcome. In this context, sensitivity is defined as the proportion of patients with poor outcome who have postoperative IED, whereas specificity is the proportion of patients with favourable outcome who do not have postoperative IED. The positive predictive value is the proportion of patients with postoperative IED who had poor outcome, while the negative predictive value is the proportion of patients without postoperative IED who had good outcome. The likelihood ratio for a positive result expresses the odds that a patient with poor outcome has postoperative IED as compared with a patient with good outcome. The likelihood ratio for a negative result expresses the odds that a patient with good outcome has no postoperative IED as compared with a patient with poor outcome. Different than predictive values, sensitivity and specificity are largely independent of the setting in which a test is used because they are quite stable with changes in prevalence of the disease in the population studied, while likelihood ratios may be more stable than even sensitivity or specificity with changes in prevalence (Sackett et al., 1991).

Subsequently, the Chi Square test was performed to test for differences in IED distribution between patients with favourable and unfavourable seizure outcome. Also, the odds ratio was calculated to estimate the relative risk associated with IED.

Then, we performed a comprehensive outcome analysis in order to identify all outcome predictors in our patient population. The Chi Square test, Fisher's exact test, and Student's *t*-test were used as appropriate to test for the association between seizure outcome and the following variables: age at epilepsy onset, duration of epilepsy, extent and location of preoperative IED, presence of secondarily generalised tonic-clonic seizures (sGTCS), evidence of lesion on preoperative MRI, presence of preoperative focal neurological deficits, mental retardation (IQ < 70), resection site, completeness of resection, aetiology, acute postoperative seizures (APOS) occurring in the first 7 days after surgery, and duration of follow-up.

Finally, multiple logistic regression analysis was performed in order to test the association between the early (2 months after surgery) postoperative IED and unfavourable outcome independent of the other outcome predictors identified in univariate analysis.

Prior to analysis, the data were preliminarily examined for the fit between their distributions and the assumptions of multivariate analysis. In particular, multicollinearity was checked by calculating tolerance and variance inflation factors for all independent variables.

3. Results

Sixty-three consecutive patients were included in the study. Thirty-six (57%) were males, and their mean age was 29.7 years (SD = 12.5, range 4–60). The mean duration of epilepsy was 15.5 years (SD = 11.1, range 1–42). All patients attended all scheduled follow-up visits, with a mean follow-up period of 6.2 years (SD = 2.3, range 2–12). Eighteen (29%) had neurological examination remarkable for focal signs and 19 (30%) had mental retardation. The presence of preoperative sGTCS was reported in 25 patients (35%). Preoperative VEEG showed IED in all patients. Forty-nine (78%) had a detectable lesion on brain MRI examination. Surgical resection was frontal in 33 patients (52%), posterior in 24 patients (38%) and multilobar in 6 patients (10%). Based on histological examination of the resected brain tissue, 3 patients had no lesion, 20 had low-grade tumours, 15 focal cortical dysplasia, and 25 other lesions.

In lesional cases, lesionectomy was performed in 25 patients, subtotal lesionectomy in 6 patients, and lesionectomy plus cortectomy in 18 patients, of whom 17 underwent total resection. In the 14 cryptogenic cases, total cortectomy was performed in 13 patients, while subtotal cortectomy in the remaining one. Overall, 55 patients underwent total resection, while in 8 patients the resection was subtotal. APOS occurred in 7 patients (11%).

At the last follow-up visit, 34 patients (54%) were in Engel's Class Ia, 5 (8%) in Class Ib, 10 (16%) in Class II, 12 (19%) in Class III, while 2 (3%) were in Class IV. Overall, 39 patients (62%) were in Engel's Class I at the last follow-up visit and were thus classified as having a favourable outcome. Of these, 26 patients (41%) remained seizure-free over the entire follow-up period.

A total of 189 EEGs were available. The 126 performed at the 1-year and 2-year follow-up visits comprised both awake and sleep recordings, while the 63 performed at the 2-month follow-up visit consisted only of awake recordings. Thirty (48%) patients had IED in the postoperative EEG at 2 months, 40 (63%) at 1 year [13 (21%) in awake recording], and 38 (60%) at 2 years [17 (27%) in awake recording].

Of patients with IED in EEG at all postoperative time points, the majority had focal ipsilateral IED (70–82%), and few had focal bilateral (7–10%), contralateral/multifocal (0–7%) or diffuse (10–13%) IED. Overall, focal ipsilateral IED was detected in 50/63 (79%), 28/30 (93%), 29/40 (72%) and 29/38 (76%), focal bilateral in 5/63 (8%), 1/30 (3%), 6/40 (15%) and 5/38 (13%), contralateral/multifocal in 1/63 (2%), 1/30 (3%), 0/40 (0%) and 0/38 (0%), and diffuse in 7/63 (11%), 0/30 (0%), 5/40 (12%) and 3/38 (8%), preoperatively, 2, 12, and 24 months after surgery, respectively. Therefore, the distribution of IEDs tended to remain similar over time.

We also examined the relationship between postoperative IED location and the focus of seizure recurrence in patients with postoperative VEEG-documented seizures. Four patients with postoperative IED experienced seizures during the VEEG recording performed 1 and 2 years after surgery. In three of them, the focus of seizure recurrence overlapped with the location of postoperative IED, as well as with the focus identified by the preoperative VEEG. The other patient presented with stable focal bilateral IED on all three follow-up visits and had a right fronto-temporal focus as identified by both preoperative and postoperative VEEG.

Table 1
Prognostic significance of postoperative IED with respect to seizure outcome at the last follow-up observation.

EEG timing	IED Present		IED Absent		Sensitivity (CI 95%)	Specificity (CI 95%)	PPV (CI 95%)	NPV (CI 95%)	*p*	Odds ratio (CI 95%)	Likelihood ratio + (CI 95%)	Likelihood ratio – (CI 95%)
	Poor outcome	Good outcome	Poor outcome	Good outcome								
2 Months	17	13	7	26	71 (49–87)	67 (50–80)	57 (38–74)	79 (60–90)	0.008	4.9 (1.6–14.6)	2.1 (1.3–3.5)	0.44 (0.23–0.84)
1 Year (awake + sleep)	23	17	1	22	96 (77–100)	56 (40–72)	57 (41–71)	96 (76–100)	<0.001	29.8 (3.6–243.0)	2.2 (1.5–3.2)	0.07 (0.01–0.52)
1 Year (awake)	8	5	16	34	33 (16–55)	87 (72–95)	61 (32–85)	68 (53–80)	0.10	3.4 (0.8–14.6)	2.6 (0.8–8.4)	0.76 (0.57–1.04)
2 Years (awake + sleep)	22	16	2	23	92 (71–98)	59 (42–74)	58 (41–73)	92 (72–99)	<0.001	3.4 (0.95–112)	2.2 (1.5–3.3)	0.14 (0.04–0.55)
2 Years (awake)	11	6	13	33	46 (26–67)	85 (69–93)	65 (39–85)	72 (56–83)	0.02	4.6 (1.2–18.1)	3.0 (1.2–8.0)	0.64 (0.44–0.94)
IED on any single EEG vs patients with 3 EEG normal	24	26	0	13	100 (83–100)	33 (20–50)	48 (34–62)	100 (72–100)	<0.001	∞	1.5 (1.2–1.9)	0
IED on all 3 EEGs vs rest of patients	15	4	9	35	62 (41–80)	90 (75–97)	79 (54–93)	80 (64–90)	<0.001	14.6 (3.3–69.8)	6.1 (2.3–16.2)	0.42 (0.25–0.70)

CI = confidence intervals, IED = interictal epileptiform discharge, PPV = positive predictive value, NPV = negative predictive value.

Fifty (79%) patients had IED in at least one EEG (11 in one, 20 in two, 19 patients in all three EEGs). In 18 patients (29%) IED was first recorded 1 year after surgery, while in two patients it was first recorded 2 years after the operation.

We found a significant association between postoperative IED at each time point and unfavourable seizure outcome. With regard to the contribution of awake EEG as considered alone, the association between IED and poor seizure outcome was found to be significant 2 years after surgery, whereas it fell short of statistical significance 1 year after surgery. Overall, the strength of the association between IED and seizure outcome was greater for awake plus sleep recording as compared with awake recording alone. Table 1 reports the sensitivity, specificity, predictive values, and likelihood ratios for the presence of postoperative IED with respect to seizure outcome.

We also tried to correlate seizure outcome with the number of EEGs with IED. Of patients without IED on all postoperative EEGs, none had unfavourable outcome. Nine persent of patients with IED in one EEG had poor outcome, while 79% of patients with IED in all three EEGs had unfavourable outcome (Fig. 2).

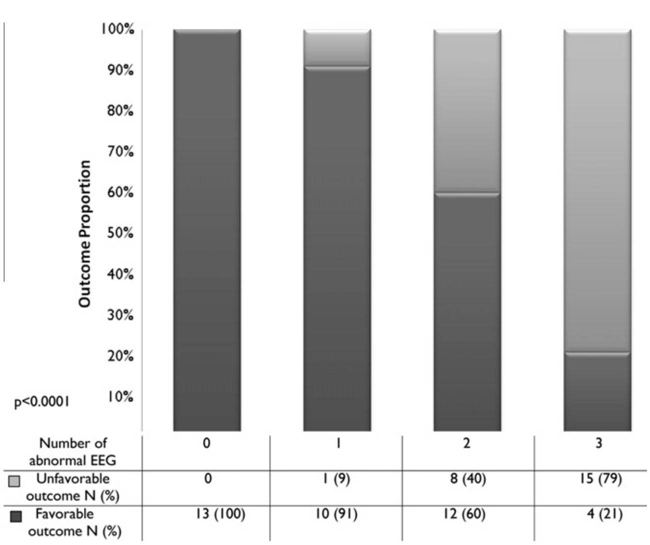

Fig. 2. Correlation between number of EEGs with IED and seizure outcome.

Apart from postoperative IED, the following pre- and post-operative factors were identified as associated with seizure outcome in univariate analysis: no evidence of lesion on preoperative MRI ($p = 0.009$), presence of sGTCS ($p = 0.002$), mental retardation ($p = 0.003$), preoperative focal neurological signs ($p = 0.008$), incompleteness of resection ($p = 0.004$). The presence of APOS fell just short of statistical significance ($p = 0.09$), while the other factors examined were not found to be associated with seizure outcome.

In multiple regression analysis, seizure outcome served as dependent variable, while all factors identified as associated with seizure outcome in univariate analysis (sGTCS, evidence of lesion on preoperative MRI, preoperative focal neurological deficits, mental retardation, incompleteness of resection) were entered as predictors together with early (2 months) postoperative IED. Given its borderline association with seizure outcome, we entered as predictor the presence of APOS, too.

In multiple regression analysis, the presence of early postoperative EEG epileptiform abnormalities was found to be independently associated with unfavourable seizure outcome (Table 2). The independent risk of unfavourable outcome was estimated as about nine times greater in patients with early postoperative IED as compared with those without IED. Unfavourable seizure outcome was also found to be independently associated with mental retardation, normal MRI, and incomplete resection of the epileptogenic cortex.

4. Discussion

To the best of our knowledge, this is the largest study of the relationship between IED after epilepsy surgery and outcome performed on ET epilepsy patients alone. As reviewed by Rathore and Radhakrishnan (2010), only 10 published studies on this topic dealt with patients with ET epilepsy, for a total of 373 patients (Godoy et al., 1992; Patrick et al., 1995; Janszky et al., 2000; Boesebeck et al., 2002; Hildebrandt et al., 2005; Jeha et al., 2007; Elsharkawy et al., 2008, 2009; Ghacibeh et al., 2009; Jehi et al., 2009). Four of these studies included also patients with TLE (Godoy et al., 1992; Patrick et al., 1995; Hildebrandt et al., 2005; Ghacibeh et al., 2009). Considering only patients with ET resections, the prevalence of IED at the first postoperative EEG was 34%, the mean follow-up time was 4.2 years, and the proportion of patients who were free from seizures at the last follow-up visit was 59%. In

Table 2
Multiple logistic regression analyses with seizure outcome as dependent variable, and presence of postoperative IED 2 months after surgery, mental retardation, preoperative focal neurological signs, presence of sGTCS, no evidence of lesion on preoperative MRI, APOS, incompleteness of resection as independent variables ($N = 63$).

	Seizure outcome					
	Chi square	42.5***				
	p	<0.001				
	Nagelkerke R^2	0.67				
		B	SE	Wald	*p*	OR (95% CI)
Incompleteness of resection		3.1	1.6	3.9	0.049	21.9 (1.0–473.0)
APOS		1.0	1.3	0.6	0.425	2.8 (0.2–33.6)
Evidence of lesion on preoperative MRI		2.8	1.3	5.0	0.025	16.8 (1.4–199.1)
sGTCS		1.2	0.9	1.7	0.185	3.2 (0.6–18.5)
Mental retardation		2.1	1.0	4.5	0.034	8.3 (1.2–58.6)
Preoperative focal neurological signs		0.4	1.1	0.1	0.736	1.4 (0.2–12.2)
Postoperative IED at 2 months		2.2	1.0	4.7	0.030	9.1 (1.2–67.2)

CI = confidence intervals, IED = interictal epileptiform discharge, APOS = acute postoperative seizures, GTCS = secondarily generalised tonic-clonic seizures.

our study, the prevalence of IED at the first postoperative EEG was slightly higher (48%), the proportion of patients who were found to be seizure-free at the last follow-up visit was similar (62%), while the mean follow up-duration was about 50% longer. In our series, consistently with the few published studies dealing with this issue (Patrick et al., 1995; Jeha et al., 2007; Jehi et al., 2009), the majority of postoperative IED were localised at the resection site. This is likely to ascribe to the fact that patients with multifocal or contralateral preoperative IED were usually not offered epilepsy surgery.

Previous studies showed a strong association between postoperative IED and unfavourable seizure outcome in ET resections (OR 5.6; 95% CI 3,9-9.3) (Rathore and Radhakrishnan, 2010). Consistently with this literature, we observed a strong association between IED following resective surgery and poor seizure outcome. Indeed, EEG epileptiform abnormalities detected as early as 2 months after surgery were found to be associated with a 9-fold increase in risk of poor outcome, even controlling for all factors identified as predictors of seizure outcome in our patient population.

Also, we found that the risk of unfavourable outcome increased with the number of EEGs with IED. This association, recently observed amongst surgically treated patients with TLE (Rathore et al., 2011), has not previously been investigated in patients undergoing ET epilepsy surgery. The reduced strength of the association between poor seizure outcome and postoperative IED 1 and 2 years after surgery in awake EEG alone as compared with awake plus sleep EEG suggests that the greater predictive power of serial postoperative EEGs is likely to ascribe to the inclusion of sleep recording. Indeed, sleep is an activation technique commonly used to help increase the occurrence of interictal epileptiform abnormalities (Mendez and Brenner, 2006). Other factors, such as the longer overall recording time or the repetition of the examination at specific follow-up time points, may also have contributed to the greater predictive power displayed by serial postoperative EEGs.

The very few studies investigating the relationship between extent of resection and postoperative EEG in surgically treated ET epilepsy yielded contradictory findings (Janszky et al., 2000; Boesebeck et al., 2002). In our study, we observed an association between incomplete resection of the epileptogenic zone and worse prognosis. Differences in lesion size and localisation may account for this inconsistency between studies.

As observed by Rathore et al. (2011) in TLE surgery, the majority of our patients with epileptiform abnormalities in postoperative EEG had IED on the same side of surgery; also, the location of postoperative IED correlated with the focus of seizure recurrence in patients with postoperative VEEG-documented seizures. This suggests that incomplete removal of the epileptogenic cortex is a more likely explanation than new epileptogenesis. Our results are consistent with the observation that recurrent seizures originate at or adjacent to the site of resection in most patients with failed TLE surgery (Hennessy et al., 2000).

This study has several limitations. First, the study sample was at the low end for studies of prognostic factors including multivariate analysis. However, the study is larger than previous similar studies on patients with ET epilepsy. Second, the epileptologist who examined the EEGs was not masked to current clinical status, which may have biased IED detection. However, given that the assessment was performed prospectively, the rater could not be aware of the long-term outcome, which differed from short-term outcome as several cases achieved sustained remission despite the occurrence of seizures during the first months after surgery. Third, our first follow-up evaluation was performed somewhat earlier as compared with previous studies. Acute postoperative factors may affect an EEG performed early in the postoperative period. However, the prognostic value displayed by early EEG epileptiform abnormalities suggests that 2 months after surgery is a reasonable time window to perform EEG in order to predict long-term seizure outcome. Fourth, we did not perform long-term EEG recording including sleep on occasion of the 2-month follow-up visit, which prevented us to examine the relative contribution of EEG during wakefulness and sleep at this time point. Further studies are needed to shed light on this issue. Finally, the discontinuation of AEDs over the follow-up period in some patients based on several clinical factors including EEG findings may have confounded the results. However, no patient underwent changes in AED treatment during the first year of follow-up. Also, if bias occurred, it was likely in the direction of underestimation of the risk of worse outcome associated with the presence of IED, as AEDs were withdrawn or reduced in dosage only in seizure-free patients without EEG epileptiform anomalies.

In conclusion, this study suggests that postoperative IED may predict long-term outcome in patients undergoing resective surgery for ET epilepsy. The independent increase in risk of poor outcome associated with EEG epileptiform abnormalities detected as early as two months after surgery may have substantial practical importance. Serial postoperative EEGs including sleep recording may add further predictive power and aid in identifying patients who may safely discontinue AEDs or reduce their dosage.

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References

Aykut-Bingol C, Bronen RA, Kim JH, Spencer DD, Spencer SS. Surgical outcome in occipital lobe epilepsy: implications for pathophysiology. Ann Neurol 1998;44:60–9.

Beleza P, Pinho J. Frontal lobe epilepsy. J Clin Neurosci 2011;18:593–600.
Boesebeck F, Schulz R, May T, Ebner A. Lateralizing semiology predicts the seizure outcome after epilepsy surgery in the posterior cortex. Brain 2002;125:2320–31.
Di Gennaro G, Quarato PP, Sebastiano F, Esposito V, Onorati P, Mascia A, et al. Postoperative EEG and seizure outcome in temporal lobe epilepsy surgery. Clin Neurophysiol 2004;115:1212–9.
Di Gennaro G, Picardi A, Sparano A, Mascia A, Meldolesi GN, Grammaldo LG, et al. Seizure clusters and adverse events during pre-surgical video-EEG monitoring with a slow anti-epileptic drug (AED) taper. Clin Neurophysiol 2012;123:486–8.
Engel Jr J. Surgery for seizures. N Eng J Med 1996;334:647–52.
Elsharkawy AE, Alabbasi AH, Pannek H, Shultz R, Hoppe M, Pahs G, et al. Outcome of frontal lobe epilepsy surgery in adults. Epilepsy Res 2008;81:97–106.
Elsharkawy AE, El-Ghandour NM, Oppel F, Pannek H, Shultz R, Hoppe M, et al. Long-term outcome of lesional posterior cortical epilepsy surgery in adults. J Neurol Neurosurg Psychiatry 2009;80:773–80.
Falco C, Sebastiano F, Cacciola L, Orabona F, Ponticelli R, Stirpe P, et al. Scalp electrode placement by EC2 adhesive paste in long-term video-EEG monitoring. Clin Neurophysiol 2005;116:1771–3.
Ghacibeh GA, Smith JD, Roper SN, Gilmore R, Elsenschenk S. Seizure recurrence following epilepsy surgery: is post-operative EEG helpful? Seizure 2009;18:193–6.
Gloor P. Contribution of electroencephalography and electrocorticography to neurosurgical treatment of the epilepsies. In: Purpura DO, Penry JK, Walter RD, editors. Neurosurgical Management of the Epilepsies. New York: Raven Press; 1975. p. 59–105.
Godoy J, Luders H, Dinner DS, Morris HH, Wyllie E, Murphy D. Significance of sharp waves in routine EEGs after epilepsy surgery. Epilepsia 1992;33:285–8.
Gotman J, Koffler DJ. Interictal spiking increases after seizures but does not after decrease in medication. Electroencephalogr Clin Neurophysiol 1989;72:7–15.
Hennessy MJ, Elwes RD, Binnie CD, Polkey CE. Failed surgery for epilepsy: a study of persistence and recurrence of seizures following temporal resection. Brain 2000;123:2445–66.
Hildebrandt M, Schulz R, Hoppe M, May T, Ebner A. Postoperative routine EEG correlates with long-term seizure outcome after epilepsy surgery. Seizure 2005;14:446–51.
Janszky J, Jokeit H, Schulz R, Hoppe M, Ebner A. EEG predicts surgical outcome in lesional frontal lobe epilepsy. Neurology 2000;54:1470–6.
Jeha LE, Najm I, Bingaman W, Dinner D, Widdess-Walsh P, Lüders H. Surgical outcome and prognostic factors of frontal lobe epilepsy surgery. Brain 2007;130:574–84.
Jehi LE, O'Dwyer R, Najm I, Alexopoulos A. A longitudinal study of surgical outcome and its determinants following posterior cortex epilepsy surgery. Epilepsia 2009;50:2040–52.
Mendez OE, Brenner RP. Increasing the yield of EEG. J Clin Neurophysiol 2006;23:282–9.
Noachtar S, Binnie C, Ebersole J, Mauguière F, Sakamoto A, Westmoreland B. A glossary of terms most commonly used by clinical electroencephalographers and proposal for the report form for the EEG findings. The International Federation of Clinical Neurophysiology. Electroencephalogr Clin Neurophysiol Suppl 1999;52:21–41.
Patrick S, Berg A, Spencer SS. EEG and seizure outcome after epilepsy surgery. Epilepsia 1995;36:236–40.
Quarato PP, Di Gennaro G, Mascia A, Grammaldo LG, Meldolesi GN, Picardi A, et al. Temporal lobe epilepsy surgery: different surgical strategies after a non-invasive diagnostic protocol. J Neurol Neurosurg Psychiatry 2005;76:815–24.
Rathore C, Radhakrishnan K. Prognostic significance of interictal epileptiform discharges after epilepsy surgery. J Clin Neurophysiol 2010;27:255–62.
Rathore C, Sarma SP, Radhakrishnan K. Prognostic importance of serial postoperative EEGs after anterior temporal lobectomy. Neurology 2011;76:1925–31.
Sackett DL, Haynes RB, Tugwell P, Guyatt GH. Clinical epidemiology: a basic science for clinical medicine. 2nd ed. Hagerstown: Lippincott Williams & Wilkins; 1991.