Electroencephalography Patterns in Children with First Unprovoked Seizure

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Research Article

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Abstract

Background

First unprovoked seizure (FUS) is a neurological health problem that occurs in an estimated 2% of children aged 16 years or younger. Electroencephalography (EEG) is an electrophysiological technique to record electrical activities arising from the brain; this technique can be used to evaluate patients with suspected seizures, epilepsy, and unusual concomitants. The objective of this study is to describe the EEG patterns in children with FUS and the factors associated with these EEG results.

Method

A retrospective analytic study was conducted in the Neuropaediatric Clinic, Dr Soetomo General Academic Hospital. The medical record data were obtained from January 2018 to December 2019. Children aged one month to 18 years with FUS and their complete EEG records were included. Descriptive statistics and the chi-square test with Cochran's Q test and Mantel–Haenszel tests were used for statistical calculations.

Results

One hundred participants enrolled the study. The majority (54%) showed abnormal EEG, which was dominated by epileptiform discharges (68.5%) consisting of benign epileptiform with centro-temporal spikes (BECTS), focal and generalized sharp waves, focal and generalized spikes, and EEG seizures. Factors associated with abnormal EEG results were children aged ≥ 5 years (p = 0.07, OR = 3.093, 95% CI = 1.361–7.030), focal seizure type (p = 0.021, OR = 6.286, 95% CI = 1.327–29.779), and long seizure duration ≥ 5 minutes (p < 0.001, OR = 8.333, 95% CI = 3.029–22.929).

Conclusion

Children with abnormal EEG were at risk for recurrent seizures. Over 50% of children with FUS had abnormal EEG results. In the present study, abnormal EEG results were frequently found in children with FUS, especially in older children (≥ 5 years old), those with focal seizures, and those with long seizure durations (≥ 5 minutes).

Introduction

Seizure is one of the most common neurological problems occurring in children. According to the International League Against Epilepsy, the first seizure in paediatric patients is defined to include one or more seizures within 24 hours with recovery of consciousness between the seizures. In the latest classification, first unprovoked seizure (FUS) can be considered epilepsy when the risk of recurrent
seizures is greater than 60%. Population-based studies of the prevalence of FUS show that there are 25,000 to 40,000 children per year who experience FUS in the United States. Several studies suggest that abnormal electroencephalography (EEG) findings in FUS are associated with a risk of recurrent seizures.

EEG is an important modality for the clinical diagnosis of seizures and epilepsy. Having an EEG examination 30 minutes after FUS is very helpful in identifying the type of seizure that has occurred and determining the risk of recurrence after the first event. However, there is a long ongoing debate regarding the benefit of EEG examinations in determining whether a seizure will recur. Several studies have reported high abnormal EEG results in children with FUS, and those with abnormal EEG results have a risk of recurrent seizures. One study conducted in Japan showed that seizure recurrence in FUS cases occurred in 16.7% of children whose EEG showed general wave spikes and 61.9% of children with focal epileptic waves ($p<0.0001$). Thus, an abnormal EEG can be a consistent predictor of recurrent seizure probability. Therefore, this research was conducted to describe the EEG patterns in children with FUS and the factors associated with their EEG results.

**Methods**

**Patient and methods**

This study used a retrospective research design. As secondary data, medical records were obtained at Dr Soetomo General Academic Hospital, Surabaya, from January 2018 to December 2019. The target population of this study consisted of all seizure patients who had EEG recordings and were treated at the Paediatric Neurology Clinic at an age of 1 month to 18 years. The inclusion criteria called for patients diagnosed with FUS based on history taking, physical diagnostics, and supporting examinations. The exclusion criteria eliminated patients whose medical records was incomplete (e.g., missing age, gender, duration of seizures, type of seizure, or EEG images); children found to suffer from fever, head trauma, epilepsy, central nervous system infection, tumours, or metabolic disorders such as hypoglycaemia, and children whose seizures were suspected to have been triggered by medication. Total population sampling was applied to FUS patients who fulfilled the inclusion criteria. EEG was performed for at least 30 minutes, within 48 hours after the event using a Nihon Kohden EEG-1200 machine and interpreted by an internationally certified electroencephalographer. In addition, data were collected on the clinical characteristics of FUS patients based on their medical records; this information included age, sex, duration of seizures, type of seizure, and EEG results.

**Statistical analysis**

The collected data were then processed with International Business Machines Statistical Package for the Social Sciences (IBM SPSS) Statistics version 21. The data were analysed using descriptive statistics and the chi-square test along with Cochran's Q test and the Mantel–Haenszel test to reveal the relationship between variables. The data are presented in tabular and narrative form.

**Ethics**
The study was reviewed and approved by the Research and Ethics Scientific Committee at Dr Soetomo General Academic Hospital, Surabaya, Indonesia (1860/KEPK/III/2020).

Results

Table 1 portrays the characteristics of 100 subjects, who were predominantly boys (62%) predominantly over five years old (56%). The most common type of seizure was generalized (86%), and the most common duration was < 5 minutes (64%). The majority of EEG examinations showed abnormal results (54%), predominantly epileptiform waves (68.5%).
| Characteristics of subjects | Total (n = 100) |
|-----------------------------|-----------------|
| Gender                      |                 |
| Boys, n (%)                 | 62 (62%)        |
| Girls, n (%)                | 38 (38%)        |
| Age                         |                 |
| < 5 years                   | 44 (44%)        |
| ≥ 5 years                   | 56 (56%)        |
| Type of seizure             |                 |
| General seizure             | 14 (14%)        |
| Focal seizure               |                 |
| Duration of seizure         |                 |
| < 5 minutes                 | 36 (36%)        |
| ≥ 5 minutes                 |                 |
| Result of EEG               | 54 (54%)        |
| Abnormal                    | 46 (46%)        |
| Normal                      |                 |
| Abnormal EEG                |                 |
| Type of abnormal wave       | 37 (68.5%)      |
| • Epileptiform discharge    | 17 (31.5%)      |
| • Non-epileptiform discharge|                 |
| Time of record              |                 |
| • Sleep phase               | 34 (62.9%)      |
| • Awake phase               | 8 (14.8%)       |
| • Sleep and awake           | 12 (22.2%)      |

Figure 1 depicts the types of EEG abnormality. EEG wave deceleration was found in 17 EEG examinations: 15 indicating focal slowing, 1 indicating generalized slowing, and 1 indicating low voltage. Meanwhile, 37 other EEG abnormalities showed epileptogenic discharge consisting of BECTS, focal and generalized sharp waves, focal and generalized spikes, and generalized seizures.
Table 2 shows the results of the chi-square test to determine how sex, age, type of seizure and duration of seizures are related to the EEG results. The correlation test between sex and EEG results showed no relationship, with \( p > 0.05 \) \((p = 0.336)\). The correlation test between age and EEG showed a significant relationship, with \( p = 0.07, \ OR = 3.093, 95\% \ CI = 1.361–7.030 \). The chi-square test between seizure type and EEG showed a statistically significant relationship, with \( p = 0.021, \ OR = 6.286, 95\% \ CI = 1.327–29.779 \). Moreover, the relationship between seizure duration and EEG was statistically significant, with \( p <0.001, \ OR = 8.333, 95\% \ CI = 3.029–22.929 \). These results indicate that, the older the child and the longer the duration of seizures, the more likely it is that the EEG results will contain an abnormality. Moreover, the focal seizures in children with FUS often led to abnormal EEG results.

### Table 2
Relations of gender, age, seizure type, and seizure duration with EEG results in children with FUS

| Subject          | Total (\%) | EEG          | Abnormal EEG | Normal | p value | OR    | 95% CI   |
|------------------|------------|--------------|--------------|--------|---------|-------|----------|
|                  |            |              | Abnormal EEG | Normal |         |       |          |
|                  |            |              | Abnormal EEG | Normal |         |       |          |
| Gender           |            |              |              |        |         |       |          |
| Boys             | 62 (62%)   | 31 (50%)     | 31 (50%)     | 0.305  | 1.533   | 0.676–3.478 |
| Girls            | 38 (38%)   | 23 (60.5%)   | 15 (39.5%)   |         |         |       |          |
| Age              |            |              |              |        |         |       |          |
| < 5 years        | 44 (44%)   | 17 (38.6%)   | 27 (61.4%)   | 0.007* | 3,093   | 1.361–7.030 |
| ≥ 5 years        | 56 (56%)   | 37 (66.1%)   | 19 (33.9)    |         |         |       |          |
| Type of Seizure  |            |              |              |        |         |       |          |
| Generalized      | 86 (86%)   | 42 (51.2%)   | 44 (51.2%)   | 0.03*  | 6,286   | 1.327–29.779 |
| Focal            | 14 (14%)   | 12 (85.7%)   | 2 (14.3%)    |         |         |       |          |
| Duration of seizure |         |              |              |        |         |       |          |
| < 5 minutes      | 64 (64%)   | 24 (37.5%)   | 40 (62.5%)   | <0.001*| 8,333   | 3.029–22.929 |
| ≥ 5 minutes      | 36 (36%)   | 30 (83.3%)   | 6 (16.7%)    |         |         |       |          |

**Discussion**

First-time seizures may take the form of isolated seizures, repeated seizures or status epilepticus. Repeated seizures within one day are considered a single seizure episode.\(^1\) Electroencephalography is a noninvasive, readily available, and inexpensive investigative tool in diagnosis, identification of specific
syndromes, and long-term prognosis. It also helps differentiate seizures and predict the risk of recurrence.\(^8\)

In this study, there were 54 abnormal EEG examinations from 100 children with FUS, and 68% of the abnormal examinations showed epileptiform discharge. The rate of abnormal EEG ranged from 41–80% in non-selected populations and from 9–63% in selected populations.\(^6\) Schreiner and Pohlmann-Eden stated that there only 10% of their patients with FUS had normal EEG results.\(^9\) Epileptiform activity was reported in 12–27% of routine EEG recordings, increasing to a range of 23–50% if the sleep phase could be recorded.\(^6\) Yusaku Miyamoto et al. found abnormal EEG results in 61% of children with FUS.\(^10\) This was similar to the results of the present study, which found that more than 50% of children in the sample had EEG abnormalities. However, Bhat et al. reported that EEG abnormalities were detected in only 32.3% of children. The difference in EEG abnormality rates between that study and the present one might be due to time variations and EEG recording methods.\(^9\)

In addition, the present study found a relationship between age and abnormal EEG results (\(p = 0.007\)), where children \(\geq 5\) years old had a higher prevalence of abnormal EEG waves (50%) than younger children. A study reported by Sakir Delil et al. described abnormal EEG results in older patients.\(^10\) Takayuki Tsuboi also noted that the amount of visible abnormal "spike-wave" EEG activity increased with age.\(^11\) The difference in EEG features by age was probably due to the first seizure onset and the migration of the EEG focus during the clinical course.\(^12\)

Seizures are produced by abnormal excessive electrical activity in neurons. A focal seizure is a type of seizure that begins in one part of the brain. Focal seizures can be caused by irritation, infection, or injury in the brain. Many children with focal seizures are eventually diagnosed with epilepsy.\(^13,14\) The present study found an association between seizure type and abnormal EEG waves (\(p = 0.03\)), with abnormal EEG waves being more common in focal than generalized seizures. A study undertaken by Khair et al., which examined the EEG results from children who suffered first-time seizure without fever, stated that children with focal seizures had a higher prevalence of abnormal EEG waves than children with generalized seizures (47.5% > 44.44%); however, this difference was not statistically significant. Despite the nonsignificance of this result, doctors still tended to obtain abnormal EEGs more easily following a focal first seizure than a generalized first seizure, perhaps in the process of trying to localize the epileptic focus.\(^14\)

Prolonged seizures (lasting 5 minutes or longer) have a remarkably unfavourable long-term prognosis, with a high risk of events such as neurological death, nerve injury, and changes in neural tissue, especially if the seizure duration is longer than 30 minutes.\(^15\) The American Academy of Pediatrics advised parents whose children had seizures to contact emergency medical services if the seizure lasted more than 5 minutes and there was no rescue medication available at home or if the seizure lasted more than 5 minutes after the rescue medication was given.\(^16\) Our findings confirmed that seizure duration is an essential factor related to abnormal EEG results (\(p < 0.001\)), with an increased prevalence of abnormal
EEG in patients whose seizures lasted ≥ 5 minutes. Several previous studies also reported that extended seizure duration was associated with intracranial abnormalities and generally increased the risk of recurrent seizures. 17–19

Strengths and limitations

The main limitation of the present study was that it used conventional EEG and not 24-hour EEG; thus, limited inferences can be made from the available recordings. The strength in this study is that brief EEG recording for maximum 48 hours after FUS can depicts the abnormality clearer and more visible. The evidence from our study expands the knowledge on the abnormality of EEG after FUS, especially in resource limited country settings.

Conclusion

In this study, more than 50% of children with FUS had abnormal EEG results. Therefore, the present study suggests that EEG examination is essential for children with FUS, especially in children who have experienced focal seizures and/or long-lasting seizures (≥ 5 minutes).

Abbreviations

BECTS  benign epileptiform with centrotemporal spikes
EEG  electroencephalography
FUS  first unprovoked seizure

Declarations

ACCORDANCE

Our research involving human data (EEG recording and patients data from medical record) and have been approved by the institutional ethics committee.

Name of the ethic committee (Komite Etik Penelitian Kesehatan RSUD Dr. Soetomo Surabaya / Medical Research Ethical Committee Dr. Soetomo General Academic Hospital, Surabaya

Ethical clearance no: 1860/KEPK/III/2020
Ethics approval: Ethical clearance no 1860/KEPK/III/2020 granted from Medical Research Ethical Committee Dr. Soetomo General Academic Hospital Surabaya.

Consent for publication: Not applicable

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Author’s contributions: Gunawan design conceptual framework, data collection, analysis and interpretation, discussion and summary. Kurube contribute to data analysis, statistics, literature review and discussion. Noviandi collected data, revised the manuscript and supervised. Samosir revised the
manuscript, figures and tables editing and literature review. All authors discussed the results and to the final version of the manuscript.

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Figures
Figure 1

Type of abnormal EEG.