ISSN 2394 - 2053 (Print)
ISSN 2394 - 2061 (Online)
RN: ASSENG/2016/70661 (RNI)
www.ojpas.com

ORIGINAL ARTICLE: RESEARCH PAPER Open Journal of Psychiatry & Allied Sciences

A retrospective analysis of interictal epileptiform activity in one year of electroencephalography records from psychiatry laboratory and its relation with clinical features/semiology, age, and sex

Abstract

Background: Electroencephalography (EEG) is a widespread test in medical setup yet there is scarcity of data of what percentage of referred EEG has abnormality that is suggestive of epileptiform discharges and what is the frequency distribution of these abnormalities. **Objective**: The study is used to retrospectively evaluate the frequency and pattern of EEG abnormality in various age groups and all sexes. **Method:** It was a retrospective cross-sectional analysis of EEG of every patient referred to EEG laboratory for finding discharges suggestive of epileptiform discharges over a one-year period. The age and sex data of patients were collected. The epileptiform discharges were classified accordingly to the International Federation of Societies of Electroencephalography and Clinical Neurophysiology definition of interictal epileptiform activities (IEA). **Result:** The study revealed that a higher percentage of patients in the younger age group (100/126 [79%]) displayed abnormal EEG results, compared to the adult population (58/106 [54%]). This discrepancy indicates a significant difference in the prevalence of abnormal EEG findings between these two age groups. Moreover, the study found no discernible variation in the occurrence of abnormal EEG results based on sex. **Conclusion:** The study found age was an important variable in predicting both frequency of abnormality and its type.

Keywords: Age, Sex, Epileptiform discharge, EEG, IEA.

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Received: 12 September 2023
Revised: 28 October 2023
Accepted: 31 October 2023
Epub: 1 November 2023
DOI: 10.5958/2394-2061.2022.00018.0

INTRODUCTION

In the last 50 years, the electroencephalography (EEG) has been a standard tool for measuring brain electrical activity in patients. The EEG laboratory at the Department of Psychiatry of Tezpur Medical College and Hospital receives referrals for EEG testing from both psychiatric and non-psychiatric cases. Patients of all age groups undergo EEG testing at this facility, and their EEG records are highly valuable for the analysis of abnormal findings. The objective of this study is to determine the proportion of normal and abnormal EEG results and to analyse the distribution of normal and abnormal EEG outcomes, as well as to categorise the specific abnormalities present. This study aims to establish the percentage of EEGs that exhibit abnormal patterns and to establish connections between EEG findings and various referral diagnoses. Recognising abnormalities in EEG recordings is a subjective process requiring clinical judgement. Standard reporting considers variables such as the patient's wakefulness/sleepiness/drowsiness state and age to assess and interpret the findings accurately.

The ontology of EEG or development of EEG from infancy pattern to adult pattern takes place around nine years of age. The presence of abnormality in EEG is not directly correlated with brain dysfunction. For example, occipital paroxysms may also occur in one per cent of normal children or more in children with congenital visual abnormalities (strabismus and amblyopia) or other conditions without a seizure. Specific abnormalities of EEG are often correlated with epilepsy. There is a definite epileptic form or pattern in many epileptic syndromes. There is also the highest number up to 40% of abnormal EEG in psychiatric patients.[1] EEGs are helpful in clinical decision-making. Both positive and negative EEG is regarded as useful technique in two-third patients who are referred.[2] EEG analysis data in the Indian population is limited regarding frequency distribution abnormalities. This study aims to expand the knowledge in the area of research.

EEG has manifold functions, it is a differentiator of epileptic seizures from non-epileptic seizures, semiology of seizure or its localisation, identifying partial or generalisation of seizure discharges, and helps also in the classification of epilepsy and epilepsy syndromes.[3] In the case of certain epilepsy syndromes, EEG is important for predicting prognosis. Even in the modern era of neuroimaging, the value of EEG in epilepsy remains important as before.[4]

Although the diagnosis of seizure remains clinical, often the EEG recording supplements the correct diagnosis if there is inadequate and misleading clinical information.[5] Despite its numerous advantages, EEG does have certain limitations. For instance, it can be overly sensitive in conditions like benign childhood seizure susceptibility syndromes, while being under sensitive or ineffective in detecting certain syndromes such as frontal or temporal lobe epilepsies. In some cases, frontal lobe seizures may not be detected on EEG, which can be considered a common occurrence for ictal events. The localisation capabilities of surface EEG are relatively weak. During the interictal period, more than 40% of patients with epileptic disorders may have a normal EEG. However, this percentage decreases to eight per cent when multiple EEGs are performed alongside appropriate activating procedures.[6]

The severity of epileptogenic findings on EEG does not always correlate with the severity of clinical presentation. Normal individuals may have non-specific EEG abnormalities in more than ten per cent of cases which dictates that EEG should be underread. Similarly, one per cent of normal individuals may have 'epileptiform paroxysmal activity without seizures'.[7] In the paediatric age group, similar abnormalities in normal children are between two to four per cent.[8] Data on the percentage of abnormal EEG in patients subjected to EEG is very limited in the Indian context due to multiple factors. This study is an attempt to highlight such a discrepancy in the data.

Aims and objectives

1. To analyse the EEG data of each patient during the study period of year 2021 according to background activity, interictal epileptiform activity (IEA), and response to photic stimulation;
2. To find whether the EEG is normal or abnormal and classify the IEA;
3. To find what percentage of EEGs are abnormal; and
4. Correlate abnormal EEGs and with referral diagnosis and seizure semiology.

METHOD AND MATERIALS

This is a retrospective study of 243 patients who were suspected of having seizure disorder, diffuse or cerebral dysfunction like delirium, encephalopathy and referred to the EEG laboratory in the Department of Psychiatry, Tezpur Medical College and Hospital for the year 2021. The study was conducted after obtaining the necessary clearance from the institutional ethics committee. The study included patients with a clinical diagnosis of seizure disorder, patients in which seizure disorder is suspected but adequate information is not possible, or patients with alteration of sensorium or behaviour which mandated a diagnosis of seizure disorder were included.

Inclusion criteria

All EEG recorded during the observation period of January 2021 to December 2021.

Exclusion criteria

All EEG that was contaminated by artefacts rendering it unsuitable for analysis.

Routine scalp, awake or sleep recording of EEG was done on all patients after a detailed explanation of the procedure was given to patients or parents/guardians (in case of paediatric age group). Cup electrodes were applied with bentonite according to ten to 20 system in adults and paediatric montage in children less than ten years of age. The data was collected on a 16-channel EEG machine. Both biauricular and mandibular montages were used in the recording of EEG. Various montages namely longitudinal and transverse bipolar montages, common average referential were used in all examinations. The filter setting of the EEG machine was a low pass filter at 1 Hz and a high pass filter at 70 Hz and a paper speed of 30mm/s was used. Most of the recording was obtained in the awake state but in paediatric age group patients and uncooperative patients, sedatives were used to obtain cooperation.

During the eye-open recordings, patients were instructed to maintain their gaze on a specific point on the ceiling and were advised to refrain from making any eye movements. The conscious state of each patient was observed, and any instances of drowsiness or sleep were duly noted. As a standard procedure, hyperventilation was conducted in all patients, unless it was contraindicated or the patient did not cooperate. The routine EEG recording lasted for approximately 30-40 minutes, while hyperventilation was administered for a duration of five minutes. Additionally, phonic stimulation was performed on all patients.

Each EEG recording was evaluated by two investigators with sufficient expertise in EEG interpretation. The interpretations provided by both investigators were compared to ensure inter-rater agreement, and these collective findings were utilised for the final reporting of the cases. During the interpretation process, several factors were taken into account. These factors included the patient's age, whether they were in an awake or sleep state during the recording, the presence or absence of baseline IEA, the specific location of focal IEA if present, and the response of IEA to activation procedures. The International Federation of Societies for Electroencephalography and Clinical Neurophysiology definition of IEA was adopted in the study.[9] The specific epileptiform discharges such as spike or sharp wave activity, polyspikes, specific patterns such as burst suppression, and hypsarrhythmia were noted and evaluated.

Data analysis

The statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) (version 25 Chicago). Descriptive statistics, such as mean and standard deviation (SD), were calculated for numerical variables, while proportions were determined for categorical variables. To compare categorical variables, the chi-square test was utilised, and risk assessment or odds ratios were calculated. A significance level of 0.05 (p-value) was chosen for determining statistical significance.

RESULTS

The study comprised a total of 243 participants who were referred for testing. However, 11 records were excluded from the analysis due to poor record quality, which hindered comprehensive analysis. Consequently, the final sample size for analysis consisted of 232 individuals with 154 being male

(66.4%) and 78 being female (33.6%).To facilitate analysis and interpretation, the study sample was divided into three age groups: paediatric (one month to 18 years), adult (18 to 60 years), and geriatric (above 60 years).The mean age of the sample was 18.6 ± 17.15 years (2SD, 95% confidence interval [CI]). The mean age in the paediatric age group is 5.47 years with a SD of 5.39. On the other hand, the mean age in the adult age group is 32.13 years with a SD of 9.87 (Table 1).

According to Table 2, among the paediatric age group, 70% of patients exhibited abnormal EEG recordings. Out of these 84% were of less than ten years and 61.5 % were in the age group of ten to 18 years, likewise, in adults 58% displayed abnormal EEG results. Among the male patients, 71.4% and similarly 61.5% of female patients had abnormal EEG.

The most significant epileptiform abnormality was in background wave 143/158 (90.5%) and focal slow wave 145/158 (91.7%) in all age groups. Most patients with abnormal EEG had multiple abnormalities (Table 3, Figures 1 and 2).

Burst suppression (eight out of 158 [five per cent]), 3Hz (three out of 158 [1.8%]), and hypsarrhythmia (nine out of 158 [5.6%]) were the least common abnormalities seen (Figures 2 and 3). Sleep recordings were 102/232 (43.96%) and done exclusively in the paediatric age group sleep; records yielded a maximum number of hypsarrhythmia and burst suppression in the paediatric age group (Figures 2 and 3). In our study, surprisingly we found 3Hz spike wave activities in only three patients of the paediatric age group (Table 3).

The sex difference among the cases with abnormal EEG was insignificant. For correlation studies, the paediatric age group and the combined adult and geriatric age groups were compared. The results of the univariate analysis indicated that as age decreases, the odds of having an abnormal EEG increase. However, no relationship was found between the sex of the patients and the odds of having an abnormal EEG. These findings were further supported by the bivariate analysis, which yielded similar results (Table 4).

In our analysis of 232 patients, 68.9% displayed abnormal EEG patterns. The most common referral diagnosis was seizure and fever cumulatively consisting of 42% of patients. The most common seizure semiology was generalized tonic-clonic seizure (GTCS) which was present in 58% patients (Table 5).

Table 1: Demographic data of sample

Variable	Mean age	Frequency	p-value
Female	18.65±14 years	78/232 (33.6%)	Not significant
Male	19.74±8.26 years	154/232 (66.4%)	
Paediatric	5.47±5.39 years	126/232 (54.3%)	-
Adult	32.13±9.87 years	96/232 (41.4%)	-
Geriatric	62 years	10/232 (4.3%)	-

Table 2: Distribution of abnormal EEG (frequency)

Variable	Abnormal EEG	
	Frequency	Percentage
Sex		
Male	110/154	71.4
Female	48/78	61.5
Age group		
Paediatric (1 month-18 years)	100/126	70.63
<10 years	84/100	84
10-18 years	16/26	61.5
Adult (18-60 years)	56/96	58
Geriatric (>60 years)	2/10	20
Clinical diagnosis		
Fever	35/44	79.5
Seizure	50/54	92.5
Mental retardation	15/16	93.7
Cerebral palsy	23/33	69.6
Pseudo-seizure	6/18	33
Psychosis	12/21	57.1
Depression	9/21	42.8
Anxiety	8/17	47
CVA	3/6	50
Dementia	0/2	0

EEG: Electroencephalography; CVA: Cerebrovascular accident

DISCUSSION

Our study revealed a high frequency of abnormal EEG and IEA as the sample was skewed in composition for the paediatric age group because the rate of abnormal EEG and IEA was high in the paediatric age group as shown in other studies.[5,7] The prevalence of epilepsy in low and middle income countries (LMIC) is found to be twice of high income countries (HIC) through survey studies with a questionnaire method that includes clinical data.[10] But data of the prevalence of abnormal EEG from such populations is very less. So, our study tried to address this lacuna of information regarding abnormal EEG from Indian subcontinent.

In our study, IEA was tabulated on basis of age rather than sex because age is a strong predictor of the ontology of EEG than sex. Developmental background of paediatric age groups EEG has been considered while reporting abnormal EEG. In generalised epilepsy in adults diagnosed clinically, previous studies have shown abnormal EEG in newly diagnosed cases from the range 54%-81%[11] to as low as 18%.[12] Our study has shown overall abnormal EEG to be 68.9% which is comparable to other studies.

Salinsky *et al.*[13] reviewed 1201 EEGs from 429 adult patients and found that on the first record 50% of patients, on the third record 84%, and on the fourth round 92% of patients had abnormal EEGs showing IEA. Our study which consisted of a single record also follows this pattern although our sample consisted of heterogenous clinical diagnosis. The IEA found in adults in our study were mostly synchronous and symmetric and generalised spike-wave complex in patients and secondly, patients showed focal and irregular discharges in overall 61% of adult patients (Table 2 and Figure 1).

Other common EEG features observed in our adult age group were polyspikes, polyspike wave activity, and

Table 3: Distribution of EEG abnormalities and IEA in different age groups

Group	BW	FSW	GSW	3Hz	NSSW	FSLW	BS	Hypsarrhythmia
1 month-18 years	88	85	77	3	51	51	8	9
18-60 years	54	58	58	0	-	39	-	-
> 60 years	1	2	2	0	-	-	-	-
Total	143	145	137	3	51	90	8	9
Percentage (%)	61.63	62.5	59.05	1.29	21.98	39.79	3.44	3.87

*Some of the patients had more than one abnormality
EEG: Electroencephalography; IEA: Interictal epileptiform abnormalities; BW: Background wave; FSW: Focal spike/sharp wave; GSW: Generalised spike/sharp wave; NSSW: Non-specific slow wave; FSLW: Focal slow wave; BS: Burst suppression

Table 4: Relationship between common variables and abnormal EEG (unadjusted) and independent predictors of abnormal EEG (adjusted)

Variable	Frequency (abnormal EEG/total)	Unadjusted		Adjusted	
		OR (95% CI)	p-value	OR (95% CI)	p-value
Age					
Adult (including geriatric)	58/106	1 reference			
Paediatric	100/126	1.022 (1.006-1.039)	0.008*	1.023 (1.006-1.04)	0.007*
Sex					
Male	110/154	1 reference			
Female	48/78	0.68 (0.382-1.225)	0.202	0.663 (0.367-1.2)	0.175

*Statistically significant
EEG: Electroencephalography; OR: Odds ratio; CI: Confidence interval

Table 5: Cross-tabulation of referral diagnosis with seizure semiology with their abnormal EEG status

Referral diagnosis	Seizure semiology					
	No seizure	Tonic partial	Atonic partial	GTCS	Myoclonic	Absence
	Abnormal EEG	Abnormal EEG	Abnormal EEG	Abnormal EEG	Abnormal EEG	Abnormal EEG
Fever	-	-	-	29/44 (66%)	6/44 (14%)	-
Seizure	3/54 (5%)	1/54 (1.8%)	1/54 (1.8%)	30/54 (56%)	14/54 (26%)	-
Mental retardation	1/16 (6%)	2/16 (12.5%)	2/16 (12.5%)	7/16 (43%)	3/16 (19%)	-
Cerebral palsy	2/33 (6%)	2/33 (6%)	-	13/33 (39%)	5/33 (15%)	-
Psychosis	3/21 (14%)	2/21 (9%)	-	5/21 (24%)	1/21 (4%)	-
Depression	5/21 (24%)	1/21 (4%)	-	1/21 (4%)	2/21 (9%)	-
Anxiety spectrum disorder	4/17 (23%)	3/17 (17%)	-	1/17 (6%)	-	-
Pseudo-seizure	-	-	-	5/18 (27%)	1/18 (5%)	-
Dementia	-	-	-			-
CVA	-	1/6 (16%)	-	1/6 (16%)	1/6 (16%)	-

EEG: Electroencephalography; GTCS: Generalised tonic-clonic seizure; CVA: Cerebrovascular accident.

intermittent rhythmic delta activity, and it was consistent with other studies done in Indian scenario.[2,12] Our study did not find any sex difference among cases with abnormal EEG, which is in contradiction to similar studies.[11,12,14] Female sex in other studies were associated with more EEG abnormalities due to delay in treatment seeking behaviour and social stigma.

The most predominant epileptiform discharges in paediatric population were focal slow waves followed by generalised slow waves in our study. This finding is in concordance with other studies. Majority of sleep records which was 44% of total recording was exclusively in paediatric age group. Sleep record yielded maximum number of hypsarrhythmia and burst suppression in this age group.

Out of 150 patients, 31 individuals with epileptiform electroencephalogram (EEG) activity showed additional and specific patterns during hyperventilation and photic stimulation. These patterns included burst suppression (Figure 2). This finding suggests a potential link between these specific EEG patterns and underlying pathologies such as mental retardation (MR), childhood encephalopathies, and other conditions that are predominantly found in paediatric patients. We found paucity of 3Hz spike wave activity in our study which is in contradiction to other studies.

Burst suppression in the paediatric age group is associated with pathologies such as hypoxic-ischaemic encephalopathy, Lennox-Gastaut syndrome, and West syndrome. Our study

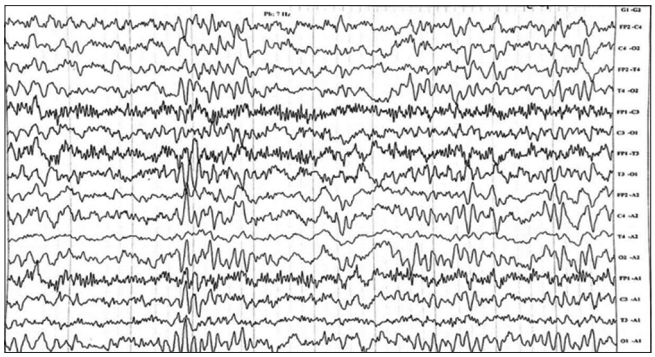


Figure 1: Generalised slow wave (GSW).

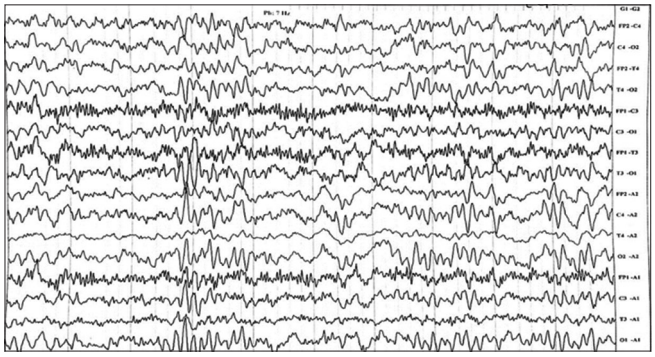


Figure 2: Burst suppression (BS).

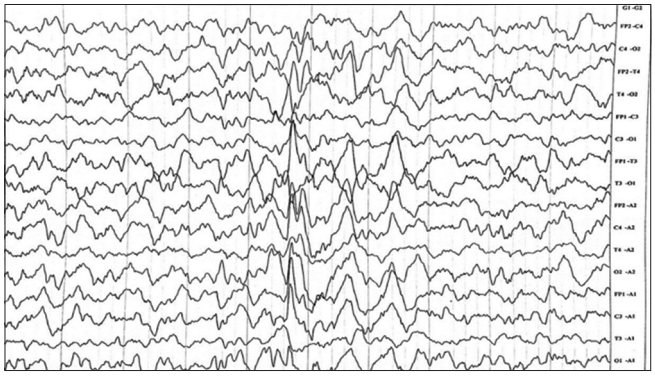


Figure 3: Hypsrrhythmia.

finding is consistent with previous studies. The study indicates that paediatric patients who are screened by clinicians based on suspicion of epilepsy have a significantly higher likelihood of having an abnormal EEG due to the high quality of the screening procedure. However, in the adult population, different types of clinical conditions and syndromes, not just epilepsy are suspected which result in a lower yield of abnormal EEG findings compared to the paediatric age group as shown in our study.[15]

In collaborating the referred diagnosis, the most common diagnosis with abnormal EEG was seizure followed by fever (Table 2). About 93.5% of cases of seizure had abnormal EEG which was higher in our case series than other studies. Our sole EEG recordings positivity rate was similar to fourth round EEG recording, i.e. 92% as reported by Salinsky *et al.*[13] Hughes[1] has reported both in elderly and adult epileptic patients' positivity rate of 92% on third and 92 to 93% on all EEG for IEA. The IEA found in this referred group (fever and seizure) were mostly synchronous and symmetric generalised spike and wave activity followed by focal and irregular discharges in overall 63% of patients. This correlate with the most common semiology in seizure and fever referral group which was GTCS followed by myoclonus in our study. There was not a single case of absence seizure in our seizure referral group. This may be due to non-identification of semiology of absence seizure by referral clinicians.

In MR referral group, 93.7% had abnormal EEG with the majority having GTCS followed by an equal amount of myoclonic, partial seizure semiology as described by referral notes. But doubt remains whether involuntary movement in mentally retarded patients was confused with seizure. Because even in other EEG studies of involuntary movement in MR, high percentage (31% to 75%) has been reported to have abnormal EEG.[8,12,15] Even in questionnaire surveys of MR in Indian studies, epilepsy was prevalent clinically between 22.9% - 43.3%.[16,17] In cerebral palsy referral patients, 68% of patients had abnormal EEG. The high rate of abnormal EEG can be understood as they may have hidden or cryptic diffuse cerebral dysfunction or seizures.

In the psychosis group which included both schizophrenia and non-schizophrenia patients, 55% of patients showed abnormal EEG which is higher than studies done by Stevens[18] but comparable to study done by Struve and Honigfeld.[19] Earlier studies and analysis by Struve and Honigfeld[19] had recorded more epileptiform activity than usual mostly on the left hemisphere as hemispheric dysfunction thought to a marker for this finding.

In the depressive patients' referral group, the rate of abnormal EEG was 45% which was comparable to another study by Bjørk *et al.*[20] Epileptiform sharp cortical waves and focal slow waves were the most common findings in our study. The abnormal EEG in depressive patients has been postulated due to disruption of the sleep-wake cycle or due to drug-induced slowing.

In the anxiety spectrum disorder referral group, 41% had abnormal EEG with partial seizures semiology. Since the 1980s, the rate of EEG abnormalities from 15 to 30% has been reported in patients with panic disorder which contradicts the findings of our study.[21] This may be due to use of drugs like antidepressants which causes slowing of EEG. Many patients with anxiety disorders who had abnormal EEG often find symptomatic relief due to the addition of antiepileptic drugs (AED) like valproic acid. In a study by Bystritsky *et al.*[22] where 25% of EEG of anxiety disorder patients were abnormal, slow wave activity in the temporal region with occasional sharp waves was noted. But Daly *et al.*[23] and Bagchi *et al.*[24] found a non-localising nature of such specific EEG abnormalities which is also found in our study

In the pseudo-seizure referral group, 33% had abnormal EEG, mostly mimicking GTCS semiology. It is higher than the reported incidence of pseudo-seizure in status epilepticus by Perez and LaFrance[25] but our incidence is lower than the 53.8% reported by Reuber *et al.*[26]

We have fewer geriatric patients in the study as the year of study had COVID-19 pandemic which decreased the footfall

of geriatric patients significantly. In the geriatric age group, the most common diagnosis was dementia and cerebrovascular accident (CVA). Only 50% of the CVA patients showed abnormal EEG but all were highly symptomatic of seizure, behavioural disturbances or impairment of consciousness. The most common EEG abnormality in this age group was focal slow waves. The paucity of generalised abnormalities such as generalised wave polyspikes has also been noticed in other studies. The mechanism of such scarcity of generalised discharges cannot be explained in our study and remains an active area of research. Research had already shown that patients with Alzheimer's disease have myoclonus, commonly occurring in about ten per cent, verified by autopsy but studies lack linking such myoclonus with EEG abnormalities. Also, non-convulsive status epilepticus is overlooked in geriatric patients who have behavioural problems and they may show a preponderance of focal activity than generalised one.

Conclusion

Our study showed that about 68.9% of patients sent for EEG testing had abnormal EEG, younger patients had significantly more chance of having an abnormal EEG. No sex difference is observed in patients with abnormal EEG. The most predominant epileptiform activity observed in the study was focal slow waves followed by generalised slow waves. The highest abnormal EEG was found in patients with a referred diagnosis of seizure and fever. Our cohort showed a higher percentage of EEG abnormality in psychiatric disease patients compared to other studies.

AUTHOR CONTRIBUTIONS

RS: Concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, data analysis, statistical analysis, manuscript preparation, manuscript editing, manuscript review, guarantor; **SG**: Concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, data analysis, statistical analysis, manuscript preparation, manuscript editing, manuscript review, guarantor; **RP**: Concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, data analysis, statistical analysis, manuscript preparation, manuscript editing, manuscript review, guarantor; **TD**: Concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, manuscript preparation, manuscript review, guarantor; **S**: Concepts, design, definition of intellectual content, literature search, clinical studies, data acquisition, manuscript preparation, manuscript review, guarantor.

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Source of support: Nil. **Declaration of interest:** None.