EEG of Partial Seizures

Amit Verma* and Rodney Radtke†

Summary: EEG remains the primary technique in the diagnosis, characterization, and localization of partial seizures. This review examines the significance and character of interictal epileptiform abnormalities, periodic lateralized epileptiform discharges, and ictal patterns in patients with partial epilepsy. Interictal epileptiform discharges are common and assist in the diagnosis and localization of partial seizures. Fortunately, true “false positive” EEGs with focal epileptiform abnormalities are distinctly rare. Periodic lateralized discharges have characteristics of both interictal and ictal activity and are an area of controversy as to their clinical significance. Ictal patterns in partial seizures are variable, with the most distinctive features seen in seizures from a mesial temporal lobe origin. The unifying EEG feature of a partial seizure is in its evolution. A partial seizure begins with a clear delineation of the onset of activity that is distinct from the preceding background, followed by an evolution of this activity in both frequency and amplitude and terminating with an identifiable cessation of the rhythmic pattern that merges again into the background activity.

Key Words: Partial seizures, EEG, Epileptiform activity, PLEDs, Ictal EEG patterns.

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The International League Against Epilepsy defines focal seizures as “a seizure whose initial semiology indicates, or is consistent with, initial activation of only part of one cerebral hemisphere.” (Commission of ILAE, 1981). The EEG findings and ictal semiology of partial seizures are varied and depend on the site of focal seizure onset. It is extremely important to understand those differences (whether interictal, ictal or postictal) not only for diagnosis and characterization but also for planning surgical procedures in patients with medically refractory partial seizures.

INTERICTAL EPILEPTIFORM DISCHARGES

Several studies have demonstrated that interictal epileptiform discharges (IIEDs) are rare in individuals without epilepsy. The most common IIEDs that are seen in normal individuals include centro-temporal spikes, generalized spike-wave discharges, and photoparoxysmal discharges. The unifying feature of these discharges is that they all have a strong genetic component. It is easy to conceive of an individual who has never had a seizure but who carries the genetic trait that would manifest itself with such an EEG pattern. Conversely, unambiguous IIEDs typical for cryptogenic partial epilepsy are distinctly rare in individuals without epilepsy. In a healthy community hospital-based pediatric population, only 1.9% to 3.5% of the population was noted to demonstrate IIEDs of any character on routine EEG (Eeg-Olofson et al., 1971; Cavazzuti et al., 1980). Similarly in healthy young adults, the frequency of IIEDs was 0.5% (Bennett, 1967; Gregory et al., 1993). The chance of recording IIEDs in hospitalized patients with a neurologic illness was 2.2% versus 0.6% in patients without a neurologic illness (Zivin and Marsan, 1968). In patients with a psychiatric diagnosis the risk was found to be somewhat higher at 2.6% (Bridge, 1987).

Even in patients with a history of seizures, the data concerning the diagnostic yield of EEG is confusing. Studies are difficult to compare due to differences of study populations, diagnostic criteria, and, most importantly, different skills and perspectives of interpreting clinicians. Initial EEGs are “positive” in 29% to 55% of patients and repeated EEGs increase the yield to 80% to 90% (Goodin et al., 1984; Marsan and Zivin, 1970; Salinsky et al., 1987). EEG recordings of longer duration, particularly if they include sleep, increase the yield of identifying epileptiform abnormalities. Remarkably, in one study in which patients with intractable partial epilepsy underwent video EEG monitoring for a mean of 6.9 days, 19% of patients did not demonstrate IIEDs (Walczak et al., 1992). This suggests that the yield of IIEDs may be lower in individuals with partial as opposed to primary generalized epilepsy. IIEDs are more commonly identified in EEGs of children independent of seizure type. Certain antiepileptic drugs (AEDs) such as barbiturates and benzodiazepines are thought to suppress IIEDs, while other AEDs do not appear to affect the frequency of IIEDs in partial epilepsy. The reported increase in IIEDs in patients that are being weaned off of AEDs while undergoing video-EEG monitoring is not thought to be due to removal of the AEDs. Instead the increase in IIEDs is associated with the appearance of seizures, as the frequency of IIEDs is seen to increase immediately after a seizure (Marciani et al., 1985).

FOCAL SLOW ACTIVITY

Focal polymorphic delta activity (PDA) is commonly seen in patients with partial epilepsy. It is primarily associ-
ated with underlying structural abnormalities and has a poor predictive value for epilepsy. However, if no structural abnormality exists to explain the slowing, continuous focal PDA is associated with seizures in about 50% of patients. Focal PDA needs to be differentiated from temporal intermittent rhythmic delta activity (TIRDA), a distinct pattern that has a strong association with epilepsy. TIRDA’s rhythmic nature is distinctly different from PDA (Fig. 1). It usually occurs in runs lasting 3 to 20 seconds and has a strong association with temporal lobe epilepsy. It is commonly seen in association with ipsilateral IIEDs and in one study was seen in approximately one fourth of patients undergoing a presurgical workup for temporal lobe epilepsy (Geyer et al., 1999; Normand et al., 1995; Reiher et al., 1989).

PERIODIC LATERALIZED EPILEPTIFORM DISCHARGES

Periodic Lateralized Epileptiform Discharges (PLEDs) are prominent moderate to high amplitude sharp wave discharges that usually occur with a frequency of 0.5 to 2 Hz (Fig. 2). These typically have variable complexity and are distributed over large areas of one hemisphere. It is unusual to see PLEDs in the setting of otherwise normal background activity. PLEDs are usually seen in the setting of an acute destructive lesion and commonly resolve over days to weeks. They are strongly associated with clinical seizures and subsequent development of epilepsy. Up to 70% to 80% of patients with PLEDs on EEG exhibit overt clinical seizures and 3% to 66% subsequently develop epilepsy (Chatrian et al., 1964; Markand and Daly, 1971; Schwartz et al., 1973; Walsh and Brenner, 1987).

Traditionally PLEDs have been considered to be an ictal pattern as it does not evolve in frequency or distribution as would be expected with a partial seizure. Additionally, PLEDs may be seen in some patients who never experience clinical seizures and in whom no accompanying symptoms or deficits are identified. PLEDs also commonly resolve in a gradual fashion without treatment or intervention.

However, focal clinical symptoms such as focal motor jerking may sometimes be seen time locked to PLEDs on EEG, which then translates to the identification of a focal seizure even without a change in the EEG discharge. Often the resolution of PLEDs parallels the improvement of neurologic deficits such as altered mental status and focal weakness, suggesting that the active discharge is associated with the accompanying neurologic symptoms as seen in partial seizures. Possibly the most compelling evidence that PLEDs are an ictal phenomenon is their association with a focal increase in blood flow seen with single photon emission tomography (SPECT; Pohlmann-Eden et al., 1996). The increased blood flow defined on SPECT is consistent with that seen during partial seizures.

ICTAL PATTERNS

Partial seizures typically have ictal patterns that are distinctly different from their interictal activity. The EEG manifestations of partial seizures usually demonstrate a definite onset, an evolution, and an end. The beginning is often

FIGURE 1. EEG demonstrating left temporal intermittent delta activity (TIRDA). (Reproduced from Current Practice of Clinical EEG; Ebersole and Pedley (eds).)
nonspecific with either focal or generalized desynchronization, low voltage fast activity, or irregular focal or bilateral delta activity. The evolution of the seizure is often the most distinct part with an evolution from lower amplitude, faster activity to higher amplitude activity with slower frequencies. The termination of the seizure is easily discernible with the seizure discharge merging into slow activity that is distinctly less rhythmic than the ictal discharge. The primary exception is seen with some simple partial seizures; such as rhythmic focal discharges with accompanying motor jerks that may not have a clear evolution of frequency or amplitude.

In scalp EEG recordings, partial seizures may not have a clear EEG correlate. This is particularly true with simple partial seizures during which 70% to 90% of the clinical seizures do not have a definite EEG correlate. With routine scalp electrodes, a discernible change has been reported in 11% to 19% of simple partial seizures while the use of sphenoidal electrodes may increase the yield to 28% (Palmini et al., 1992; Devinsky et al., 1988; Lieb et al., 1976; Sirven et al., 1996). On the other hand, scalp EEG changes are present in 85% to 95% of complex partial seizures. An absence of a change on scalp EEG during complex partial seizures is most commonly seen in patients with frontal lobe epilepsy. The lower incidence of EEG changes seen with frontal lobe seizures is attributed to the large area of mesial and inferior frontal cortex that is not easily assayed by scalp electrodes. Secondarily generalized tonic clonic seizures are essentially always associated with a scalp EEG correlate. If there is rapid spread of the ictal activity, a focal onset may not be readily apparent. Additionally, the scalp EEG recording may be obscured by myogenic artifact and may be difficult to discern. However, profound postictal slowing will be identified consistently after a secondarily generalized tonic-clonic seizure. When able to be identified, the EEG pattern during secondarily generalized tonic-clonic seizures is similar to that seen with primarily generalized tonic-clonic seizures. The usual pattern is rapid low amplitude spiking evolving to a slower spike-slow wave discharges. These patterns correlate with the tonic and clonic activity respectively. The EEG ictal patterns seen with seizures arising in different brain regions can be very distinct and are discussed in further detail later.

**MESIAL TEMPORAL LOBE EPILEPSY**

In patients with mesial temporal lobe epilepsy (MTLE), interictal EEGs often demonstrate anterior temporal spikes with maximal amplitude in the anterior temporal or temporal basal electrodes (Fig. 3). These are commonly detected using either anterior subtemporal (T1–T2) or sphenoidal electrodes. In roughly one third of patients, the IIEDs are present bilaterally during sleep. Strongly lateralized IIEDs (>90%–95%) are predictive of side of seizure onset (Chung et al., 1991). The interictal, ictal, and postictal EEG in MTLE demonstrate some very characteristic findings. No definite EEG change is usually seen with auras or the initial clinical behavior change (Fig. 3A). However, lateralized rhythmical theta or alpha activity (5Hz or greater) is seen in 80% of patients with mesial temporal lobe epilepsy and typically occurs 10 to 40 seconds after clinical seizure onset (Fig. 4B; Walczak et al., 1992; Risinger et al., 1989). If present, this activity correctly lateralizes seizure onset in about 95% of patients. Focal postictal slow activity is present in about 70% of seizures and if present is consistent with side of seizure onset correctly in about 90% of patients (Fig. 4C; Walczak et al., 1992; Ebersole and Pacia, 1996).
Neocortical temporal lobe epilepsy has certain EEG features that may help differentiate it from mesial temporal lobe epilepsy (Foldvary et al. 1997; Walczak, 1995; Gil–Nagel and Risinger, 1997). The IIEDs and the ictal rhythmic activity are more broadly distributed, often extending to the parasagittal area. The rhythmic ictal activity is also slower, less stable in terms of both frequency and amplitude, and the amplitude distribution of this activity is often higher in the parasagittal electrodes. In addition, an absence of an identifiable EEG change is slightly more common with neocortical temporal lobe epilepsy as compared mesial temporal lobe epilepsy.
FIGURE 4. (B): Approximately 30 seconds later, EEG demonstrates lateralized rhythmic theta activity maximal over the left temporal region.

FIGURE 4. (C): EEG following termination of temporal lobe seizure demonstrating left temporal slowing.
Fronsal Lobe Epilepsy

In frontal lobe epilepsy, interictal EEGs are more frequently normal, and even with repeated EEGs IIEDs are seen in only 65% to 70% of patients. Focal IIEDs are seen in 40% to 60% of EEGs as midline or bilateral discharges are more common than in patients with temporal lobe epilepsy. The bilateral spike and wave discharges seen often have an amplitude asymmetry and represents secondary bilateral synchrony rather than true generalized onset. The duration of the seizures seen in frontal lobe epilepsy tends to be shorter compared to the seizures seen with TLE, and the postictal periods are shorter as well. As discussed previously, frontal lobe seizures more commonly show no definite correlate on scalp EEG as compared to seizures of temporal lobe onset. The vigorous physical activity frequently present in frontal lobe seizures may result in greater myogenic and movement artifact to further complicate the interpretation. Given these difficulties, it is understandable how scalp localization in frontal lobe seizures is often problematic. False localization may occur especially to the ipsilateral temporal lobe. Ictal onset and evolution may appear generalized and often represents secondary bilateral synchrony, further limiting the confidence even in lateralizing the side of seizure onset (Salanova et al., 1993; Williamson et al., 1985; Rasmussen, 1983).

Parietal Lobe Epilepsy

Parietal lobe epilepsy, somewhat surprisingly, represents the most difficult seizure type to evaluate and localize with scalp EEG. Scalp EEG recordings are usually nonlocalizing or falsely localizing. In one study centroparietal IIEDs were seen in only 5% to 15% of patients with parietal lobe seizures (Salanova et al., 1995). The IIEDs are typically widely distributed and it is common to have them reflected to surrounding regions. Ictal patterns are similarly poorly localized. Less than 10% of ictal patterns are well localized to the parietal region and 30% are associated with secondary bilateral synchrony. Ictal patterns may also falsely localize to the ipsilateral temporal lobe (Cascino et al., 1993; Williamson et al., 1992). The difficulties with the localization of parietal lobe seizures even extends to invasive monitoring, such that in the absence of a structural lesion localization of parietal onset seizures remains extremely problematic.

OcCipital Lobe Epilepsy

Scalp EEG recordings in occipital lobe epilepsy are once again a poor source for attempted seizure localization. IIEDs are restricted to the occipital lobe in less than 20% of patients. As was seen with frontal and parietal onset, IIEDs are often falsely localized to the ipsilateral temporal region or may manifest as synchronous or bilateral IIEDs. A rhythmic ictal pattern may be seen in the occipital region at onset in about 15% to 20% of patients. This may spread to motor areas and result in rapid generalization, or alternatively the seizure activity may spread to the ipsilateral temporal lobe and have EEG and clinical features similar to MTLE (Salanova et al., 1992; Williamson et al., 1992). Often the clinical features (visual hallucinations, identified structural abnormality) are more helpful than scalp EEG in ascertaining an occipital onset to partial seizures.

Summary

Scalp EEG continues to serve a dominant role in the diagnosis and characterization of partial seizures. As can be seen from the above discussion, IIEDs are common, particularly in MTLE, and are somewhat less common in patients with seizures arising from the frontal, parietal, or occipital lobes. Fortunately, true false positives for focal IIEDs are distinctly rare. The ictal patterns are variable in partial epilepsy and depend, to a certain degree, on the region of onset. There are, however, unifying characteristics of partial seizures that can be used for diagnosis. These include an identifiable change from the interictal background at seizure onset, a clear evolution in the frequency and amplitude of this activity during the seizure, and an identifiable end of this activity. Seizures in MTLE appears to have the most consistent identifiable ictal pattern and are the most useful in confidently localizing sight of seizure onset from scalp EEG recordings.

References


