



The diagnostic value of electroencephalography in pediatric patients presenting with syncope

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Abstract

Aim: In the investigation of the diagnosis of pediatric syncope, it was aimed to evaluate the rate of abnormal EEG findings and the diagnostic yield of the EEG in the electroencephalography (EEG) taken following their neurological examination.

Materials and Methods: EEG records of 332 patients younger than 18 years of age who presented to the pediatric neurology outpatient clinic with syncope were retrospectively analyzed. The EEG results were classified as normal and abnormal. Based on the abnormal EEG results, four subgroups were formed as focal epileptiform discharge, generalized epileptiform discharge, focal slowing and generalized slowing. Abnormal EEG results were categorized according to age and gender.

Results: Of the cases included in the study, 195 (58.7%) were female and 137 (41.3%) were male. The mean age of the patients was calculated as 12.67 ± 3.21 years. Analysis of the EEG results revealed that 92.5% were normal and 7.53% were abnormal. The most common abnormal EEG finding was focal slowing, which was detected in 12 (3.6%) patients, followed by focal epileptiform discharge which was detected in eight (2.4%) and generalized epileptiform discharge which was detected in five (1.5%) patients.

Conclusion: EEG should not be routinely performed to evaluate the diagnosis of pediatric syncope. Therefore, EEG should be performed only on patients to be selected based on their medical history and the results of their neurological examination. In this way, it will be possible to derive more benefits out of EEG and to reduce the associated medical costs.



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Introduction

Electroencephalography (EEG) is a useful neurophysiological test, particularly in making clinical decisions about suspected and actual epileptic seizure disorders in children. EEG is widely used in neurology practice given its availability in most outpatient clinics, safety, and relatively low cost [1]. EEG may be the most informative diagnostic tool in investigating changes in consciousness of a patient following a detailed review of the medical history of the patient and performance of neurological examination. However, there are some limitations to the diagnostic usefulness of EEG, and it may cause unnecessary medical costs if not utilized efficiently [2].

Syncope is a temporary, self-limiting condition that lasts between 8-10 seconds to 1-2 minutes, featuring a brief loss of consciousness and postural tone [3]. The incidence of syncope in children and adolescents has been reported as

86.5/100.000 [4]. Syncope constitutes 1% of the pediatric emergency department admissions [5]. The rate of children who experienced at least one syncope attack during the first 20 years of their lives was determined as approximately 15% [6]. It is more common in childhood period and in girls between the ages of 15-19 [7]. The most common cause of unconsciousness incidents in the pediatric group is neurally mediated syncope (NMS). The combination of NMS bradycardia and inappropriate vasodilation is characterized by systemic hypotension causing reflex-mediated insufficient cerebral blood flow [8]. NMS should be differentiated from serious or potentially life-threatening cardiac and neurological causes in patients with altered consciousness. This is best accomplished with a comprehensive clinical assessment [8]. Functional disorders such as vasovagal syncope, orthostatic hypotension, hyperventilation and breath-holding are more common in childhood [9]. Asystole and anoxia can induce epileptic seizures, in addition, ictal asystole can trigger syncope during epileptic seizures [9]. Syncope may be accompanied by symptoms such as long-term loss of consciousness, abnor-

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mal body movements, eye deviation, vocalization, tongue biting, urinary incontinence, hallucination, automatism, and muscle activity, which, if present, are often misdiagnosed as epilepsy [10]. EEG accurately explains some of these symptoms. Nevertheless, it has been reported in the literature that EEG has a low diagnostic efficiency in the diagnosis of syncope [2,11,12]. Then again, the relevant literature is dominated by adult studies, and there are only a few studies on pediatric cases.

In view of the foregoing, the objective of this study is to determine the rate of abnormal EEG findings and the diagnostic value of EEG, in cases where EEG is requested subsequent to neurological examination for the evaluation of the etiology of pediatric syncope.

Materials and Methods

The study was conducted in accordance with the principles of the Declaration of Helsinki. Approval of the Ethics Committee of institution Necmettin Erbakan University Meram Faculty of medicine was received for the study (No/date: 2022/3663:(8845). Written informed consent was obtained from patient parents/guardians. All data were analyzed retrospectively from our institution's patient database.

The population of the study comprised 332 patients under the age of 18 who were referred to Konya City Hospital pediatric neurology outpatient clinic with the diagnosis of syncope between January 2020 and January 2022. The EEG records of these 332 patients were retrospectively reviewed by a certified pediatric neurologist. Patients who have been using medication that could affect EEG, with a comorbidity and cognitive retardation were excluded from the study. Additionally, EEG recordings which contain excessive artifacts, elapsed less than 30 minutes, and during which induction methods such as sleep deprivation, photic stimulation and hyperventilation were not utilized, were excluded from the study.

Scalp surface electrodes of EEG were placed in accordance with the international 10-20 system and the EEG recording was performed using 21 channel Nihon Kohden EEG recorder.

The EEG results were classified as normal and abnormal. Epileptiform discharges (spiky/sharp waves) and slow waves were deemed as abnormal EEG findings. Based on the abnormal EEG results, four subgroups were formed as focal epileptiform discharge, generalized epileptiform discharge, focal slowing and generalized slowing. Abnormal EEG results were categorized according to age and gender. Accordingly, four groups were formed taking into account the different rates of diseases seen in age groups: children (C): C1 (<2 years), C2 (2-6 years), C3 (7-12 years) and adolescent: A (13-18 years) groups.

Statistical analysis

All pediatric patients who were admitted to the study with the diagnosis of syncope and planned EEG recording after evaluation by a pediatric neurologist were included in the study, retrospectively using purposive sampling (non-probability sampling) method. Therefore, since the fundamental assumption of the power analysis was not fulfilled, it could not be applied.

The EEG evaluation outputs and the subgroups of patients with abnormal EEG evaluation (focal epileptiform discharge, generalized epileptiform discharge, focal slowing and generalized slowing) were the primary outcome variables of this study.

The variables used in study, were summarized as mean \pm standard deviation or frequency (percent). The comparisons of groups with respect to quantitative variables was made using independent samples t-test. The comparisons of groups with respect to qualitative variables was made using chi-square tests. Normality assumption was checked by Shapiro-Wilk test for quantitative variables. The p-values of tests were considered to be significant at <0.05 . All statistical tests were conducted using the Statistical Package for the Social Sciences (IBM SPSS Corp., Armonk, USA) version 21 software for Windows.

Results

EEG recordings of a total of 384 patients were analyzed, and 332 of these patients that met the inclusion criteria were included in the study. Of these cases, 195 (58.7%) were female, 137 (41.3%) were male, and the female/male ratio was 1.42. The mean age of the patients was calculated as 12.67 ± 3.21 years (min.8 months-max.18 years). Categorization of the patients according to the age groups resulted in 11 patients to be classified under the C1 group, 30 patients under the C2 group, 114 patients under the C3 group, and 177 patients under the A group.

Analysis of the EEG results revealed that 307 (92.5%) were normal and 25 (7.53%) were abnormal. Of the patients with abnormal EEG results, 8 were male and 17 were female. The abnormal EEG results have not differed significantly by gender ($p=0.512$). Demographic characteristics and EEG results of the age groups are shown in Table 1.

Distribution of the abnormal EEG results by age and gender is shown in Table 2. Abnormal EEG findings were most common in the C3 (7-12 years) age group. Focal slowing was the most common abnormal EEG finding in 12 patients (3.61%). The most common abnormal EEG finding was focal slowing, which was detected in 12 (3.6%) patients, followed by focal epileptiform discharge which was detected in eight (2.4%) and generalized epileptiform discharge which was detected in five (1.5%) patients. Generalized slowing and hemispheric asymmetry were not observed in any of the patients. Distribution of focal epileptiform discharge by its subtypes revealed that five patients had focal frontal epileptiform discharge, two patients had temporal discharge, and one patient had occipital discharge. Simultaneous electrocardiography (ECG) recordings of all patients were available and none of them indicated any abnormal findings. Results of the cranial magnetic resonance imaging (MRI) of patients with focal epileptiform discharge were normal as well.

Discussion

The analysis of the EEG recordings of the syncope patients included in the study revealed abnormal EEG findings in 7.53% of the cases. In other words, most of the EEG results (92.5%) were normal. The most common (3.61%) abnormal EEG finding was focal slowing, which was observed the most in the C3 group (7-12 years old).

Table 1. Demographic characteristics and EEG results of the groups.

	C1 (n=11)	C2 (n=30)	C3 (n=114)	A (n=177)	p value
Age group (years)	< 2	2-6	7-12	13-18	
Gender, n (%)					0.18
Female	4 (2.1%)	19 (9.7%)	63 (32.3%)	109 (55.9%)	
Male	7 (5.1%)	11 (8%)	51 (37.2%)	68 (49.6%)	
EEG, n (%)					0.27
Normal	11(3.6%)	28 (9.1%)	101 (32.9%)	167 (54.4%)	
Abnormal	0	2 (8%)	13 (52%)	10 (40%)	

C; children (C1= < 2 years, C2=2-6 years, C3= 7-12 years), A; adolescent= 13-18 years, EEG; Electroencephalography.

Table 2. Abnormal EEG results according to gender and age group.

	Focal epileptiform discharge	Generalized epileptiform discharge	Focal slowing	Generalized slowing
Number, n (%)	8 (2.4%)	5 (1.5%)	12 (3.61%)	0
Age (mean±SD)	12.67 ±3.45	13.81±4.27	11.63±4.64	
Abnormality in groups, n (%)				
C1	0	0	0	0
C2	1 (12.5%)	0	1 (8.3%)	0
C3	4 (50%)	1 (20%)	8 (66.6%)	0
A	3 (37.5%)	4 (80%)	3 (25%)	0
Gender, n				
Female	6	4	7	
Male	2	1	5	

C; children (C1= < 2 years, C2=2-6 years, C3= 7-12 years), A; adolescent= 13-18 years, SD: Standard deviation.

There are only a few number of studies available in the literature on the diagnostic yield of EEG in pediatric patients with syncope. In one of these studies with relevant information on the pediatric population, Abubakr et al.[11] studied the EEG records of 1094 patients aged between 6 and 103 years (67% > 60 years, 3.8% < 20 years) with a diagnosis of syncope, and found that 67.18% were normal and 29.61% were abnormal (focal or generalized slowing in 28.15% and epileptiform discharge in 1.46% of the patients). It was stated in the same study that only 2 cases in the group younger than 20 years had abnormal EEG findings featuring focal slowing and generalized slowing associated with old structural abnormalities in the brain. In another study, in which EEG results of 1003 children and adults aged between 1 and 94 years with a diagnosis of syncope were studied, Dantas et al.[2] reported that 89.53% of the EEG records were normal and 10.5% were abnormal (focal or generalized slowing in 8.67% and epileptiform discharge in 1.79% of the patients). Patients were grouped according to their age, considering that the causes may vary according to the etiology. The most common abnormal finding in the 26-50 years and over 51 years age groups was the diffuse slowing, which was attributed to age-related brain injury susceptibility. In another study, age has been designated as a risk factor for cerebrovascular and cardiac syncope and epileptic discharge, which were observed in 50% of the elderly patients, and it was concluded that epileptic activity and cardiovascular mechanisms played a role in syncope episodes [13]. Poliquin et al. [12] examined 517 EEG recordings which were requested by both neuro-

logists and non-neurologists within the scope of the differential diagnosis of syncope, and found abnormal findings and epileptic activity in 11% and 1.6% of the recordings, respectively. The rate of EEGs with abnormal findings among syncope patients in the said study was found to be similar to that of general population, thus did not lead to a change in the therapeutic management of these patients. Interestingly, it was also found that the diagnostic yield of EEGs requested by neurologists was not higher than that of the EEGs requested by non-neurologists. It has been noted in the literature that EEG plays a minor role in the evaluation of the diagnosis of syncope, and that the rate of EEGs with epileptiform abnormalities does not differ between children and adolescents with syncope and healthy children and adolescents [1,2]. Additionally, it has been reported in many studies that the diagnostic value of EEG is in the evaluation of syncope is low and that the most common abnormal EEG finding is focal/diffuse slowing pattern [2,11,12].

In comparison, in this study, the rate of females whose EEGs recorded during the evaluation of syncope revealed abnormal findings was 2.13 times higher than that of males, which might be attributed to the higher ratio of females included in the study group. The findings of this study, i.e., low rate (7.53%) of EEGs with abnormal findings, focal slowing as the most common abnormal EEG finding, and low (3.9%) EEG diagnostic yield, were compatible with the relevant findings reported in the literature [2,11,12]. Generalized slowing was not observed in any of the cases included in this study. Focal and generalized

epileptiform discharge in EEG results was observed in 13 (3.9%) patients. Focal epileptiform discharge (2.4%) was detected most frequently in the frontal region. Cranial MRI results of patients with focal epileptiform discharge were normal. All patients who were determined to have epileptiform discharge in EEG were started on antiepileptic medication. Cases suspected for epilepsy were followed up. Given that focal epileptiform discharges are most commonly found in the frontal region and that the semiology of frontal lobe epilepsies is not always straightforward and can be confused with neurological presentations such as syncope and paroxysmal disorders, EEG may play an important role in the diagnostic process of the cases with the said features [14].

Interictal epileptiform discharges can be seen in 2% of the healthy individuals without a history of epileptic seizures. The finding of epileptiform discharge in the EEGs of these individuals strengthens the diagnosis of epilepsy [15]. However, the EEGs may not reveal any finding indicative of a pathology even in cases with a history of episodic and paroxysmal attacks where there are clues suggesting epileptic seizure. As a matter of fact, the rates of epilepsy patients with normal EEG findings reported in the literature vary within a wide range between 12% and 50%. Thus, performing a series of EEGs with longer recording times will increase diagnostic yield [16]. In addition, hyperventilation, photic stimulation and sleep deprivation may also trigger epileptiform discharge in EEG [17]. Diagnosis of epilepsy is a clinical one, thus EEG is merely an auxiliary diagnostic tool in making the final diagnosis of epilepsy. A normal EEG does not exclude the diagnosis of epilepsy.

Brenner et al.[18] stated that the EEG may show abnormalities in syncope patients with a medical history explicitly indicating a cardiac and hemodynamic cause, yet will not help with the diagnosis. In the said study, the EEG findings were categorized in four main groups of syncope: neurocardiogenic, neurologic, decreased cardiac output, and orthostatic hypotension. They found that the EEG findings during an episode were similar irrespective of the cause of syncope, and reflected cerebral hypoperfusion, and concluded that none of the findings were indicative of any prominent epileptic discharge. In EEG, the initial slowing of background rhythms during presyncope is followed by high amplitude delta activity. If hypoperfusion continues, then flattening occurs in the EEG, and convulsive syncope may occur in cases of severe and prolonged ischemia during the flattening of the EEG. This situation is often confused with epilepsy in clinical practice. Conversely, epileptic seizures with ictal bradycardia syndrome or ictal asystole may sometimes indicate syncope [18]. EEG should not be routinely performed in the evaluation of syncope in children. However, an EEG should be requested in patients who have symptoms that suggest epileptic seizures such as witnessed convulsions or automatism with transient loss of consciousness, prolonged unconsciousness, typical auras, incontinence, and amnesia. In the event that the EEG is evaluated as normal in this patient group, serial EEGs involving sleep deprivation and sometimes continuous video EEG recordings may be required to detect seizure activity [19].

In cases of syncope in children and adolescents, a review of the detailed medical history followed by a comprehensive neurological examination helps to identify etiologic causes. The main purpose of this process is to decide whether there is loss of consciousness associated with actual syncope. In addition, it is very important to rule out cardiovascular causes due to the associated risk of mortality and high incidence of sudden death. Most pediatric patients with syncope present no warning symptoms or triggering events, while some may present warning symptoms that can help differentiate syncope from seizures and other conditions. The physician should heavily rely upon clinical information while establishing a diagnostic approach for a patient with syncope [19]. EEG will not help unless there are suspicious information in the medical history of the patient and physical and neurological examinations reveal suspicious findings. EEG is widely used in the evaluation of patients with syncope, but the diagnostic value of EEG in syncope is very low at 1.5% [2]. Performing cranial MRI, which is also widely used in the evaluation of syncope and has low diagnostic value may exacerbate the costs associated with the diagnosis of syncope [20].

Limitations of the study

The major limitation of the study was its retrospective design, which prevented the analysis of the interpretations of the physician who requested the EEG about the medical history of the patient and the impressions of the same physician about the patient in the context of the etiology of syncope.

Conclusion

EEG provides low diagnostic yield in evaluating the etiology of pediatric syncope. A duly review of the medical history and comprehensive physical and neurological examinations can prevent unnecessary investigations and reduce medical costs in these patients. EEG should not be routinely requested. EEG imaging will provide more diagnostic benefits if performed on selected patients only.

Ethics approval

Approval of the Ethics Committee of institution Necmettin Erbakan University Meram Faculty of medicine was received for the study (No/date: 2022/3663:(8845)).

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