Pediatric Neurology 169 (2025) 177–184

Contents lists available at ScienceDirect

Pediatric Neurology

journal homepage: www.elsevier.com/locate/pnu

Research Paper

Urgent Video Electroencephalography in the Pediatric Emergency Department: Is It Useful?

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ARTICLE INFO

Article history:
Received 3 March 2025
Accepted 23 May 2025
Available online 30 May 2025

Keywords:
Electroencephalography (EEG)
Emergency department (ED)
Pediatrics
Seizures

ABSTRACT

Background: Seizures account for about 1% of pediatric emergency department (PED) visits. Electroencephalography (EEG) is essential for evaluating seizures and other neurological concerns. The utility of urgent video-EEG (vEEG) in the PED remains unclear. The objective of this study was to study the role of vEEG in evaluating children presenting with seizures and other paroxysmal events.

Methods: A retrospective chart review analysis was conducted at a single tertiary children's hospital over a three-year period in children (0-18 years) presenting to a PED with neurological symptoms and underwent vEEG.

Results: A total of 277 patients underwent vEEG (142 females [52%]; mean age, 7.7 years). The most common indications were new-onset paroxysmal events (37%) and first unprovoked seizure (20%). vEEG was performed within 24 hours of the event and sleep was achieved in 92% and 80% of patients, respectively. Most patients (61%) had abnormal findings. Perinatal risk factors, pre-existing developmental delay, pre-established epilepsy, and an abnormal neurological examination highly correlated with vEEG abnormalities ($P < 0.05$). Clinical events captured during monitoring differentiated epileptic from nonepileptic episodes (16%). New-onset paroxysmal events were diagnosed as epileptic in 60%. Specific epilepsy syndromes were identified in 57% of this subgroup. vEEG contributed to initiation of antiseizure medications (47%) and impacted decisions to change antiseizure medications in 67% of patients with known epilepsy. Abnormalities on neuroimaging were found in approximately half of the patients with abnormal vEEG who were imaged.

Conclusions: This study suggests that urgent vEEG in PEDs can lead to early diagnosis and treatment, reduce the need for further investigations, and potentially improve outcomes. However, the cost-effectiveness and availability of vEEG in PEDs need further evaluation.

Introduction

Recurrent seizures in children have a cumulative incidence of 1% for children aged less than 16 years.[1] In the United States, seizures account for up to 1% of all emergency department (ED) visits, most notably in young children aged less than five years.[2] Seizures can occur in the context of provoked etiologies (fever, meningoencephalitis, trauma, tumor, intracranial bleed, and stroke) or unprovoked causes such as in the case of first presentation of epilepsy.[3] Children can also present to the ED with altered mental states as well as other paroxysmal nonepileptic events that are often a cause of concern for caregivers.[4,5]

Electroencephalography (EEG) is an important noninvasive tool in the evaluation of epileptic and nonepileptic paroxysmal events in children, both in the acute and in the outpatient settings.[4,6,7] Using surface electrodes placed on the scalp, this neurodiagnostic

Disclosures: None of the authors have any conflict of interest to disclose. This study was approved by the Institutional Review Board (IRB # 958989).

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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https://doi.org/10.1016/j.pediatrneurol.2025.05.024

tool helps in evaluating different aspects of brain activity including the background, presence and type of abnormal epileptic discharges, and response to activation procedures (intermittent photic stimulation, hyperventilation, sleep).[8]

EEG can be a useful tool in the evaluation of patients presenting to the ED with seizures (new or recurrent), unexplained paroxysmal events, altered mental status, suspicion of subclinical seizures specifically in patients with witnessed seizures, and prolonged postictal states as well as other neurological concerns.[9,10] EEG carried out after new-onset seizures can show abnormal interictal epileptic abnormalities that can aid clinicians in determining the seizure type, estimating the risk of seizure recurrence, and deciding upon the type of antiseizure medication to start. The overall diagnostic yield of an EEG after a first-onset seizure is approximately 30%,[11] with a higher yield obtained when performed within the first 24-48 hours after the event.[12]

In a recent study, the role of EEG without simultaneous video recording in evaluating children presenting to the ED showed that EEG findings were helpful in confirming or ruling out suspected diagnosis in up to 87.7% of 183 patients who underwent this test.[13] In this study, only a small subset of patients (31) who were admitted eventually underwent a repeat video-EEG (vEEG). Nevertheless, the role of vEEG (EEG coupled with simultaneous video recording) in the evaluation of paroxysmal events in the pediatric ED (PED) remains unclear.[14,15] When captured, the additional video recording can, in certain circumstances, enable the characterization of the clinical events, thereby increasing the yield of this diagnostic study and guiding further management or avoiding unnecessary further investigations.[16,17]

The objective of this study was to carry out a retrospective chart review analysis of all patients presenting to the ED at a single pediatric tertiary hospital, between January 2019 and December 2021, who underwent vEEG as part of their evaluation in the ED. At our institution, vEEG studies can be done in the ED, even after regular working hours if the clinical situation so requires, with remote access to the recordings for instant interpretations and recommendations by neurologists. The aim of this analysis was to determine the utility of this diagnostic test in the PED. We hypothesized that the availability of this service enables the early diagnosis and treatment of patients, reduces the need for further investigations, and possibly reduces the need for hospital admissions.

Methodology

Study design and patient population

This research project was a retrospective chart review analysis of all pediatric patients presenting to the ED at Sidra Medicine between January 2019 and December 2021 inclusive (three-year period). Sidra Medicine is the only pediatric tertiary hospital for the country, with a PED that now caters to an average of 120,000 patients yearly, for children starting from the neonatal period to age 18 years. During the study period it catered to 77,000 patients in 2019, 68,000 patients in 2020, and 92,000 patients in 2021.

At our institution, vEEG studies can be done in the ED even after regular working hours, if deemed necessary and after consultation of the neurology on-call team. As per departmental protocol, for all vEEGs done in the ED, the EEG technician communicates directly with the on-call neurologist by phone during the study (after at least 40 minutes has been recorded) and before disconnection of the patient. The on-call neurologist reviews the vEEG recording, provides a verbal report to the ED team with management recommendations, and subsequently completes a finalized written report within 24 hours.

The primary objective of this study was to determine the utility of vEEG in the evaluation of children presenting to the PED with seizures, other paroxysmal events, and altered mental status. The secondary objectives were to determine the yield of vEEG in identifying abnormalities on EEG in children presenting with events suspicious of seizures and to determine the role of vEEG in decision making, in the management of patients, and in affecting the clinical outcomes of children presenting to the ED with abnormal movements or altered levels of consciousness.

Inclusion criteria

1. Age: birth to 18 years (inclusive)
2. Patients presenting with a clinical event consistent or suspicious for seizures
3. Patients presenting with altered level of consciousness
4. vEEG performed in the ED

Exclusion criteria

1. Children >18 years old
2. Children who underwent vEEG outside the ED
3. EEG performed without video

Data collection

The initial step in the data collection was the identification of all patients who underwent vEEG in the ED within the specified study period, meeting the inclusion and exclusion criteria. Subsequently, electronic medical records of all identified subjects were reviewed.

Various clinical variables were collected including demographic data (age, sex, country of origin) and indication for vEEG, which were categorized as follows: (1) new-onset paroxysmal events (rule out seizure), (2) first seizure (unprovoked), (3) seizures in the context of intercurrent illness/fever/trauma (provoked), (4) recurrent/breakthrough seizure in a patient with known epilepsy, (5) status epilepticus—rule out subclinical status epilepticus, and (6) altered level of consciousness—rule out subclinical seizures and encephalopathy. Clinical risk factors were also reviewed including the presence of recent head trauma, previous history of febrile convulsions, previous history of meningitis/encephalitis, perinatal risk factors (preterm, perinatal asphyxia, neonatal seizures), pre-existing developmental delay, known diagnosis of epilepsy, toxic ingestion, known case of brain tumor, family history of epilepsy/febrile seizures, and sleep deprivation. Details of the vEEG study were examined, including EEG findings (normal, abnormal, type of abnormality) and EEG parameters (duration, timing of EEG from ED presentation/last clinical event, activation procedures). Of note, all vEEG recordings were carried out using portable Nihon Kohden machines equipped with camera and as per institutional protocol, following the American Clinical Neurophysiology Society (ACNS) criteria for technical requirements for recording pediatric EEGs.[8] As per departmental protocol, activation procedures (hyperventilation, intermittent photic stimulation) were attempted in all patients. Finally, the outcome of ED visit was denoted by evaluating several factors including the length of stay in the ED, disposition (discharge home, admission to hospital wards), ED visit recurrence, medication initiation in the ED, clinical outcome at one year, and final diagnosis.

Statistical analysis

The data were coded and entered into SPSS 22.0 software (SPSS Inc., Chicago, IL, USA). Demographic and clinical characteristics available for each variable are reported as descriptive statistics using counts (percentage). Owing to the inherent limitations of chart review analysis, some data were not available for each variable for all patients. As such, the descriptive statistics are described as a percentage of the counts available for each variable. Evaluation of the risk factors contributing to the presence of comorbidities and intractability of the epilepsy was estimated by odds ratio, and the 95% confidence interval was calculated. Multivariate analysis was carried out using logistic regression for binary data, and P value of ≤ 0.05 was considered significant.

Results

vEEG abnormalities and diagnoses

During the three-year study period, data were collected from a total of 277 pediatric patients presenting with paroxysmal events consistent or suspicious for seizures who underwent vEEG in the ED. Among these, 51% (142 of 277) were female. The mean age at presentation was 7.7 years (±5.4 years, range 1 week-18 years). Most patients were from the Middle East North African region (194 of 277, 70%), whereas the remainder were of South Asian (53 of 277, 19%), African (20 of 277, 7%), European (four of 277, 1%), or North American (six of 277, 2%) descents. The most common indication for undergoing a vEEG in the ED was new-onset paroxysmal events (37%), followed by first unprovoked seizure (20%); convulsive status epilepticus was the least common indication (1%) (Table 1).

The average length of stay in the ED for patients who underwent vEEG monitoring was 11 hours (±6.9 hours). The median time from ED presentation to initiation of the vEEG recording was 4 hours (mean 6.2 ± 4.8 hours) The majority of patients (~75%) underwent vEEG monitoring within 12 hours from their initial symptom onset, and 92% of the vEEGs were done within 24 hours of the event. Duration of the vEEG recording ranged from 30 minutes to 3 hours (mean 77 ± 36 minutes), with the majority (70%) lasting more than 40 minutes. A sleep recording was achieved in most patients (80%, 221 of 277), and other activation procedures including photic stimulation and hyperventilation were possible in 70% and 44% of patients, respectively (Table 2).

In 39% (109 of 277) of patients, the vEEG was normal. However, in the remaining 61% (168 of 277), vEEG revealed abnormalities in the form of isolated background abnormalities (8%, 21 of 277), presence of epileptic discharges (42%, 130 of 277), electroclinical seizures (9%, 24 of 277), and/or electrographic seizures (2%, five of 277) (Fig). The yield of the vEEG in patients with first unprovoked seizure and new-onset paroxysmal events confirmed to be seizures was 78% (81 of 104). Clinical events were captured during vEEG in 43 patients (16%), with electroclinical seizures confirmed in 70% in the form of generalized (17 of 43), focal (eight of 43), or epileptic spasms (five of 43). The remainder (30%) were found to have nonepileptic events that included motor tics (one of 43), behavioral staring (two of 43), hyperventilation episode (one of 43), hyperekplexia (one of 43), nonepileptic limb movements (three of 43), nonepileptic abnormal eye movements (two of 43), breath-holding spells (two of 43), and subjective dizziness (one of 43) (Table 2). Interestingly, two of these 13 patients with nonepileptic events captured on vEEG had abnormalities on their vEEG in the form of focal epileptic discharges or isolated background slowing. Subclinical (electrographic-only) seizures were recorded in five patients (2%) of whom four were patients with known epilepsy and one was a patient presenting with new-onset encephalopathy with no history of clinical seizures. Notably, none of the four patients with status epilepticus, of whom two were known epileptic patients, were found to have subclinical seizures.

TABLE 1.
Summary of Patient Demographics and vEEG Indications

Gender	
Male	135 (49%)
Female	142 (51%)
Ethnicity	
MENA region	194 (70%)
South Asia	53 (19%)
African	20 (7%)
North American	6 (2%)
European	4 (1%)
Mean age at presentation (± S.D.)	7.7 yrs (±5.4 yrs)
Indications of the EEG	
New-onset paroxysmal events (query seizure)	102 (37%)
First seizure (unprovoked)	54 (20%)
Recurrent unprovoked seizure (not on ASMs)	34 (12%)
Seizures (provoked)*	9 (3%)
Status epilepticus—rule out subclinical status epilepticus	4 (1%)
Altered level of consciousness	28 (10%)
Recurrent/breakthrough seizure in patient with known epilepsy	46 (17%)

Abbreviations:
ASM = Antiseizure medication
EEG = Electroencephalography
MENA = Middle East North African region
vEEG = Video-EEG
* In the context of intercurrent illness/fever/trauma.

New-onset paroxysmal events (query seizures) were the most common indication for vEEG in the ED, representing 37% of the requests for this diagnostic test (102 of 277 patients). In this subgroup of patients, 97% (99 of 102) had no pre-existing history of epilepsy. Based on clinical evaluation and vEEG results, new-onset paroxysmal events were diagnosed as epileptic in approximately 60% (60 of 102) of patients, with abnormalities on vEEG present in most of these cases (49 of 60 patients, 82%). Furthermore, the vEEG findings, together with the clinical history, resulted in the diagnosis of specific epilepsy syndromes in 57% (34 of 60) of these patients (including infantile epileptic spasms syndrome, self-limited epilepsy with autonomic seizures, self-limited epilepsy with centrotemporal spikes, epilepsy with myoclonic-atonic seizures). It was found that 41% (41 of 99) of the patients presenting to the ED with new-onset paroxysmal events and having no prior history of epilepsy received a diagnosis of epilepsy in the ED and were started on antiseizure medications. All these patients maintained this diagnosis and were still on antiseizure medications at one-year follow-up.

vEEG was requested for 28 patients presenting with altered level of consciousness, with vEEG abnormalities observed in 12 patients (43%). Of the 28 patients presenting with altered level of consciousness, the clinical evaluation and vEEG study taken together resulted in the diagnosis of seizures in eight patients (none of whom had a previous history of epilepsy). Abnormalities on vEEG in this subgroup were characterized by epileptic discharges (eight of eight) and electroclinical seizures (six of eight). Encephalopathy was diagnosed in three of 28 patients (all of whom had background slowing with no epileptic discharges). The remaining 17 patients presenting with altered level of consciousness were diagnosed with nonepileptic events including conversion disorder (three of 17) and syncope (seven of 17), as well as metabolic derangements (seven of 17), with normal vEEG findings in most of these patients (14 of 17).

Although most patients (83%, 230 of 277) were not on any antiseizure medications upon presentation to the ED visit, more

TABLE 2.
Summary of vEEG Characteristics and EEG Findings

vEEG Details	N (%)
Duration	
Routine EEG (up to 40 minutes)	82 (30%)
>40 minutes-120 minutes	186 (67%)
>120 minutes	9 (3%)
Timing from clinical events	
0-6 hours	137 (50%)
6-12 hours	70 (25%)
13-24 hours	49 (17%)
>24 hours	21 (8%)
Timing from ED presentation	
0-6 hours	169 (61%)
6-12 hours	75 (27%)
13-24 hours	28 (10%)
>24 hours	5 (2%)
Activation procedures used	
Sleep	221 (80%)
Photic	197 (71%)
Hyperventilation	121 (44%)
All	96 (35%)
None	16 (6%)
vEEG findings	
Normal	109 (39%)
Abnormal	168 (61%)
Clinical events captured on vEEG (N = 43 patients)	
Epileptic events	30 (70%)
Generalized seizures	
Tonic-clonic	3
Tonic seizure	3
Myoclonic	6
Absence	4
Eyelid myoclonia	1
Focal seizures	
Motor	6
Dyscognitive	2
Infantile epileptic spasms	5
Nonepileptic events*	13 (30%)

Abbreviations:
ED = Emergence department
EEG = Electroencephalography
vEEG = Video-EEG
* These included motor tics (1), behavioral staring (2), hyperventilation episode (1), hyperekplexia (1), nonepileptic limb movements (3), nonepileptic abnormal eye movements (2), stiffening and crying (2), and subjective abnormal feeling of dizziness (1).

than half (55%, 126 of 230) were found to have abnormal vEEG findings, with epileptic discharges in 84% (106 of 126) and isolated background slowing in 14% (18 of 126). The vEEG findings resulted in the initiation of antiseizure medications in 47% of patients not on any treatment (107 of 230) and impacted the decision to change antiseizure medications in 67% of patients with pre-established epilepsy (31 of 46).

Neuroimaging (computed tomography (CT) of the head or magnetic resonance imaging [MRI] of the brain) was requested in the ED in 34% (93 of 277) of patients based on abnormal vEEG results, of whom approximately half (47%, 45 of 93 patients) were found to have abnormalities on neuroimaging. These abnormalities included focal changes in most patients (27 of 45), as well as diffuse malformative, neurocutaneous, cystic, demyelinating, and other nonspecific changes (Supplementary Table 1). The majority (71%) of patients with neuroimaging abnormalities were found to have focal vEEG findings in the form of either focal epileptic discharges (27 of 45) or focal background slowing (five of 45). Nonfocal findings (multifocal/generalized epileptic discharges, diffuse background slowing) were noted in only 29% (13 of 45). Furthermore, focal abnormalities on vEEG were more likely to be associated with focal neuroimaging findings (70%, 23 of 32) as opposed to nonfocal vEEG findings (30%, four of 13), although this was not statistically significant ($P > 0.05$). Focal vEEG abnormalities were lateralizing to the neuroimaging findings in 20 of 32 patients (63%).

Risk factors and vEEG abnormalities

The association between various clinical risk factors and abnormalities on vEEG was evaluated using univariate logistic regression analysis (Table 3). The presence of perinatal risk factors, pre-existing developmental delay, a known diagnosis of epilepsy, and an abnormal neurological examination in the ED were all associated with a statistically significant risk ($P < 0.05$) of having an abnormal vEEG (Table 3). With respect to indication for vEEG in ED, patients presenting with new-onset paroxysmal events (with high clinical suspicion for seizure as per ED physician evaluation) as well as breakthrough seizures in patients with known epilepsy were more likely to have abnormalities on their vEEG monitoring with a statistically significant risk ($P < 0.05$) (Table 3).

Outcome

In 75% of patients (208 of 277), the outcome of the ED visit (disposition) was a home discharge, whereas subsequent hospital admission occurred in only a quarter of patients. In patients with abnormal EEGs in the ED who were discharged and followed in the neurology outpatient clinics and had a repeat EEG within 6-12 months following the ED visit, 51% (74 of 168 patients) had persistent abnormalities on repeat follow-up EEG within this time period.

Discussion

This study represents the largest pediatric cohort evaluating the utility of vEEG in the evaluation of 277 patients presenting with neurological complaints to the ED and sheds light on the usefulness of this noninvasive bedside test in contributing to the early diagnosis and treatment of patients, minimizing the need for further investigations, and reducing the need for hospital admissions. EEG is a valuable diagnostic tool that has long been used in the neurological evaluation of patients. Although EEG recording is considered an affordable, noninvasive, and highly accurate diagnostic method, it has not yet become a routine procedure in the emergency setting.[13]

Epilepsy and seizures are considered to be one of the most common neurological problems, especially in the pediatric age group.[3] Previous literature has identified a number of indications for EEG studies in the PED, most commonly for the evaluation of suspected cerebral death, convulsive status epilepticus, and myoclonic status epilepticus.[14] Over time, the indications have expanded, with new-onset seizures and paroxysmal spells becoming the most common reasons for such studies.[13] In this present study, similar to previous publications,[13] the most common indication for performing vEEG in the ED was for children presenting with new-onset paroxysmal events (37%) or first unprovoked seizure (20%). Conversely, convulsive status epilepticus was the least common indication, accounting for only 1.4% of the cases.

EEG in the ED plays an essential role in the evaluation of suspected seizures, which, particularly in children, can have ambiguous clinical presentations and for whom detecting abnormalities on EEG is relevant for diagnosis and management. The overall diagnostic yield of an EEG after a first-onset seizure is approximately 30%[11,18] and is influenced by several factors. EEG abnormalities are more likely to be seen in focal as opposed to generalized seizures,[12] earlier timing of the EEG after the event,[19] younger age,[20]

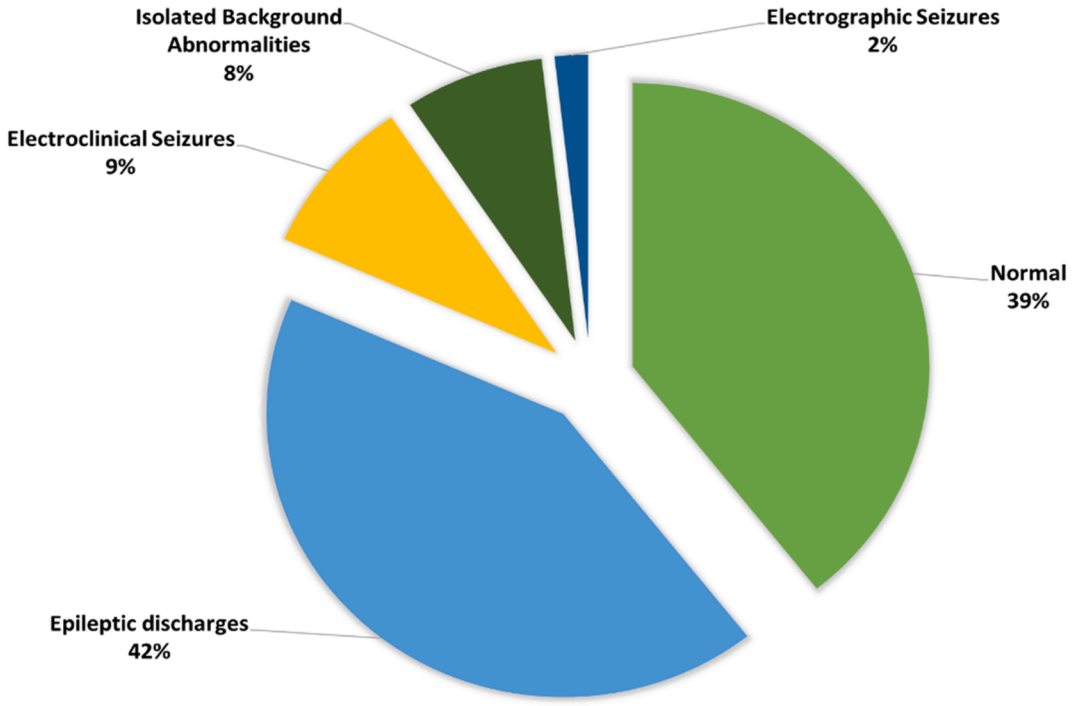

FIGURE. Breakdown of video electroencephalography findings. The color version of this figure is available in the online edition.

and patients presenting with unprovoked seizures.[21] Abnormalities on vEEG were found in 61% of all patients who underwent vEEG in the ED in this study and in 78% of patients presenting with new-onset paroxysmal events (confirmed to be seizures) or first unprovoked seizure. Multiple factors contributed to the high yield of vEEG in this study including the early timing of the study (92% were done within 24 hours from the event in question), as well as the success in achieving activation procedures such as sleep (80%), intermittent photic stimulation (70%), and hyperventilation (40%). Activation procedures, especially sleep, are well known for their role in increasing the yield in EEG recordings.[21] Although attaining sleep in infants and children is typically challenging, especially in a

TABLE 3.
Risk Factors for Abnormal vEEG Findings

	Abnormal vEEG (N)	Normal vEEG (N)	OR	95% CI	*P* Value
Clinical Risk Factors					
Head trauma	10	12	1.371	0.627-2.997	0.428
Previous history of febrile convulsions	7	11	2.350	0.940-5.877	0.518
Previous history of CNS meningitis	2	0	1.012	0.995-1.029	0.246
Perinatal risk factors[†]	21	3	0.214	0.065 -0.699	0.004*
Pre-existing developmental delay	50	15	0.449	0.266-0.758	0.001*
Known diagnosis of epilepsy	40	7	0.262	0.122-0.563	<0.001*
Toxic ingestion	0	1	0.991	0.974-1.009	0.402
Known case of brain tumor	2	1	1.341	0.120-14.974	1.000
Family history (epilepsy/febrile seizures)	23	14	0.910	0.490-1.691	0.766
Sleep deprivation	4	3	1.371	0.256-4.915	1.000
Abnormal neurological examination	35	8	2.350	0.165-0.709	0.002*
Indications for vEEG					
New-onset paroxysmal events (query seizure)	52	50	1.438	1.060-1.951	0.020*
First seizure (unprovoked)	32	22	1.028	0.632-1.673	0.911
Recurrent unprovoked seizure (not on ASMs)	25	9	0.538	0.261-1.109	0.084
Seizures (provoked)[‡]	3	6	2.991	0.764-11.711	0.163
Status epilepticus—rule out subclinical status epilepticus	2	2	1.495	0.214-10.461	1.000
Altered level of consciousness	10	11	1.645	0.723-3.742	0.231
Recurrent/breakthrough seizure in patients with known epilepsy	40	6	0.224	0.098-0.511	<0.001*

Abbreviations:
ASM = Antiseizure medication
CI = Confidence interval
CNS = Central nervous system
OR = Odds ratio
vEEG = Video electroencephalography
* Statistical significance.
† Preterm birth, history of perinatal asphyxia, and/or neonatal seizures.
‡ In the context of intercurrent illness/fever/trauma.

high-paced and noisy ED setting, this study demonstrates that achievement of natural sleep is feasible and aids in increasing the yield of the vEEG study.[14] These present findings reflect the high yield of vEEG in pediatric patients presenting with episodes suspicious for seizures and highlight a crucial role for this tool in early diagnosis and in predicting the risk for seizure recurrence,[20,22] especially when performed early in the ED as opposed to being delayed for days or weeks.

Interestingly, based on the clinical evaluation and vEEG findings, new-onset paroxysmal events (suspected seizures) were diagnosed as epileptic in more than half of the patients in this subgroup in which vEEG abnormalities were prevalent (82%) and in whom up to 41% eventually received a diagnosis of epilepsy in the ED and were started on antiseizure medications. This percentage is higher compared with previous literature in which EEG (without video) carried out in the PED resulted in a diagnosis of epilepsy in only 28% of patients presenting with suspected seizures.[13] Furthermore, specific epilepsy syndromes (including infantile epileptic spasms syndrome, self-limited epilepsy with autonomic seizures, self-limited epilepsy with centrotemporal spikes, epilepsy with myoclonic-atonic seizures) were diagnosed in the ED based on vEEG findings in 57% of patients presenting with new-onset paroxysmal events. EEG findings are crucial in the diagnosis of childhood epilepsy syndromes, which are defined by a constellation of clinical and electrophysiologic findings.[23] Recognition of childhood epilepsy syndromes is pivotal in the management of children with epilepsies, enabling timely tailored management with antiseizure medications, predicting prognosis, and providing families with more precise counseling.[24]

Nonepileptic events in children are common and can present a significant diagnostic challenge for clinicians.[25] These paroxysmal events may include psychogenic nonepileptic seizures[4] or physiologic seizure-like mimics such as breath-holding spells, vasovagal syncope, or sleep-related disorders.[26] Nonepileptic events can often be mistaken for seizures, resulting in unnecessary investigations, misdiagnosis, and inappropriate treatments in up to 10%-30% of cases.[27] Little is known about the utility of simultaneous vEEG in the PED in the characterization of clinical events.[14] In one recent pediatric study, vEEG provided additional information and was helpful for diagnosis in only 5% patients after they were admitted for further evaluation following EEG in the ED.[13] In our present study, clinical events were captured on vEEG in the ED in 16% of patients, of which 70% were confirmed to be epileptic and the remaining were nonepileptic. In these latter cases, the use of vEEG in the ED enabled accurate diagnosis, ended the diagnostic odyssey, and guided further management by avoiding unnecessary investigations and providing appropriate counseling to families.[16,17] Notably, two patients with nonepileptic events captured on vEEG had abnormalities on their recording, also highlighting that the presence of EEG abnormalities by itself does not confirm the diagnosis of epilepsy, as EEG abnormalities can be seen in 3%-5% of children with no history of seizures, and underscores the importance interpreting the EEG findings in the context of the clinical history and evaluation.[28] In these cases, capturing the events on vEEG likely prevented a misdiagnosis of epilepsy, significantly reduced family stress, and subsequently prevented unnecessary treatment.[29]

Beyond differentiating between nonepileptic and epileptic events, EEG can also serve as a helpful tool for diagnosing other conditions. Postictal symptoms, nonconvulsive status epilepticus, or other causes of altered mental status (metabolic disturbances, infections, trauma, nonepileptic causes) may be challenging to diagnose merely on clinical evaluation.[30] EEG can assist in identifying encephalopathy, nonconvulsive status epilepticus, and altered mental status and in detecting its specific EEG patterns.[30,31] One particularly interesting patient in our cohort presented with episodes of staring and inappropriate laughing. The EEG revealed bifrontal sharp waves and slowing, which indicated the request for imaging. The MRI subsequently showed demyelinating lesions consistent with multiple sclerosis.

vEEG contributed to treatment decisions in this cohort, when taken into context of the overall presenting clinical picture. vEEG abnormalities were found in 55% of patients presenting with new-onset paroxysmal events (suspected seizures), first unprovoked seizure, or recurrent unprovoked seizures who were not previously on treatment and contributed to the initiation of antiseizure medications in almost half of these cases. Furthermore, vEEG findings impacted the decision to change antiseizure medications in 67% of patients with pre-established epilepsy who had presented to the ED with recurrent seizures and were already on treatment. Indications for repeating the vEEG in this subgroup were mostly for change in seizure semiology, breakthrough seizures, or if the patient presented with a prolonged postictal period. Although historically the diagnosis of epilepsy was based on recurrence of two or more unprovoked seizures, with the more recent International League Against Epilepsy terminology,[32] this diagnosis can be attained even after a first unprovoked seizure in the presence of risk factors that increase the risk of seizure recurrence.[33] The presence of abnormalities on EEG is known to be associated with an increased risk of seizure recurrence after a first unprovoked seizure[18] and plays an important role in treatment decisions. Despite the fact that the results of the EEG alone should not be used in isolation to make clinical decisions and that it is important to consider the overall clinical picture, including seizure type, patient history, and risk factors for epilepsy, this diagnostic tool can, nevertheless, aid in risk stratification and impact the decision to start antiseizure medications, even after a single unprovoked seizure.[34] This fact highlights the utility of EEG in the ED, facilitating the timely initiation of therapy.

In the 61% of patients in this study who were found to have abnormalities on vEEG, the presence of isolated epileptic discharges was the most common (42%) followed by electroclinical seizures (9%). Isolated background abnormalities and electrographic seizures were recorded in 8% and 2% of patients, respectively. Subclinical (electrographic-only) seizures were recorded in five patients, the majority of whom (four of five) had a pre-existing history of epilepsy and only one patient presenting with new-onset encephalopathy with no history of clinical seizures, highlighting the role of vEEG in the evaluation of new-onset encephalopathy with or without clinical seizures.[31] These findings are in concordance with literature demonstrating that patients with epilepsy are at higher risk for subclinical seizures.[35]

Abnormalities on vEEG prompted neuroimaging to be done in the ED in 34% of patients, with focal neuroimaging findings being the most prevalent. Focality on EEG, whether in the form of focal epileptic discharges or focal background slowing was highly correlated with the presence of focal abnormalities on neuroimaging in 70% of cases and was lateralizing in 63% of cases. Although this did not reach statistical significance, these results align with the literature on the lateralization value of EEG and MRI findings.[36] Similarly, the study by Kuzniecky et al.[37] found that MRI correctly lateralized the EEG focus in 29 of 37 patients (78%).

Despite the potential for its utility, there are many factors that limit the use of vEEG in the ED setting including availability of technical and human resources. Setup of conventional vEEG is not only time consuming but also requires available EEG equipment as well as trained technicians, which are not necessarily present in all EDs, including in many tertiary hospitals worldwide.[38,39] Furthermore, accurate interpretation of EEG recordings requires specialized trained neurophysiologists, who are often not

physically present in the ED, and would require remote access to the recordings to make timely interpretations that could guide the management of patients.[9] More recently, point-of-care EEG (POC-EEG) has been suggested as a more accessible and alternative diagnostic solution in the acute setting, including in the PED or intensive care units.[40,41] POC-EEG systems are available at the bedside and can be deployed immediately by bedside nurses and other nonspecialist staff due to their simplified and user-friendly setup. As such, these diagnostic solutions enable immediate detection of seizures or encephalopathy, without the need to wait for the conventional EEG setup.[42] Nevertheless, the majority of POC-EEG systems are not without limitations. Their reduced channels result in decreased spatial resolution and diminished diagnostic accuracy, are prone to noise and artifacts, are often not equipped with video features, and still may require on-call neurologists for remote interpretation. As such, although POC-EEG may serve well for rapid screening, it cannot fully replace conventional vEEG. This being said, with the current rapid technological advancements some POC-EEG systems now incorporate full electrode montages, comparable to those used in the standard 10-20 or even 10-10 systems, and are equipped with video capabilities. Several of these advanced rapid EEG systems are starting to be used globally, mostly in research contexts. Although some have been approved for clinical use and are starting to be integrated into hospital workflows, at present accessibility to these technologies remains limited.

Considering the above points, it remains essential to determine which patients presenting to the ED with paroxysmal events or suspected seizures would benefit most from a vEEG recording in the ED. This knowledge can assist in early diagnosis and guide immediate management, especially in resource-limited settings. Our study identified several clinical factors associated with a higher risk of abnormal EEG results. The presence of perinatal risk factors, pre-existing developmental delay, a known diagnosis of epilepsy, and abnormal neurological findings in the ED were all significantly correlated with abnormal vEEG outcomes. These risk factors have been previously described[43] and can be used in risk stratification and decision pathways to help identify patients who would benefit from a vEEG in the ED, while considering resource restrictions.

There are a few limitations in this study worth mentioning. The lack of a comparison with a control group without EEG monitoring limits our ability to effectively compare admission and discharge rates. This absence may impact the generalizability of our findings, as we cannot determine how the inclusion of EEG influences these outcomes compared with standard practices that do not utilize EEG. Furthermore, the cost-effectiveness of vEEG in the evaluation of children presenting with paroxysmal events/seizures in PED as opposed to delaying the study to be done as an outpatient was not analyzed, and further studies in this respect are needed.

Conclusions

EEG is a powerful tool with significant potential for enhancing the diagnostic and therapeutic capabilities of the ED. EEG plays a key role in the evaluation of seizures, altered mental status, and neurological emergencies. Despite its challenges, such as time delays, equipment availability, and interpretative complexity, advances in portable EEG technology and telemedicine are improving its feasibility in the ED. By enabling rapid detection of subclinical seizures, status epilepticus, and other neurological abnormalities, EEG could lead to more accurate diagnoses, optimized patient management, and better outcomes in emergency care. As technology and access continue to improve, EEG may become a more routine part of emergency neurological evaluation. However, variations in health care systems must also be considered, including limitations on how long a patient can remain in the ED, which may impact the ability to perform certain neurodiagnostic procedures like EEG. In some settings, patients may need to be admitted for observation, allowing EEG to be conducted during their inpatient stay. These differences emphasize the need for flexibility when implementing vEEG across diverse health care environments, as clinical protocols may vary depending on patient flow, available resources, and health care policies. Understanding these distinctions is key to assessing the applicability and limitations of vEEG in both emergency and inpatient settings. Meanwhile, risk factors, such as those identified in this study, can be used to identify patients who may benefit from vEEG in resource-limited EDs, ensuring that patients receive timely and accurate diagnoses.

CRediT authorship contribution statement

Mohammad Y. Sawahreh: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Amani Hamid:** Writing – review & editing, Formal analysis, Data curation. **AbdelRahman T. Salem:** Writing – review & editing, Formal analysis, Data curation. **Khoulod Mohamed:** Writing – review & editing, Formal analysis, Data curation. **Colin V.E. Powell:** Writing – review & editing, Writing – original draft, Supervision, Formal analysis, Conceptualization. **Ruba Benini:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank Ms Farheen Ahmed for her help with some of the statistical analysis. Open Access funding was provided by Qatar National Library.

Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.pediatrneurol.2025.05.024.

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