A Retrospective Evaluation of the Characteristics of Patients Undergoing Electroencephalography in a Newly Established Pediatric Neurology Clinic

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Abstract

Objective: The aim of this study was to examine the clinical and demographic findings of patients who underwent electroencephalography (EEG) for various clinical indications in a newly established pediatric neurology clinic.

Methods: EEG records in the pediatric EEG laboratory, requested by the pediatric neurology outpatient clinic of Balıkesir University Faculty of Medicine, Department of Pediatrics, between November 2019 and August 2020, were retrospectively reviewed.

Results: 884 EEGs were taken and 450 patients who had EEG for the first time were included in the study. The mean age of the children was 111.11±65.06 months (range 7-216 months). Of the patients who underwent EEG, 224 (49.8%) were female and 226 (50.2%) were male. When grouped by age, the least number of cases was between 0 and 12 months (n=6, 1.3%), while the highest number of cases was in the >12 age group (n=168, 37.3%). The three most common clinical indications for EEG imaging were; diagnosed/suspected epilepsy (n=279, 62%), syncope (n=58, 12.9%) and febrile seizures (n=32, 7.1%). While the EEGs of 314 (69.8%) cases were normal, 43 (9.6%) cases had abnormal EEGs and 93 (20.7%) cases had EEGs with epileptiform character. Localizations of EEGs with epileptiform character; the most common localization was generalized (n=48, 10.7%), secondly focal (n=23, 5.1%) and thirdly multifocal (n=8, 1.8%).

Conclusion: We revealed the profile of a routine EEG laboratory in a newly established pediatric neurology clinic.

Keywords: Children, electroencephalography, epilepsy

INTRODUCTION

Electroencephalography (EEG) has long been used as an important tool in the study of children with various neurological disorders.[1,2] It is also a sensitive detector of diffuse cortical dysfunction seen in toxic, metabolic, and hypoxic encephalopathies.[3,4] Although the diagnosis of seizures and epileptic syndromes is primarily based on clinical findings, EEG provides supportive evidence and assists with seizure classification.[5] Epileptiform abnormalities are detected at EEG in approximately one-third of children and adults presenting with new onset seizures.[6] In some publications, the rate is as high as 56%, and an additional 11% increase in epileptiform abnormalities has been reported with repeated EEG scans.[7]

EEG is also the gold standard method in the differential diagnosis of numerous paroxysmal attacks other than epilepsy, such as syncope and non-epileptic psychogenic seizures with epilepsy. While it is a useful guide in encephalopathies, cognitive or behavioral changes, and neurodegenerative diseases, it can also be diagnostic in cases with specific EEG findings, such as Creutzfeldt-Jakob disease.[8] EEG is also useful in identifying non-convulsive seizures and in the differential diagnosis of seizure-mimicking conditions such as neonatal jitteriness, sleep disturbances, breath-holding spells, startle responses, paroxysmal movement disorders, migraine, syncope, dizziness, masturbation, panic attacks, and non-epileptic seizures.[9]

Although EEG is one of the basic diagnostic methods in pediatric neurology, its use is recommended only in selected cases.[9] The widespread use of EEG raises concerns about the appropriate justification and optimization of EEG requests.[10] Various studies have reported that EEG requests are mostly made by general pediatricians and child psychiatrists, rather than pediatric neurologists.[9] This can affect abnormal

activity detection rates. The aim of this study was to examine the clinical and demographic findings of patients who underwent EEG for various clinical indications in a newly established pediatric neurology clinic, to evaluate normal and abnormal EEG findings, and to present the diagnostic profile of the routine EEG laboratory.

METHODS

EEG records in the pediatric EEG laboratory requested by the pediatric neurology outpatient clinic of the Balıkesir University Faculty of Medicine, Department of Pediatrics, Turkey, between November 2019 and August 2020 were reviewed retrospectively. Scalp electrodes were attached to all patients according to the International 10-20 system consisting of 21 electrodes, and signals were recorded for 30-60 minutes, typically using appropriate standard mounts with a 16-channel Nihon Kohden EEG machine. All the EEGs were evaluated by the same pediatric neurologist. Reasons for requesting EEG, age, gender, birth weight, birth type, gestational age, body weight, height and head circumference percentiles, EEG abnormalities, pathological localizations at EEG, the number of repeated EEG records, family history of febrile convulsion/epilepsy, antiepileptic drugs used, and cranial imaging [magnetic resonance imaging (MRI)] findings were recorded. Approval for the study was obtained from the Balıkesir University Local Ethics Committee (date: 13.01.2021, permission no: 2021/04).

EEGs that could not be evaluated adequately due to artifact or technical reasons were excluded from the study. Standard activation procedures (eye opening, hyperventilation, and photic stimulation) were applied to all patients unless contraindications were present. EEG recordings are noted. Clinical preliminary diagnoses of patients for whom EEG was requested were classified into six groups: 1) suspected/newly diagnosed epilepsy, 2) diagnosed epilepsy, 3) non-paroxysmal epileptic attack, 4) non-epileptic chronic central nervous system (CNS) diseases, 5) acute CNS disorders, and 6) febrile seizure. EEG findings were classified into three groups - normal, abnormal, and epileptiform anomaly. Patients were also grouped by age - <1 year old, 1-3 years, 3-6 years, 6-9 years, 9-12 years, and >12 years. Height and weight were grouped as <3rd percentile, 3rd-97th percentile, and >97th percentile. The head circumference was classified as <-2 standard deviation (SD), between (-2) SD and (+2) SD, and >+2 SD. In terms of gestation weeks, patients were grouped as <28 weeks, 28-32 weeks, 33-37 weeks, and 38-42 weeks. Finally, birth weight classification was classified as <2000 g, 2000-3000 g, 3000-4000 g, and >4000 g.

Seizures in patients with evidence of epilepsy at both clinical examination and EEG were classified according to the International League Against Epilepsy classification.[11]

Statistical Analysis

All analyses were performed on Statistical Package for the Social Sciences (SPSS) version 23.0 software (SPSS, Armonk, NY, USA). Descriptive variables were expressed as percentage, frequency, mean, SD, and minimum and maximum values.

RESULTS

Eight hundred eighty-four EEGs were taken, and 450 patients undergoing EEG for the first time were included in the study.

The mean age of the children was 111.11±65.06 months (range 7-216 months). Two hundred twenty-four (49.8%) patients who underwent EEG were female and 226 (50.2%) were male. Mean ages were 108.84±4.85 months (13-216) for girls and 113.89±65.51 months (1-212) for boys. In terms of age, the lowest number of cases was observed at 0-12 months (n=6, 1.3%) while the highest number was in the >12 age group (n=168, 37.3%).

The three most common clinical indications for EEG imaging were diagnosed/suspected epilepsy (n=279, 62%), syncope (n=58, 12.9%), and febrile seizures (n=32, 7.1%). EEG findings were divided into normal, abnormal, and epileptiform anomaly. EEGs were normal in 314 (69.8%) cases, abnormal in 43 (9.6%), and epileptiform in character in 93 (20.7%). EEGs with epileptiform character were most frequently generalized (n=48, 10.7%), followed by focal (n=23, 5.1%), and multifocal (n=8, 1.8%). One hundred fifty-eight (35.1%) patients diagnosed with epilepsy received monotherapy and 55 (12.2%) received polytherapy (2-4). The most commonly used antiepileptic drugs in monotherapy were levetiracetam (n=121, 26.9%), followed by valproic acid (n=50, 11.1%).

Cranial MRI was also performed in 212 (47.1%) cases undergoing EEG. Cranial imaging revealed abnormalities in 45 (21.2%) of these patients. The most common abnormal cranial imaging findings were white matter lesions (n=13, 2.9%), intracranial mass (n=7, 1.6%), and corpus callosum agenesis/dysgenesis (n=6, 1.3%). The clinical and demographic characteristics of the 450 patients who underwent EEG for the first time are shown in Tables 1 and 2.

Arrhythmia was detected in five (1.1%) of the 450 patients who underwent EEG. A total of 435 repeat EEGs were performed during the study. The rate of detection of abnormal findings at repeat EEG was 44.64%.

DISCUSSION

EEG was abnormal/epileptiform in character in 30.2% of the patients undergoing the first EEGs in this study, while abnormal findings were detected at a rate of 44.64% at repeat EEGs. The most frequent indication for EEG was diagnosed/suspected epilepsy (62%).

Jan[1] reported that seizures were the most common reason for requesting EEG (78%). In that study, 32% of EEGs were requested by pediatric neurologists, and EEGs were studied for the first time in 65% of cases. Overall, 55% of EEGs were abnormal, and the likelihood of abnormality at repeat EEG was twice as high as that for the first record.[1] Airoldi et al.[12] reported that 55% of requested EEGs were abnormal, and that 28.6% of patients with definite diagnoses of epilepsy and 6.1% of those with possible seizures

Table 1. Characteristics of pediatric patients undergoing EEG for the first time (n=450)

Age	n (%)
0 to 12 months	6 (1.3%)
1 to 3 years	82 (18.2%)
3 to 6 years	65 (14.4%)
6 to 9 years	65 (14.4%)
9 to 12 years	64 (14.2%)
>12 years	168 (37.3%)
Gender	
Female	224 (49.8%)
Male	226 (50.2%)
Height percentiles	
<3rd percentile	1 (0.2%)
3-97th percentile	446 (99.1%)
>97th percentile	3 (0.7%)
Weight percentiles	
<3rd percentile	33 (7.3%)
3-97th percentile	383 (85.1%)
>97th percentile	34 (7.6%)
Head circumference	
<-2 SD	27 (6%)
(-2) SD - (+2) SD	401 (89.1%)
>+2 SD	22 (4.9%)
Gestational week	
<28 weeks	8 (1.8%)
28-32 weeks	26 (5.8%)
33-37 weeks	99 (22%)
38-42 weeks	317 (70.4%)
Birth weight	
<2000 grams	27 (6%)
2000-3000 grams	131 (29.1%)
3000-4000 grams	259 (57.6%)
>4000 g	33 (7.3%)
Delivery type	
NSVR	187 (41.6%)
C/S	263 (58.4%)
Positive family history of epilepsy	97 (21.6%)
Positive family history of febrile seizures	57 (12.7%)

NSVR: Normal spontaneous vaginal route, C/S: Cesarean section, SD: Standard deviation, EEG: Electroencephalography

Table 2. Characteristics of pediatric patients undergoing EEG for the first time (n=450)

Diagnostic classification	
Suspected/newly diagnosed epilepsy	101 (22.4%)
Diagnosed epilepsy	178 (39.6%)
Non-paroxysmal epileptic attack	98 (21.8%)
Non-epileptic chronic CNS diseases	31 (6.9%)
Acute CNS disorders	10 (2.2%)
Febrile seizure	32 (7.1%)
EEG	
Normal	314 (69.8%)
Abnormal	136 (30.2%)
- Non-epileptiform	43 (9.6%)
- Epileptiform	93 (20.7%)
Localization of epileptiform discharges	
Generalized	48 (10.7%)
Multifocal	8 (1.8%)
Focal	37 (8.1%)
- Temporal	12 (2.7%)
- Frontal	9 (2%)
- Other	16 (3.4%)
Cranial MRI	
Normal	167 (37.1%)
Abnormal	45 (10%)
- Encephalomalacia	4 (0.9%)
- Mass	7 (1.6%)
- White matter lesion/gliotic focus	13 (2.9%)
- Hydrocephalus	2 (0.4%)
- Cortical dysplasia	2 (0.4%)
- Calcification	2 (0.4%)
- Demyelinating diseases	2 (0.4%)
- Corpus callosum lesion	6 (1.3%)
- Cerebral atrophy	2 (0.4%)
- Hydranencephaly	1 (0.2%)
- Chiari malformation	2 (0.4%)
- Arachnoid Cyst	2 (0.4%)

CNS: Central nervous system, MRI: Magnetic resonance imaging, EEG: Electroencephalography

exhibited epileptiform discharges at EEG. Some studies have reported that approximately half of the EEG records obtained were normal.[13] In a study involving 300 adults and 59 children presenting with the first seizure, 43% of the initial EEG recordings exhibited epileptiform abnormalities.[14] Shinnar et al.[15] reported that EEG was abnormal in 42% of children presenting with unprovoked seizures. In this study, 69.8% of EEGs were normal, 9.6% abnormal, and 20.6% epileptiform.

In their study published in 2003, Aydin et al.[9] performed EEG tests on 534 children due to clinical seizures (33.8%), definite diagnosis of epilepsy (31.2%), attention deficit hyperactivity disorder (9.1%), headache (8%), syncope (3.5%), learning difficulties (2%), tic disorders (1.4%), or sleep disorders (1.1%), and described 63.8% of all EEGs as normal. Epileptiform activity was detected in 37.1% of definitively diagnosed epilepsy cases in that study, in 13.2% of clinically suspected cases, and in 10% of patients with

febrile seizures.[9] Tekin Orgun et al.[10] examined 2045 pediatric EEG records and observed an overall 43.6% rate of abnormalities and 38.2% rate of epileptiform activity at EEG. They reported that definite diagnoses of epilepsy were present in 54.2% of these patients, suspicion of epilepsy in 29.4%, and nonepileptic chronic CNS diseases in 20%. In this study, 39.6% of the patients referred to the EEG laboratory were diagnosed with epilepsy, 22.4% had suspected epilepsy, 21.8% nonparoxysmal epileptic attacks, 7.1% febrile seizures, 6.9% non-epileptic chronic CNS diseases, and 2.2% acute CNS disorders.

Tekin Orgun et al.[10] observed focal abnormal activity in 67.9% of cases with epileptiform activity at EEG, generalized activity in 20.6%, and multifocal activity in 11.9%. In this study, 51.6% cases exhibited generalized activity, 8.6% multifocal, and 39.8% focal epileptic focus. The most common localization in the focal foci was the temporal and frontal regions. In Tekin Orgun et al.'s[10] study, and similarly to this research, 90.5% of EEGs were requested by pediatric neurologists. Those authors also reported that the use of EEG had become more selective in the last decade and that the rate of detection of abnormalities had increased due to a rise in the number of pediatric neurologists.[10]

While the rate of detection of abnormality at the first routine EEG in patients with epilepsy is 30-40%, the detection of epileptiform abnormalities increases with repeated EEG images.[16,17] Jan[1] described repetition of EEGs as a factor that significantly increases the possibility of detection of abnormality at EEG. In Tekin Orgun et al.'s [10] study, the rate of detection of abnormalities with repeated EEGs was 58.2%. Those authors reported that 11.9% of repeated EEGs contributed to the diagnosis. Carpay et al.[7] detected epileptiform abnormalities at a rate of 56% at the first EEG in newly diagnosed patients with epilepsy. Interestingly, and similarly to Tekin Orgun et al.[10] they detected an additional 11% increase in epileptiform abnormalities with repetitive EEG records. In this study, the rate of epileptiform/abnormal feature detection in repeated EEG records was 44.64%, a figure consistent with the previous literature.

Electrocardiogram (ECG) recording during EEG is important for detecting ictal and interictal arrhythmias in paroxysmal disorders of cardiac origin and epilepsy.[18,19] EEG can be requested in some life-threatening arrhythmias due to their seizure-like clinical appearance.[20] A study conducted in 2013 reported that arrhythmia was detected at a rate of 2% with simultaneous ECG recording during routine EEG.[20] A compatible figure of 1.1% was determined in this study.

Brain imaging was performed in 47.1% of the patients who underwent EEG. Abnormal cranial imaging was detected in 45 cases (10% of all patients). The most common abnormal cranial imaging findings were white matter lesion (n=13, 2.9%), intracranial mass (n=7, 1.6%), and corpus callosum agenesis/dysgenesis (n=6, 1.3%). In another study, the most common findings detected during cranial imaging performed due to epilepsy were encephalomalacia due to chronic infarcts (n=18, 6.3%), cerebral atrophy (n=11, 3.8%), neuronal migration disorders (n=11, 3.8%), periventricular leukomalacia (n=9, 3.1%), and hippocampal sclerosis (n=8, 2.8%). However, in contrast to the present research, only cranial imaging findings of patients diagnosed with epilepsy were presented in that study.[21] In our study, the rate of detection of any abnormality was higher with EEG than with cranial MRI.

The rate of abnormality detection gradually changes due to additional factors such as advances in EEG techniques, changes in the time and duration of EEG recording, and the adoption of other simultaneous diagnostic methods such as video EEG. The recent rise in the number of pediatric neurologists has also been reported as a factor.[10]

Study Limitations

The principal limitations of this study can be listed as follows; a) some records were lacking due to its retrospective nature, b) our EEG center is new, and the number of patients admitted to the outpatient clinic was relatively low due to the 2019 Coronavirus disease-19 pandemic, c) EEG was evaluated by only one physician, and interobserver agreement could not be evaluated, and d) the absence of an intensive care unit in our center limited the number of patients with acute encephalopathy.

CONCLUSION

This study aimed to describe the profile of a routine EEG laboratory in a newly established pediatric neurology clinic. We hope that our study will be a useful point of reference for new pediatric neurology clinics to be established due to the increase in the number of pediatric neurology specialists. In conclusion, multi-center, prospective studies with more patients are now needed to better interpret our results.

Ethics

Ethics Committee Approval: The Balıkesir University Non-Interventional Clinical Research Ethics Committee approval was obtained (date: 13.01.2021, permission no: 2021/04).

Informed Consent: Informed consent was not required because of the retrospective design.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept: H.A., S.Y., G.B.A., Design: H.A., S.Y., Data Collection or Processing: H.A., S.Y., G.B.A., Analysis or Interpretation: H.A., S.Y., G.B.A., Literature Search: H.A., S.Y., G.B.A., Writing: H.A., S.Y., G.B.A.

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