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Original Research Article

Interictal wave pattern study in EEG of epilepsy patients

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ABSTRACT

Background: EEG or Electroencephalogram is the most important diagnostic tool to detect Epilepsy. Interictal period is the time interval between two seizure episodes of an Epileptic patient. Certain wave patterns appear in the interictal period in the EEG which might predict the onset of a seizure or may give information about the last seizure attack. The aim of the study was to know how the interictal wave patterns help in diagnosing and classifying Epilepsy cases
Methods: The present study was done in the Department of Physiology in association with the Department of Neurology, Assam Medical College and Hospital, Dibrugarh, Assam from June 2014 to May 2015. 113 clinically diagnosed cases of Epilepsy were studied and analyzed through Electro-encephalogram using the internationally accepted 10-20 electrode placement method. The interictal period was enquired in the history and the wave patterns that appeared in the EEG were recorded. The EEG findings were compared with the clinical diagnosis.
Results: The IEDs detected were mainly of four types: Sharp waves, Spikes, Spike and wave and Polyspikes. It was found that the sharp waves (88.89%) were the predominant waveforms in the IEDs detected and this was followed by the '3 Hz spike and wave pattern'. It was also seen that the '3 Hz spike and wave pattern' was associated with 'Absence seizures'. And Myoclonic seizures were associated with polyspikes.
Conclusions: It is hereby concluded that certain wave patterns in EEG appear in certain types of epilepsy that can be clinically correlated for proper diagnosis of epilepsy.

Keywords: Epilepsy, Electroencephalography, Interictal wave patterns

INTRODUCTION

A long fascinating journey accomplished by medical science has helped mankind in unmasking various scientific truths behind age old debilating diseases with social myths behind; one of them being Epilepsy. Various innovative techniques were discovered to investigate the roots of such deadly diseases that created panic among mankind once upon a time. Electroencephalography was one such novel diagnostic technique that found its birth way back in 1827, when a medical practitioner from Jena, Dr. Hans Berger, found interest in recording high voltage human brain waves through galvanometers. Time flew and today EEG has become one of the common practice in the diagnosis and treatment of Epilepsy.

Electroencephalogram (EEG) is a measure of scalp-recorded voltages across time and represents the spontaneous electrical activity of the brain. It represents the summated extracellular pre-synaptic potentials (PSPs) that occur simultaneously in a large number of cortical pyramidal neurons that are oriented perpendicular to the scalp.[1]

Epilepsy may be defined as an intermittent derangement of the nervous system due to presumably a sudden, excessive, disorderly discharge of cerebral neurons. Each episode of neurologic dysfunction is called a seizure. Seizure may be convulsive when they are accompanied by motor manifestations or may manifest by other changes in neurologic functions like sensory, cognitive or emotional events.

The EEG is most useful in evaluating patients with suspected epilepsy. The presence of electrographic seizure activity, i.e., of abnormal, repetitive, rhythmic activity having an abrupt onset and termination and a characteristic evolution clearly establishes the diagnosis.

Interictal period is the time interval between two seizure episodes of an Epilepsy patient. Although the patient appears normal during this period, his brain exhibits certain changes in EEG, which has been interpreted by some authors as physiological adaptations. The EEG findings may be helpful in the interictal period by showing certain abnormalities that are strongly supportive of a diagnosis of epilepsy. Such epileptiform activity consists of bursts of abnormal discharges containing spikes or sharp waves. The presence of epileptiform activity is not specific for epilepsy, but it has a much greater prevalence in epileptic patients than in normal individuals. The EEG findings have thus been used in classifying seizure disorders and selecting appropriate anticonvulsant medication for individual patients.[2]

The International Federation of Societies for Electroencephalography and Clinical Neurophysiology describes interictal discharges as ‘a subcategory of epileptiform pattern, in turn defined as distinctive waves or complexes, distinguished from background activity, and resembling those recorded in a proportion of human subjects suffering from epileptic disorders’.[3]

The interictal discharges may be divided morphologically into sharp waves, spikes, spike-wave complexes and polyspike-wave complexes.

The following definitions are used

- *Sharp wave:* transient, clearly distinguishable from background activity, with pointed peak at conventional paper speeds and a duration of 70 to 200 milliseconds (mSpiks).
- *Spikes:* Same as sharp wave, but with a duration of 20 to 70 ms.
- *Spike-wave complex:* Pattern consisting of a spike followed by a slow wave.
- *Polyspike-wave complex:* Same as spike-wave complex, but with two or morespikes associated with one or more slow waves.[4]

There are variety of EEG patterns in different seizures, such as- a generalized symmetric,3 Hz spike and wave complex, beginning and ending abruptly on a normal EEG background- is the hallmark of absence seizures.[5] TIRDA (Temporal intermittent rhythmic delta activity) is specific of temporal lobe epilepsy.[6] Spikes/Sharp waves in corresponding area found in complex partial seizures and periodic complexes, slow spike wave discharges found in Myoclonic seizures, generalized polyspike and slow waves found in Juvenile Myoclonic Epilepsy.

Thus, EEG wave pattern study during the interictal period can give us a lot of information about how the brain waves vary with different types of Epilepsy. They may even reveal about which parts of the brain are involved in the disease process.

The aim of the study was to know the EEG wave patterns in Epilepsy patients presenting with different type of seizures, during the interictal period.

The objective of the study was to know about the predominance of the type of EEG wave forms in the different types of epileptic seizures, to know how the abnormal EEG findings in the interictal period supports the diagnosis of epilepsy in clinically suspected patients and how it helps in classifying epilepsy.

METHODS

The study included 113 clinically diagnosed patients of epilepsy attending the OPD of the Neurology Department of Assam Medical College over a period of one year from June 2014 to May 2015. Patients of all age groups of both the sexes were included in the study. And patients with uncontrolled hypertension, alcohol abuse, head injury, increased intracranial tension, chronic liver disease, substance abuse, severe cardiopulmonary disease, pseudo seizures and severe comorbidity were excluded.

Equipment

‘24 channel EEG NEURO PAGE PLUS Electroencephalograph NP-3200 P’ was the apparatus used to record an EEG.

Procedure

The patient was explained about the whole procedure and a written consent taken from all the cases. A detail history and proper physical findings were recorded. Subjects were requested to stay calm and relaxed during the recording period to avoid artefacts.

EEG recording was done with the patient in recumbent position with the eyes closed. The scalp was made oil free and the electrodes were placed over the scalp according to the international 10-20 system using bentonite paste. The patients level of consciousness whether awake or asleep noted. Any activation procedure like hyperventilation if used noted down. A 21 channel EEG was run using bipolar and referential montage for about 20 minutes.

Data recording

After a 20-minute recording, the EEG waveform and the electrodes from where they arose with the montage were observed. Any change of background activity and the appearance of transients noted down. The following definition of IEDs were used to interpret the results.

- *Sharp waves*: Transients clearly distinguishable from background activity with pointed peak at conventional paper speeds and a duration of 70 to 200 milliseconds (mSpiks).
- *Spikes*: Same as sharp waves but with a duration of 20 to 70 ms.
- *Spike wave complexes*: Pattern consisting of a spike followed by a slow wave.
- *Polyspike wave complexes*: Same as spike wave complex but with two or more spikes associated with one or more slow waves.

The EEG interpretation was done with the help of a consultant neurologist experienced in electrophysiologic studies. The presence and topography of bursts of slow waves and epileptiform paroxysms were evaluated. The EEG findings were compared with the clinical findings. Stastical analysis was done using chi square and percentage method in graphpad prism 6 software.

RESULTS

Epilepsy detected by EEG in the study population

The study population during the one-year period of the study comprised of 113 diagnosed cases of Epilepsy of different age groups and both the sexes.

Of the total number of 113 cases that were clinically diagnosed as Epilepsy, EEG could detect only 63 cases as Epilepsy with positive IEDs (Interictal epileptiform discharges).

Of the total 113 cases, 102 cases were diagnosed clinically as generalized epilepsy and 11 cases were diagnosed clinically as focal epilepsy cases.

Of the 102 generalized epilepsy cases, EEG could detect 56 cases with positive IEDs; And of the 11 cases of focal epilepsy, EEG could detect 7 cases with positive IEDs.

Of the 113 cases, 14 cases used sleep as the activation procedure and 99 cases were awake records. Hyperventilation was used in 28 selected awake cases.

Thus, out of the total 113 cases, EEG detected 63 cases with positive IEDs and 50 cases had no IEDs in their EEG recording.

The distribution of the Epilepsy cases detected by EEG in the study population is shown in the Table 1.

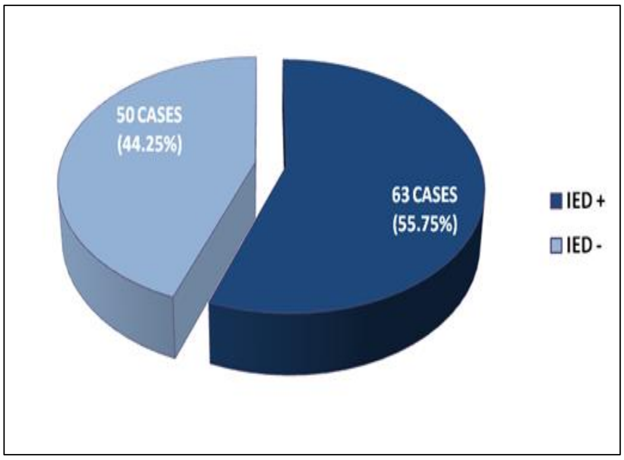

Figure 1: IED detection by EEG.

In the present study, of all 63 cases detected by EEG, there were 51 cases of generalized tonic clonic seizure (GTCS), 4 absence seizures, 1 myoclonic epilepsy, 3 simple partial seizures (SPS), 3 complex partial seizures (CPS) and 1 was partial seizure with secondary generalization.

Generalized seizures were defined as “originating at some point within, and rapidly engaging, bilaterally distributed networks,” which do not necessarily include the entire cortex (Berg et al).[7]

Partial-onset seizures begin with a discharge in a focus, although they then can spread to other parts of the brain. Partial seizures are further subdivided into simple partial and complex partial. Simple partial seizures do not disturb consciousness, whereas complex partial seizures disturb consciousness. Complex partial seizures were previously termed psychomotor because of the cognitive disturbance. Partial-onset seizures can spread to involve most of the brain, and this is termed secondary generalized seizure (Misulis KE).[8]

Absence seizures, previously known as petit mal seizures, often occur in children and are characterized by staring into space or subtle body movements such as eye blinking or lip smacking. These seizures may occur in clusters and cause a brief loss of awareness (few seconds). These seizures begin and end abruptly and may occur several times a day. Patients are usually not aware that they are having a seizure,

Myoclonic seizures consist of sporadic jerks, usually on both sides of the body. Patients sometimes describe the jerks as brief electrical shocks. When violent, these seizures may result in dropping or involuntarily throwing objects.

In the 63 cases detected by EEG, it was seen that the female population (63.49%) had greater predominance than males (36.51%). The case distribution, as detected by EEG showed greater prevalence of Generalized epilepsy (88.8%); with generalized tonic clonic seizure (GTCS-80.95%), presenting as the most commonly occurring epilepsy of all the cases in the study group, followed by absence seizures. (ABS-6.35%).

Table 1: Distribution of epilepsy cases detected by EEG in the study population.

Category	Sub type	Male patients	Female patients	Total no. of patients	Grand total
Generalised seizures	GTCS	18 (78.26%)	33 (82.5%)	51 (80.95%)	56 (88.8%)
	Absence seizure	0 (0.0%)	4 (10.00%)	4 (6.35%)	
	Myoclonic seizure	0 (0.0%)	1 (2.5%)	1 (1.59%)	
Partial seizures	SPS	3 (13.04%)	0 (0.00%)	3 (4.76%)	7 (11.1%)
	CPS	2 (8.69%)	1 (2.5%)	3 (4.76%)	
	PSSG	0 (0.00%)	1 (2.5%)	1 (1.59%)	
Total		23 (36.51%)	40 (63.49%)	63	63

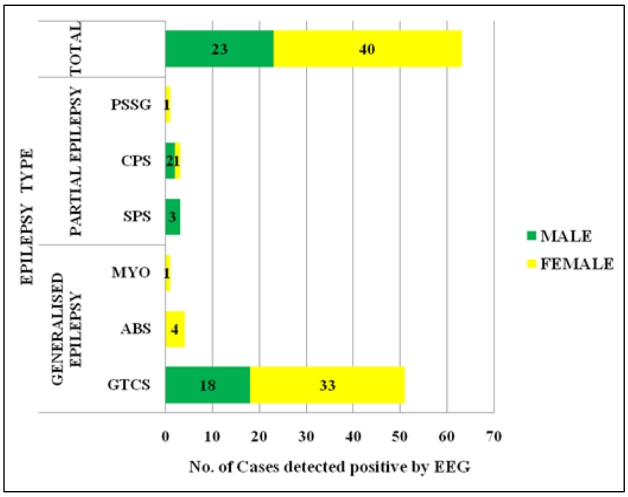

Figure 2: EEG detected epilepsy distribution in the study population.

Features of the EEG tracings of all the cases

In order to analyse, how abnormal EEG findings helps in the diagnosis of Epilepsy; all the findings in the EEG recordings of all the 113 cases were studied and tabulated (Table 2).

The EEG was found normal in 32.74% of cases and abnormal changes, including epileptiform and non-epileptiform features were found in 67.25% of cases.

It was seen that, in maximum number of cases, intermittent IEDs (36.28%) appeared in the EEG; some of the IEDs were accompanied with background slowing (8.85%). In most of the other cases, EEG mainly showed a normal recording (32.74%). Few slow waves were also recorded in some cases (10 cases). Slow waves were however not considered as IEDs and thus could not account to epilepsy diagnosis. The p value was significant. So IEDs detected in the EEG must have some association with the diagnosis of Epilepsy.

Table 2: The distribution of the EEG features in all the cases, diagnosed as epilepsy.

EEG features	No. Of cases	Percentage (%)	P value
Intermittent IEDS only	41	36.28	<0.0001
IEDS + background slowing	10	8.85	
Only background slowing	3	2.65	
Slow waves	10	8.85	
Fast background + IEDS	11	9.73	
Irregular background + IEDS	1	0.88	
Normal EEG	37	32.74	
Total	113	100	

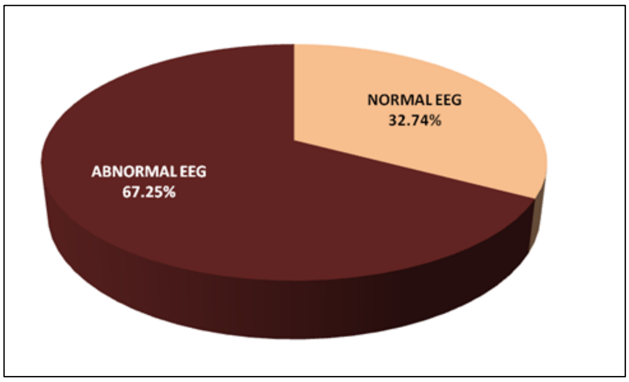

Figure 3: EEG findings.

Waveforms detected by EEG in the Epilepsy cases

Certain wave patterns appeared in some particular types of epilepsy that confirmed the clinical correlation. In order to recognize a wave as epileptiform, the pattern must include a wave that stands out from the background in frequency, amplitude and/or field. Commonly identified IEDs are spikes and sharp waves with or without after going slow waves. Polyspikes (or multispikes) are also IEDs. Both spikes and sharp waves are referred to as interictal epileptiform discharges (transients).

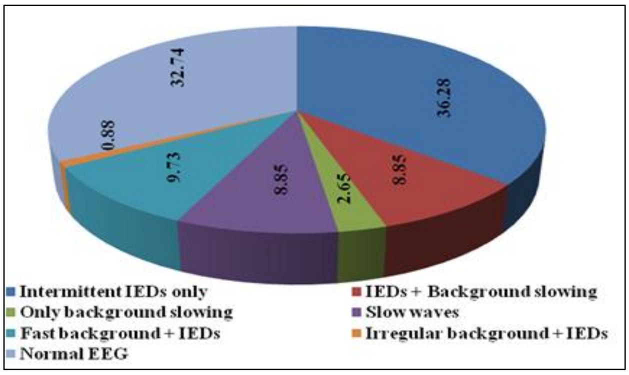

Figure 4: Distribution of EEG features in all the cases.

Sharp waves are more "blunted" than spikes and are IEDs with a duration of 70 to 200 msec.

Combinations of IEDs often occur in the same patient at different times. Spike is defined as a transient discharge, clinically distinguished from background activity, having a pointed peak at conventional paper speed and duration of 20 to 70 msec. Polyspikes has been defined as a complex paroxysmal EEG pattern with close association of two or more diphasic spikes occurring more or less rhythmically in burst of variable duration usually having large amplitude. The polyspikes in scalp recording are generally seen as bilateral and synchronous discharges.

The interictal EEG in patients with absence seizures typically demonstrates brief bursts of 3 Hz spike-and-wave activity that are bilaterally synchronous and symmetric (Penry et al and Holmes et al).[9-10]

The spike represents diffuse depolarization (excitation) of cortical neurons, whereas the wave is considered to represent diffuse inhibition (hyperpolarization). This post excitatory inhibition is presumably adequate to prevent behavioral manifestations (e.g., overt convulsions) from being initiated by the massive depolarization.

The distribution of these wave patterns, which are actually different types of IEDs, in the EEG recordings of the epilepsy patients have been studied in Table 3.

Table 3: Table to show distribution of EEG waveforms in the IEDS detected.

	Total IEDS	Sharp waves	Spikes	Spike and wave	Polyspikes
Number	63	56	2	4	1
%	100	88.89	3.17	6.34	1.59
P value	0.000001 (highly significant)				

Table 4: Table to show association of EEG waveforms with different seizure types.

	GTCS	Myoclonic	Absence	SPS	CPS	PSSG
Sharp waves	50 (98.03%)	0	0	2 (66.6%)	3 (100%)	1 (100%)
Spike and wave	0	0	4 (100%)	0	0	0
Spikes	1 (1.96%)	0	0	1 (33.3%)	0	0
Polyspikes	0	1 (100%)	0	0	0	0
Total IEDS	51 (100%)	1 (100%)	4 (100%)	3 (100%)	3 (100%)	1 (100%)
P value	<0.00001					

The IEDs detected were mainly of four types: Sharp waves, Spikes, Spike and wave and Polyspikes. Other features found in the EEG recording are not usually considered specific for Epilepsy. It was found that the sharp waves (88.89%) were the predominant waveforms in the IEDs detected and the p value was found to be significant.

The interictal EEG has a pivotal role in providing ancillary support for a clinical diagnosis of epilepsy (seizure disorder). In EEG, IEDs may help classify the epilepsy or epilepsy syndrome by identifying IEDs in conjunction with the clinical semiology.

It was seen that, there was the predominance of 'the sharp wave pattern' in the IEDs detected. This was followed by the '3 Hz spike and wave pattern'.

It was also seen that the '3 Hz spike and wave pattern' was associated with 'Absence seizures'.

Myoclonic seizures were associated with polyspikes.

The p value was significant. Thus, certain wave patterns detected by EEG must be related to the type of epilepsy diagnosed.

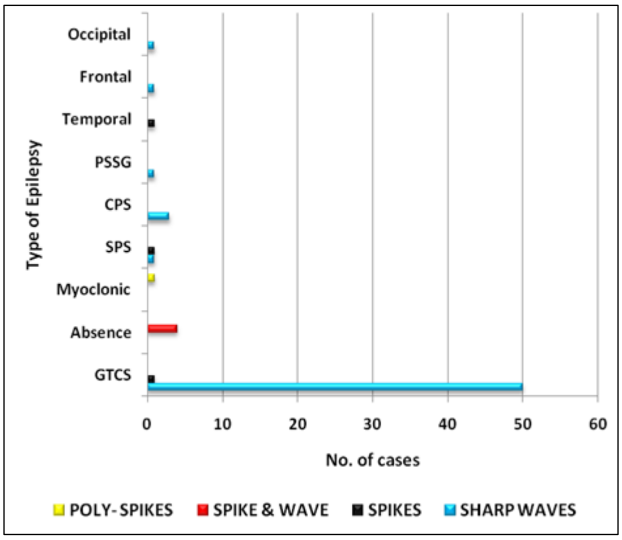

Figure 4: relation between wave forms and epilepsy detected.

DISCUSSION

Epileptiform transients such as spikes and sharp waves are the interictal marker of a patient with epilepsy and are the EEG signature of a seizure focus, as many great authors have already said. In the present study too, we encountered spikes and sharp waves as the interictal waves in the EEG of many of the Epilepsy patients and they also helped us to classify the seizures.

In our present study, we related IEDs to the clinical diagnosis to find out the waveforms recorded by EEG in the Epilepsy patients. It was seen that, in maximum number of cases, intermittent IEDs (36.28%) appeared in the EEG; some of the IEDs were accompanied with background slowing (8.85%). In most other cases, EEG mainly showed a normal recording (32.74%). Few slow waves were also recorded in some cases (8.85%).

In the present study, it was found that, there was the predominance of 'the sharp wave pattern' in the IEDs detected (88.89%). This was followed by the '3 Hz spike and wave pattern' (6.33%). It was also seen that the '3 Hz spike and wave pattern' was associated with 'absence seizures' and myoclonic seizures were associated with polyspikes. Spikes were recorded in two cases, one in GTCS and another in temporal epilepsy (SPS).

Our interpretation matches to that of Miguel E Fiol who said that the interictal abnormalities refer to findings in the EEG between seizures and these have been traditionally described as transients of faster frequency than the background, specifically spikes and sharp waves with associated slow potentials. Of course, focal slowing without these transients may be persistent over the abnormal area or intermittent and indicate also dysfunctional areas of great importance (Fiol ME).[11]

In the study conducted by Aneesh P et al in, the 10 abnormal EEG readings in generalised tonic clonic seizures showed polyspikes and wave discharges, spike and wave discharges, slow wave discharges and symmetrical and synchronous. In 3 cases of absence seizures showing abnormal EEG record, showed 3 Hz generalised spike and wave discharges. In 3 cases of juvenile myoclonic seizure showing abnormal EEG recording, showed polyspike and wave discharges.In the partial seizure cases showing abnormal EEG findings, the abnormal waves were either confined to a discrete area i.e. focal or in the entire brain (Aneesh P et al).[12]

This study matched with the present study with respect to the fact that the generalized tonic clonic seizures showed slow waves discharges in some; the absence seizures showed 3 Hz generalized spike and wave discharges and the myoclonic seizure showed polyspikes.

In a study held in Nigeria in 2013, 'Interictal electroencephalography in patients with epilepsy in northwestern Nigeria' by Owolabi LF et al, the most common IEA found in their study were focal spike/sharp and wave and generalized spike/sharp and slow waves (Owolabi LF et al).[13]

This finding also matches with our present study where we found intermittent generalized sharp wave followed by a slow wave to be the most common wave pattern in the IEDs detected. We also found 7 cases of focal IEDs being detected by EEG.

In a study held by Majeed AA et al, it was found that the most common electroencephalographic abnormality in the 81 patients examined was focal slowing with or without diffuse slowing. This does not match with our study where the most common EEG finding was sharp waves in the IEDs detected. Focal slow waves or diffuse slow waves alone accounted to only 10 cases of the EEG recordings. The dissimilarity may be due to the fact that the authors considered only postinfarction seizures for their study (Majeed AA et al).[14]

Okanishi T et al, said that interictal slow wave may be the component to inhibit epileptic seizures; interictal and preictal slow wave analysis in slow wave component can predict seizure occurrence.[15] Thus interictal brain wave pattern in EEG may have a great significance in the prognosis of an Epilepsy patient.

CONCLUSION

The EEG brain waves that we study quite often in physiology are very fascinating and motivated us to know more and more about the working of the brain under various normal and abnormal conditions. Epilepsy has been an age old dreaded disease that has been successfully exposed by EEG to a very good extent and so we tried to learn about this disease better with the help of EEG. It appears quite amazing that an epileptic brain functions almost normally in between seizures in a good number of people; that raises the possibility that indeed the interictal period might be a physiological adaptation to the abnormal changes, as certain theories have said. However, for knowing this, we would require a more detail analysis of the waveforms and working in the molecular level which was beyond the scope of our present study.

Gibbs wrote in 1958, "ideally the clinical and EEG data should be interrelated and fused in the mind of the informed physician; this permits the full utilization of information from all sources and leads to the most accurate diagnosis and the selection of the most appropriate treatment.". Thus, a lot of experience along with a keen clinical examination and a very careful correct EEG recording and interpretation is required to establish a correct diagnosis of Epilepsy.[12]

Many epileptics may not show IEDs in EEG and many a normal EEG may record a benign variant of epileptiform discharge. EEG spiking may also be a common phenomenon in various other morbid brain conditions. To know better, would require indulging further into the study with long time monitoring, follow up EEG sessions and better developed sophisticated computer softwares so that the functioning of an epileptic brain can be well understood and seizures can be prevented in right time with the use of appropriate anti-convulsant medications.

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