Seizure 2002; **11**: 99–103
doi:10.1053/seiz.2002.0621, available online at http://www.idealibrary.com on IDEAL®

Assessment of the utility of paediatric electroencephalography

MOHAMMED M. S. JAN

Department of Neurosciences, Division of Paediatric Neurology, King Faisal Specialist Hospital & Research Centre, Jeddah, Kingdom of Saudi Arabia

Correspondence to: Dr Mohammed M. S. Jan, Department of Neurosciences, Division of Paediatric Neurology, King Faisal Specialist Hospital & Research Centre, MBC J-76, P.O. Box 40047, Jeddah 21499, Kingdom of Saudi Arabia

Electroencephalography (EEG) is an important tool in investigating children with neurological disorders, particularly epilepsy. The objectives were to examine the relationship between clinical indications and EEG results, and assess the predictability of a normal result. 438 consecutive paediatric EEGs were included prospectively. One certified electroencephalographer (EEGer) reviewed EEG requisitions and recorded his prediction of a normal result. EEGs were reviewed separately and the relationship between the clinical indications and EEG abnormalities was recorded. The children's mean age was 5 years (SD 4.2). Paediatric neurologists ordered 32% of EEGs. The first EEG was studied in 65% of cases. Overall, 55% of the EEGs were abnormal. Repeat EEGs were twice as likely to be abnormal (95% CI 1.3–3, $P = 0.001$). Established epilepsy, using antiepileptic drugs, and sleep record, highly correlated with an abnormal result ($P < 0.0001$). The EEGer predicted 26% of the EEGs to be normal. A normal EEG was correctly predicted in 97% of non-epileptic paroxysmal events, however, normalization of EEG was correctly predicted in only 54% of children with seizures. EEGs of 15 (3.4%) children with epilepsy revealed unexpected findings that completely changed their management. To conclude, a normal EEG is highly predictable in non-epileptic paroxysmal events. EEGs of children with epilepsy are not predictable and may yield unexpected results.

Key words: child; EEG; epilepsy; seizures; result; utility.

INTRODUCTION

Electroencephalography (EEG) is a very important tool in investigating children with various neurological disorders, particularly epilepsy. The EEG is also a sensitive marker of diffuse cortical dysfunction as seen in toxic, metabolic, or hypoxic encephalopathies[1]. Although the diagnosis of seizures and epileptic syndromes is primarily clinical, EEG often provides supportive evidence and helps in seizure classification[2]. Many episodic events may simulate epilepsy including breath holding spells, syncope, tics, migraine related phenomena (e.g. benign paroxysmal vertigo), and psychogenic seizures[3]. The neurological examination and interictal EEG are usually normal, however, a complete event description accurately identifies the nature of these events in most cases[3–7].

The interictal EEG is not useful in assessing children with simple febrile seizures and does not add significant information regarding the likelihood of seizure recurrence[8]. Ordering an EEG is also not clinically useful in the assessment of the majority of children with migraine or tension headaches[4]. In our experience, we frequently encounter unnecessary EEG requisitions including those for headaches, attention deficit hyperactivity disorder, and other non-epileptic paroxysmal events (e.g. breath holding spells). The EEG in these conditions could be easily predicted as normal, however, the assessment of the utility of EEG using the predictability of the test result has received limited study[9]. In one study, up to 40% of EEG requests were considered to be unnecessary[10].

The objective of this study was to evaluate the EEG findings in children with various acute and chronic CNS disorders. We aimed to examine the relationship between the clinical indication and EEG abnormalities and assess the predictability of a normal EEG result. We also planned to study how common are unexpected EEG findings that could strongly influence the management of individual patients.

1059–1311/02/$22.00/0

METHODS

Consecutive paediatric EEGs performed at the neurophysiolgy laboratory of King Abdulaziz University Hospital (KAUH) were included prospectively. All EEGs were recorded between February 16, 1999 and March 1, 2000. KAUH is a multispecialty adult and paediatric hospital providing primary care to the Jeddah area, as well as secondary and tertiary care for a regional population of western Saudi Arabia. KAUH is the main teaching centre of western Saudi Arabia and is linked to King Abdulaziz University Medical School. The paediatric neurology group is a major referral center for the western region, particularly the Jeddah area. All paediatric EEGs at KAUH are reported by one certified electroencephalographer (EEGer).

All EEG requisitions were reviewed without concurrent EEG review by one EEGer to identify the referral source, EEG number, child's age, EEG indication, history of epilepsy, and current antiepileptic drugs. Based on the description of the child's events and the underlying clinical scenario, the clinical indication responsible for requesting the EEG was coded as one of five categories: (1) established epilepsy; (2) probable seizure or seizures of new onset; (3) non-epileptic paroxysmal events (e.g. migraine, syncope, breath holding spells); (4) acute CNS disorders (e.g. toxic, metabolic, infectious, or hypoxic encephalopathy); and (5) non-epileptic chronic CNS disorders (e.g. mental retardation, autism, attention disorder). The EEGer then recorded his prediction of a normal EEG result. The EEGer was to predict a normal EEG in all cases of non-epileptic paroxysmal events and children with more than 1-year seizure free. Predictions were not made for chronic CNS disorders because of the heterogeneity of this group. A normal EEG was not to be predicted in acute CNS disorders,

The same EEGer subsequently reviewed all EEG recordings in a random order. The EEGer was therefore blind to all clinical data. He evaluated the EEGs to identify epileptiform or background abnormalities, photic driving response, activation by photic stimulation or hyperventilation (HV), and sleep staging. The EEG abnormalities were coded as follows: (1) focal epileptiform discharges; (2) multifocal epileptiform discharges; (3) generalized epileptiform discharges; (4) focal background disturbance; (5) diffuse background disturbance; (6) burst suppression pattern; and (7) alpha or spindle coma. At the end of each assignment, the EEG requisitions were reviewed for clinical correlation. At this stage the relationship between the clinical indication and EEG result was recorded. Unexpected EEG findings that may influence the management were also recorded. Based on the clinical and EEG data, epileptic syndromes were identified and recorded.

Statistical analyses were performed using Epi Info, version 6[11,12]. Tabular data were examined by chi-square statistics. The magnitude of significant associations is presented as P-values, odds ratios (OR), and the 95% confidence interval for the OR. A P-value less than 0.05 was considered statistically significant.

RESULTS

438 consecutive paediatric EEGs were included. All EEGs were performed using the International 10–20 System of electrode placement and recorded on paper using an 8–16 channel EEG machines. Most EEGs (59%) were ordered from the outpatient paediatric clinics, 35% from the inpatient unit, and 6% were ordered from the intensive care units. The children's ages ranged between 3 days and 17 years (mean 5 years, SD 4.2). The first EEG was studied in 65% of cases and the number of EEGs in 35% of cases ranged between two and 15. A paediatric neurologist ordered the EEG in 32%, general paediatrician in 44%, paediatric subspecialist in 19%, and a general practitioner (GP) in 5% of the cases. Seizures were the commonest indication (78%) and 50% were on antiepileptic drugs ranging between one and four (mean 1.4) drugs. Based on the clinical and EEG features, an epileptic syndrome was identified in 138 (31%) cases as shown in Table 1.

Table 1: Identified epileptic syndromes based on the clinical and EEG data ($n = 138$).

Epileptic syndrome	Number (%)
Febrile seizures	28 (20%)
Frontal lobe epilepsy	17 (12.5%)
Neonatal seizures	15 (11%)
Lennox–Gastaut syndrome	14 (10%)
Temporal lobe epilepsy	10 (7%)
Infantile spasms	10 (7%)
Absence epilepsy	9 (6.5%)
Benign Rolandic epilepsy	8 (6%)
Atypical absence epilepsy	7 (5%)
Occipital lobe epilepsy	5 (3.5%)
Early myoclonic encephalopathy	5 (3.5%)
Parietal lobe epilepsy	4 (3%)
Landau–Kleffner syndrome	4 (3%)
Juvenile myoclonic epilepsy	1 (1%)
Benign myoclonic epilepsy of infancy	1 (1%)

Of all EEGs, 55% were abnormal. The relationship between the clinical indications and EEG results is shown in Table 2. Most children (98%) with non-epileptic paroxysmal events had a normal EEG (Table 2). All patients with febrile seizures (including

Table 2: Relationship between the clinical indications and EEG results ($n = 438$).

Clinical indication	EEG result (%)					
	Normal	Focal or multifocal spikes	Generalized epileptiform discharges	Focal background disturbances	Diffuse[a] background disturbances	Total (%)
Established epilepsy	44 (24%)	52 (28%)	51 (27%)	8 (4%)	32 (17%)	187 (43%)
Probable seizure or seizures of new onset	95 (62%)	18 (12%)	12 (8%)	5 (3%)	24 (15%)	154 (35%)
Non-epileptic paroxysmal event	39 (98%)	1 (2%)	0	0	0	40 (9%)
Acute CNS disorder	5 (17%)	1 (3%)	0	0	23 (80%)	29 (7%)
Chronic CNS disorder	16 (57%)	2 (7%)	0	1 (4%)	9 (32%)	28 (6%)
Total (%)	199 (46%)	74 (17%)	63 (14%)	14 (3%)	88 (20%)	438

[a] Included categories 6 and 7 of EEG abnormalities (method section).

Table 3: Factors significantly increasing the likelihood of an abnormal EEG result ($n = 239$).

Significant factors	Number/total (%)	Odds ratio (95% CI)	P value
Ordered by a specialist[a]	237/421 (56%)	2.7 (1.1–8)	0.04
Neonatal seizures	19/22 (86%)	5.6 (1.6–30)	0.004
Repeated EEG	99/152 (65%)	2 (1.3–3)	0.001
In-hospital admission	104/153 (68%)	3 (1.9–4.6)	<0.0001
Intensive care admission	27/28 (96%)	37 (5.3–748)	<0.0001
Established epilepsy	143/187 (76%)	6 (3.8–10)	<0.0001
Acute CNS disorder	24/29 (83%)	9 (3–31)	<0.0001
Sleep recorded EEG	154/254 (61%)	2.5 (1.6–3.8)	<0.0001
On antiepileptic drugs	163/218 (75%)	5.6 (3.6–9)	<0.0001

[a]Paediatrician, neurologist, or other paediatric subspecialist.

atypical) had a normal EEG result. The highest EEG abnormality rate (86%) was found in neonatal seizures. Several factors significantly increased the likelihood of abnormal EEG results as shown in Table 3. Photic driving was identified in 99 (24%) EEGs and was more common in children older than 13 years when compared to infants (46% vs. 12%, $P = 0.01$). None of the EEGs of patients with acute CNS disorder contained photic driving. Activation of epileptiform discharges occurred in 3.5 and 6.4% of EEGs on photic stimulation and HV respectively. When we only included the EEGs with focal or generalized epileptiform discharges, 19% had spike activation on photic or HV.

Children with established epilepsy were twice as likely to show these activating effects (95% CI 1.1–5.6, $P = 0.04$). Furthermore, children with absence epilepsy were 6.8 times more likely to have spike activation with HV (95% CI 2.1–19, $P = 0.0006$). Sleep was recorded in 61% of EEGs and was more likely in patients admitted to hospital ($P < 0.0001$). A sleep EEG was least likely ordered by a GP ($P = 0.001$). Sleep recording correlated with abnormal EEG result as shown in Table 3.

The EEGer predicted 26% of the EEGs to be normal. A normal EEG was correctly predicted in 97% of non-epileptic paroxysmal events, however, normalization of EEG was correctly predicted in only 54% of children with seizures. The EEGs of 15 (3.4%) children with epilepsy revealed completely unexpected findings that strongly influenced each child's management. These findings are summarized in Table 4.

DISCUSSION

This study highlights certain important issues in the utility of EEG in children. The EEG was very helpful in diagnosing epileptic syndrome and in seizure classification. The EEGs of some patients with epilepsy also revealed completely unexpected findings that strongly influenced their management. This highlights the very important role of EEG in patients with epilepsy. We also identified a number of factors that are significantly associated with an abnormal EEG result including neonatal seizures, acute CNS disorder or ICU admission, and sleep recording. Sleep is one of

Table 4: Summary of the unexpected EEG findings ($n = 15$).

No of patients	EEG indication/treatment	Unexpected EEG findings
3	Complex partial seizures/carbamazepine	Generalized slow spike wave discharges (atypical absence)
2	Coma (encephalitis), but no seizures	Subclinical focal electrographic seizure
2	Partial seizures/carbamazepine	Generalized 3 HZ spike wave discharges (typical absence)
1	Simple partial seizures/no treatment	Findings consistent with eyelid myoclonia with absence
1	Post-encephalitic developmental delay, hyperactivity, no seizures	Very active focal (frontal) epileptiform discharges
1	Complex partial seizures/no treatment	Frequent generalized 3 HZ spike wave discharges (typical absence)
1	Congenital heart disease and failure (on digoxin), with attacks of syncope	Very active focal (bi-temporal) epileptiform discharges
1	Complex partial seizures/phenobarbitone	Generalized slow spike wave discharges (atypical absence)
1	Infantile clonic seizures/carbamazepine	Hypsarrhythmia
1	Leukodystrophy with remote epilepsy	Subclinical focal electrographic seizure
1	Developmental delay and chorea	Very active focal (occipital) epileptiform discharges

the well-known procedures of activating epileptiform discharges on EEG[13,14]. Our findings support the recommendation of obtaining sleep EEG when the clinical suspicion of epilepsy is high and the awake EEG is normal[13]. Patients with established epilepsy were more likely to have an abnormal EEG, however, children with a new onset of seizures were less likely to have an abnormal EEG. In both groups the result was poorly predicted from the EEG requisition. The value of EEG in the diagnostic evaluation of a first childhood seizure was recently reviewed by Gilbert and Buncher[15]. Quantification of sensitivity, specificity, and probability of recurrence indicated that routine EEG provides too little information to affect recommendations for treatment. They concluded that EEG should be ordered selectively, not routinely, after a first unprovoked seizure in children[15]. Other investigators found epileptiform discharges in 28.6% of definite epilepsy, and only in 6.1% of patients with possible seizures[16].

Most children (98%) with non-epileptic paroxysmal events (e.g. migraine, syncope, and breath holding spells) had a normal EEG. Other investigators found normal EEGs in up to 87.5% of adults with non-epileptic paroxysmal events (headache, syncope, and vertigo)[16]. In fact, a normal EEG was highly predictable (97%) in our sample. The EEG is therefore not helpful in these children and a complete event description will accurately identify the nature of these events in most cases[3–7]. All our patients with febrile seizures (including atypical) had a normal EEG result. This is consistent with the findings of other investigators who concluded that EEG is not useful in assessing children with simple febrile seizures and does not add significant information regarding the likelihood of seizure recurrence[8].

Some investigators found that HV and photic stimulation contributed little to the final EEG report[16]. We disagree with this conclusion, as both procedures seemed very helpful in our patients. None of the patients with acute CNS disorders had photic driving suggesting that it could be used as a sensitive marker in acute cerebral insults. Many of our children with focal or generalized epileptiform discharges had spike activation on photic or HV (19%). HV was particularly helpful in children with absence epilepsy, which is consistent with the findings of other investigators[17].

To conclude, a normal EEG is highly predictable in children with non-epileptic paroxysmal events. EEGs of children with epilepsy are not predictable and may yield unexpected results. Although epilepsy remains a clinical diagnosis, valuable diagnostic information with important management implications can be obtained from EEG. However, EEG should not be used routinely or as a screening test but rather used selectively.

ACKNOWLEDGEMENTS

Dr Amira R. Al-Buhairi is acknowledged for her helpful advice regarding the various statistical tests used in the analyses of this study. I would like to thank Ms Marilou F. Aquino (Paediatric EEG technologist)

for providing the EEG recordings and for her technical support, and Dr Leopold Streletz (Professor of Neurology and Clinical Neurophysiology, Jefferson Medical College, Philadelphia, PA, USA) for critically reviewing the final manuscript.

REFERENCES

1. Saunders, M. G. and Westmoreland, B. F. The EEG evaluation of disorders affecting the brain diffusely. In: *Current Practice of Clinical Electroencephalography* (Eds D. W. Klass and D. D. Day). New York, Raven Press, 1997: pp. 370–371.
2. Sundaram, M., Sadler, R. M., Young, G. B. and Pillay, N. EEG in epilepsy: current perspectives. *Canadian Journal of Neurological Sciences* 1999; **26**: 255–262.
3. Barron, T. The child with spells. *Pediatric Clinics of North America* 1991; **38**: 711–724.
4. Blume, W. T. and Kaibara, M. Role of the electroencephalogram in some pediatric neurological problems. In: *Atlas of Pediatric Electroencephalography* (Eds W. T. Blume and M. Kaibara). Philadelphia, Lippincott Raven, 1999: pp. 361–371.
5. Donat, J. F. and Wright, F. S. Episodic symptoms mistaken for seizures in the neurologically impaired child. *Neurology* 1990; **40**: 156–157.
6. Metrick, M. E., Ritter, F. J., Gates, J. R., Jacobs, M. P., Skare, S. S. and Loewenson, R. B. Nonepileptic events in childhood. *Epilepsia* 1991; **32**: 322–328.
7. Wyllie, E., Friedman, D. and Luders, H. Outcome of psychogenic seizures in children and adolescents compared to adults. *Neurology* 1991; **41**: 742–744.
8. Kuturec, M., Emoto, S. E., Sofijanov, N., Dukovski, M., Duma, F., Ellenberg, J. H., Hilrtz, D. G. and Nelson, K. B. Febrile seizures: is the EEG a useful predictor of recurrences? *Clinical Pediatrics* 1997; **36**: 31–36.
9. Camfield, P. R. and Camfield, C. S. How often does routine EEG in children have a surprise result. *Canadian Journal of Neurological Sciences* 1999; **26**: 10.
10. Nicolaides, P., Appleton, R. E. and Beirne, M. EEG requests in paediatrics: an audit. *Archives of Disease in Childhood* 1995; **72**: 522–523.
11. Dean, A. G., Dean, J. A., Burton, A. and Dicker, R. Epi Info: A general-purpose microcomputer program for public health information systems. *American Journal of Preventive Medicine* 1991; **7**: 178–182.
12. Dean, A. G., Dean, J. A. and Coulombier, D *Epi Info, Version 6: A Word Processing, Database, and Statistics Program for Public Health on IBM-compatible Microcomputers* Atlanta, GA, Centers for Disease Control and Prevention, 1995.
13. El-Ad, B., Neufeld, M. Y. and Korczyn, A. D. Should sleep EEG record always be performed after sleep deprivation. *Electroencephalography and Clinical Neurophysiology* 1994; **90**: 313–315.
14. Dinner, D. S. Sleep and pediatric epilepsy. *Cleveland Clinic Journal of Medicine* 1989; **56**: 234–239.
15. Gilbert, D. L. and Buncher, C. R. An EEG should not be obtained routinely after first unprovoked seizure in childhood. *Neurology* 2000; **54**: 635–641.
16. Airoldi, L., Beghi, E., Bogliun, G., Crespi, V. and Frattola, L. Rational use of EEG in adults in clinical practice. *Journal of Clinical Neurophysiology* 1999; **16**: 456–461.
17. Dalby, M. A. Epilepsy and three per second spike and wave rhythms. A clinical and electroencephalographic and prognostic analysis of 346 patients. *Acta Neurologica Scandinavica* 1969; **45**: 1–180.