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Clinical Research

Lateralized Postictal EEG Delta Predicts the Side of Seizure Surgery in Temporal Lobe Epilepsy

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Summary: *Purpose:* The concordance of lateralized EEG postictal polymorphic delta activity (PPDA) to the side of seizure origin in temporal lobe epilepsy (TLE) has received limited study. Our objective was to study the lateralizing value of PPDA in patients with documented TLE.

Methods: A cohort of consecutive adults with TLE, detailed presurgical evaluation before temporal lobectomy, and minimal follow-up of 2 years were included. One author masked the ictal rhythm of presurgical EEGs and randomly presented 20 s of preictal and the postictal EEG to two electroencephalographers who were blind to all clinical data. They independently assigned PPDA to one of three categories: not present, bilateral, or lateralized (defined as newly appearing or an amplitude >50% of the preictal record).

Results: Eighty seizures from 29 patients were studied. Fifteen patients had a left, and 14 had a right temporal lobectomy. Twenty-three patients were seizure free or substantially improved (defined as simple partial or nocturnal seizures only). Lateralized PPDA was present in 64% of all EEGs and at least one record from 22 (76%) patients. Lateralized PPDA, when present, was concordant with the side of surgery in 96% of the EEGs.

Conclusions: Lateralized PPDA is highly predictive of the side of ultimate temporal lobectomy, and by inference the side of seizure origin. **Key Words:** Postictal—Delta—EEG—Temporal—Epilepsy.

Accurate interpretation of ictal electroencephalograms (EEGs) is important for identifying the anatomic seizure focus of patients considered for resective epilepsy surgery. Ictal features previously studied include the EEG changes at seizure onset, rhythmic patterns during seizure evolution, and postictal changes (1). The postictal EEG features of partial seizures include regional polymorphic delta activity, regional attenuation, activation of focal spikes, or no change (2). Kaibara and Blume (2) studied 51 seizures (42 of temporal lobe origin) from 51 patients and found regional delta as the most common postictal change (57% of seizures). Other authors identified lateralized delta in ≤69% of postictal EEGs from patients with focally originating seizures (1,3).

The congruity of lateralized EEG postictal polymorphic delta activity (PPDA) to the side of ictal onset in temporal lobe epilepsy (TLE) has been infrequently studied (1–3). Previous studies suggested that PPDA, when present and clearly depicted, was highly correlated with the side of seizure onset (1–3). However, the electroencephalographers in these studies were not blind to the ictal rhythms in the examined EEGs. Ictal lateralization (deduced from the EEG changes at seizure onset and rhythm changes during seizure evolution), clinical data, and neuroimaging could bias EEG interpretation of the presence and laterality of PPDA.

The objective of this study was to evaluate the relationship of PPDA to the side of seizure onset in patients with TLE by reviewing postictal EEGs with the electroencephalographers blind to clinical data and ictal EEG. We hypothesized that lateralized PPDA reliably indicates the side of seizure onset.

METHODS

A cohort of consecutive adult patients with TLE, temporal lobectomy after detailed presurgical evaluation, and minimal follow-up of 2 years were included. All

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patients had detailed inpatient video-EEG monitoring before temporal lobectomy between 1990 and 1996. Patients were followed up in the adult epilepsy clinic of the Queen Elizabeth II Health Sciences Centre, Halifax, Nova Scotia, Canada.

Clinical data obtained from the hospital medical records included patient age, sex, side of epilepsy surgery, pathologic diagnosis of resected tissue, and surgical outcome at last patient contact. The patients were categorized to one of two surgical outcomes groups: group A patients were defined as seizure free or substantially improved (auras only or nocturnal seizures only) and group B (patients with continuing seizures). Patients who experienced seizures coincident with abrupt drug discontinuation or seizures in the first postoperative week were included in group A if they subsequently completed 2 postoperative years without seizures.

At our institution we generally record a minimum of three seizures before surgical decisions are made. We studied only the first three technically satisfactory complex partial ictal EEGs from each patient to avoid bias from patients who had many seizures recorded.

Electrodes were applied in accordance with the International 10-20 System of electrode placement. All EEGs were originally recorded on videotape (Telefactor recording system) and subsequently transcribed to paper using a Grass (model 8) 16-channel EEG machine with a paper speed of 30 mm/s.

An EEG technologist (S.R.) separated the paper recordings into three segments: (a) a preictal EEG sample of 20 s obtained from the EEG immediately preceding the onset of any EEG change that initiated a seizure; (b) an ictal segment (defined as the earliest identifiable EEG ictal change and continuing until the cessation of repetitive epileptiform potentials and/or rhythmic waves); and (c) a postictal segment (beginning at the end of the ictal segment and continuing until the EEG returned to the preictal state or 300 s elapsed, whichever occurred first. Only a brief segment of preictal EEG (20 s) was reviewed to identify baseline delta activity; longer segments would likely reveal focal interictal spikes that could bias the interpretation of PPDA toward the ipsilateral side.

PPDA was defined as a one- to three-cycle/s polymorphic waveform that was newly appearing or an amplitude >50% compared with any delta in the preictal EEG segment.

An EEG grading system was developed. Each postictal EEG sample was assigned to one of the following three categories: (a) not present, (b) bilateral, or (c) lateralized (defined as delta with voltage more than twice the voltage of delta present contralaterally, and present for ≥20 s from the beginning of the postictal segment).

Co-author S.R. shuffled and randomly presented the preictal and corresponding postictal EEG segments to the electroencephalographers (M.J. and M.S.) for interpretation. Records from the same patient were not interpreted sequentially. The postictal segments were compared with the preictal segments. Each author independently interpreted the EEGs according to the grading system described earlier. They were blind to all patient-identifying data, the ictal EEG segment, and all other clinical information at the time of EEG interpretation.

Other EEG data collection included the recording montage, sensitivity, filter settings, presence of additional electrodes, and the duration of the postictal segments. PPDA was compared with the side of temporal lobectomy.

Statistical analyses were performed using Epi Info, version 6 (4,5).

RESULTS

Twenty-nine patients met the study admission criteria. There were 16 women and 13 men, with ages at the time of temporal lobectomy ranging from 17 to 45 years (mean, 28 ± SD 6.9). Fifteen patients had a left and 14 had a right temporal lobectomy. The pathology revealed mesial temporal sclerosis (MTS) in 18 (62%), normal pathology in eight (28%), and a tumor in three (10%). Twenty-three (79%) patients were 2 years seizure free or substantially improved (group A), and six (21%) patients continued to have recurrent seizures (group B).

Eighty EEGs from the 29 patients were studied. Seven EEGs from five patients could not be retrieved. Ranges of EEG settings among the samples were: sensitivity, 5–15 μV/ mm; high-frequency filter, 70 Hz; and time constant, 0.3 s. All seizures were recorded on bipolar montages (anterior-posterior or coronal); montage reformatting was not available. Sphenoidal electrodes were used in 28 (35%) EEGs.

The duration of the postictal EEG segments ranged from 50 to 300 s (mean, 245 s). Figure 1 shows an example of a postictal EEG segment assigned by both electroencephalographers as lateralized, left side. Lateralized PPDA was present in 51 (64%) of all 80 EEGs and in at least one recording from 22 patients (22 of 29 or 76%).

Table 1 shows the PPDA assignment by each EEGer. The two authors agreed on the postictal EEG findings in 73 (91%) of the 80 seizures. There were seven recordings in which the findings were discordant: on two records, author 1 thought there was no postictal PPDA, and author 2 interpreted bilateral PPDA; on five recordings, author 1 thought there was bilateral PPDA, whereas author 2 interpreted a lateralized PPDA. They were never discordant for the laterality (i.e., left side vs. right side) of PPDA.

The correlation between PPDA in which *both* authors were in agreement (73 EEGs) and the side of ultimate

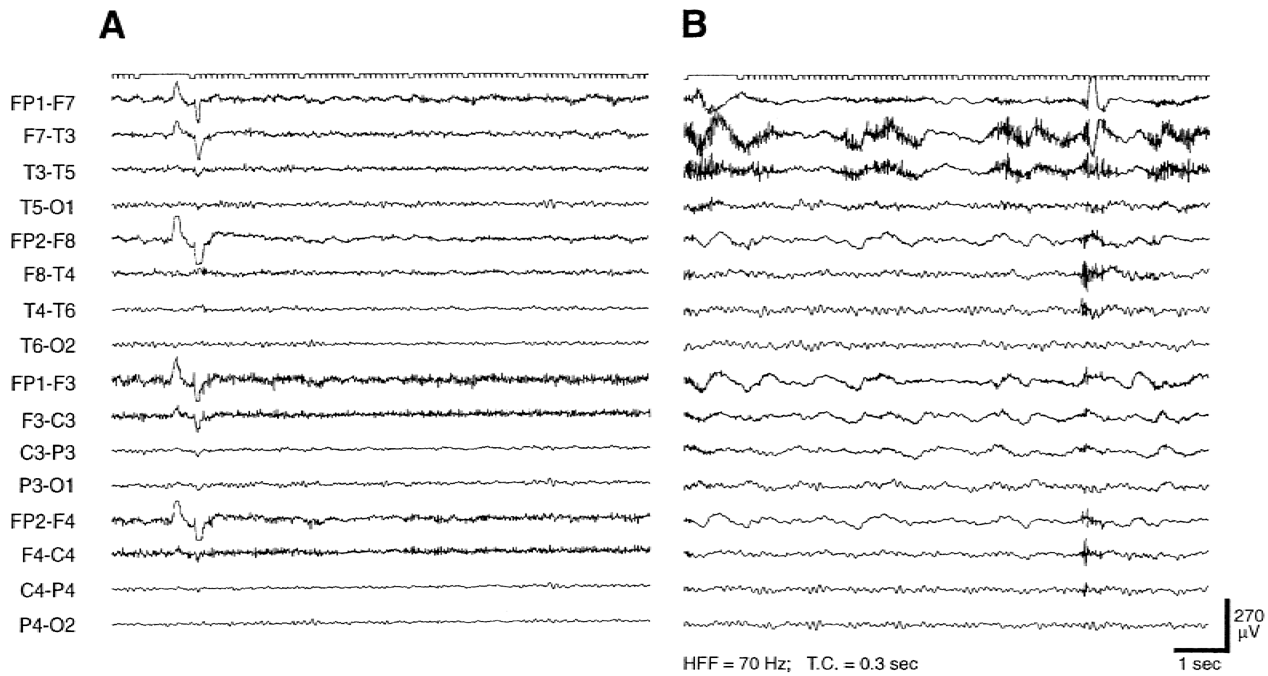

FIG. 1. Postictal EEG segment showing lateralized (left) polymorphic delta activity. **A**: Preictal segment. **B**: Postictal segment.

temporal lobectomy is shown in Table 2. Twenty EEGs demonstrated right-sided PPDA, and all of these recordings were obtained from patients who had a right temporal lobectomy; 26 EEGs demonstrated left-sided PPDA, and 24 (92%) of 26 were obtained from patients who had a left temporal lobectomy. Therefore, lateralized PPDA, when present, was concordant with the side of surgery in 44 (96%) of 46 EEGs.

There were only two EEGs with lateralized PPDA that were discordant from the side of temporal lobectomy. These two EEGs (from the same patient) demonstrated left-sided PPDA, whereas the third EEG showed right-sided PPDA. Subsequent subdural EEGs at another institution revealed seizures arising independently from each temporal lobe, with the majority of seizures of right-sided origin. This patient had a right temporal lobectomy but is not seizure free. Thus the two EEGs demonstrating left-sided PPDA may not have been falsely lateralizing. Excluding this patient from the analysis would result in 100% concordance of lateralized PPDA with the surgery side (sensitivity, 62%; specificity, 100%; and positive predictive value, 100%).

Only four EEGs from four patients revealed focal temporal spikes in the preictal segments. These spikes were not always associated with ipsilateral lateralized PPDA; one patient had left preictal spikes that were associated with right PPDA (assigned by both authors). This patient remained seizure free after a right temporal lobectomy.

DISCUSSION

Scalp EEG is inherently predisposed to poorly or incompletely record many aspects of seizures. Some factors that limit the accuracy of scalp recordings include the distance between the recording electrodes and the neural generators, the attenuating effects of intervening tissues (scalp, bone, cerebrospinal fluid), and artifacts (muscle and movement). An additional problem relates to the relatively unique EEG complexities of temporal lobe epilepsy "that cannot be reduced to a single mode of

TABLE 1. *The postictal polymorphic delta activity assignment by the two electroencephalographers*

	EEGer 1				
EEGer 2	Not present	Bilateral	Left	Right	Total
Not present	15*	0	0	0	15
Bilateral	2	12*	0	0	14
Left	0	3	26*	0	29
Right	0	2	0	20*	22
Total	17	17	26	20	80

n = 80 EEGs. Numbers refer to numbers of EEGs. Figures with an asterisk are those in which both EEGers agreed.

TABLE 2. *The correlation between lateralized postictal polymorphic delta activity assigned by both EEGers and the side of temporal lobectomy*

PPDA	Left temporal lobectomy number of EEGs	Right temporal lobectomy number of EEGs
Not present (n = 15)	8	7
Bilateral (n = 12)	7	5
Left (n = 26)	24	2
Right (n = 20)	0	20

PPDA, postictal polymorphic delta activity.

expression" (6). Temporal lobe ictal EEGs may manifest as an initial focal attenuation of background rhythms (7), a "start–stop–start" phenomenon (8), evolve to complex combinations of sinusoidal waves and repetitive epileptiform potentials of varying frequencies (9), and terminate with regional delta activity, regional attenuation, activation of spikes, or no residua (2). Accurate interpretation of ictal scalp EEG is of fundamental importance for patients considered for resective epilepsy surgery. EEG researchers should endeavor to answer the following questions: (a) Do distinctive EEG ictal scalp patterns exist? (b) How frequently are these patterns encountered? (c) Are these patterns readily recognizable (i.e., have high interobservor agreement)? and (d) How reliable are these patterns for localizing and lateralizing seizures?

Relatively few scalp-derived EEG patterns have been subjected to rigorous study with respect to their localizing or lateralizing utility. Risinger et al. (10) demonstrated the value of an easily identified 5-Hz (or faster) rhythm maximum at one sphenoidal or temporal electrode early in the course of a seizure. This rhythm was present in 52% of patients and, of these, 82% had an ipsilateral temporal lobe onset determined by depth recordings.

Walczak et al. (1) studied a similar pattern (defined as a theta or alpha frequency rhythm lasting ≥10 s and occurring within 40 s of seizure onset) but also analyzed EEG "activity at seizure onset" and postictal findings. In this study the authors used outcome from epilepsy surgery as the gold standard of the accuracy of scalp ictal EEG for identifying the epileptogenic zone. Three authors independently interpreted 119 seizures from 35 patients who had a temporal lobectomy and were seizure free for ≥2 years. Among the three EEG features addressed, the alpha–theta pattern and postictal slowing were more accurate than activity at seizure onset. The activity at seizure onset correctly lateralized the side of seizure onset in 33–59% of EEGs, postictal slowing in 43–64%, and rhythmic theta–alpha in 64–76%. Activity at seizure onset was generalized or obscured by artifact in 36–66%; when these records were *excluded* from the analysis, the lateralizing value of activity at seizure onset was 92–97%. Postictal slowing was 96–100% accurate if EEGs were excluded in which no lateralizing judgments could be made (34–57% of all EEGs). Rhythmic theta–alpha was absent or could not be lateralized in 22–35% of recordings; the lateralizing value was 97–99% accurate in the records that clearly contained this pattern.

In our study group we found that 64% of partial complex seizures of temporal lobe origin have lateralized PPDA. This EEG abnormality, as we defined it, is readily recognizable with the concordance between the authors of 91%. Lateralized PPDA was concordant with the side of temporal lobectomy in 96%. In the study group, 79% of patients are seizure free or substantially improved, therefore suggesting that the seizure focus was resected. These results support the findings of the few previously published retrospective studies of postictal EEG abnormalities, all of which suggested the strong association of lateralized PPDA with the side of ictal onset (1–3).

A potential strength of the present study is the method. In previous studies that addressed PPDA, the authors were not blind to the clinical information (2,3), and more important, the other ictal EEG features (1–3). Focal or lateralized EEG abnormalities at seizure onset or during the evolution of the seizure could substantially bias the interpretation of PPDA to that side.

A potential confounding factor in this study is the influence of lateralized PPDA on the original decision to proceed with a temporal lobectomy. Surgical decisions at our institution are made using a combination of clinical features of the seizures, interictal and ictal EEG, magnetic resonance imaging, and neuropsychology data (including sodium amytal studies if required). A strict decision-making algorithm is not used, and we cannot quantitate, in retrospect, the relative weight that was given to lateralized PPDA in comparison with other components, alone or in combination, at the time of surgical decisions. A blinded prospective study of lateralized PPDA is warranted.

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