ORIGINALARTICLE

How Often Does Routine Pediatric EEG Have an Important Unexpected Result?

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ABSTRACT: ***Background:*** Electroencephalogram recordings are requested for the assessment of many childhood disorders. To assess the utility of the EEG in children, we studied how often routine EEG results can be correctly predicted from the EEG requisition. ***Method:*** Five hundred consecutive initial EEG requests from the IWK Grace Health Centre from two time epochs were examined. All EEGs were 16 channel (10-20 electrode system). Based only on the requisition (patient demographics, referring physician, and reason for EEG), we coded our prediction of the result and then the actual result. When results were discordant from prediction, a judgment was made about the potential importance of the result. ***Results:*** Overall, EEG results were correctly predicted in 81%. Prediction for all nonepilepsy reasons was accurate in 91% (n=320) and 96% for paroxysmal nonepileptic events (n=158) but only 59% for epileptic disorders (n=141) ($p<0.0001$). Neurologists ordered 45% of EEGs, pediatricians 32%, and GP's 17%. Predictions were least accurate for neurologists'requests ($p<0.006$) however, neurologists were more likely to request EEG for epileptic disorders ($p<0.0001$). Age of the child and urban versus rural address did not affect the accuracy of prediction. ***Conclusion:*** Results of routine pediatric EEG for most nonepilepsy reasons appear highly predictable and therefore, possibly of little value to an experienced clinician. When requested for epilepsy, this "ancient" test remains full of surprises.

RÉSUMÉ: Quelle est la fréquence d'un résultat inattendu important à l'ÉEG de routine en pédiatrie? ***Introduction:*** L'enregistrement ÉEG fait partie de l'investigation de plusieurs maladies de l'enfance. Nous avons étudié à quelle fréquence les résultats de l'ÉEG peuvent être prédits correctement à partir de l'information mentionnée sur la réquisition, afin d'évaluer l'utilité de l'ÉEG chez les enfants. ***Méthode:*** 500 réquisitions consécutives pour un premier ÉEG au IWK Grace Health Centre à deux époques différentes ont été examinées. Tous les ÉEG comportaient 16 dérivations (systèmes à 10-20 électrodes). En nous basant seulement sur la réquisition (informations démographiques, médecin référant et motif de la demande), nous avons codé notre prédiction du résultat et ensuite le résultat. Quand les résultats ne concordaient pas avec la prédiction, nous évaluions l'importance potentielle du résultat. ***Résultats:*** Dans l'ensemble, les résultats de l'ÉEG étaient correctement prédits dans 81% des cas. La prédiction était exacte dans 91% des cas quand il ne s'agissait pas d'épilepsie (n=320) et dans 96% quand il s'agissait d'événements paroxystiques non épileptiques (n=158) mais seulement dans 59% quand il s'agissait d'épilepsie (n=141) ($p<0.0001$). L'ÉEG avait été demandé par un neurologue dans 45% des cas, par un pédiatre dans 32% des cas et par un généraliste dans 17% des cas. La prédiction était moins juste pour les réquisitions de neurologues ($p<0.006$), alors que les neurologues étaient plus susceptibles de demander un ÉEG quand il s'agissait d'épilepsie ($p<0.0001$). L'âge de l'enfant et l'adresse postale urbaine ou rurale ne modifiait pas la justesse de la prédiction. ***Conclusion:*** Les résultats de l'ÉEG de routine en pédiatrie, dont l'indication n'est pas de l'épilepsie semblent très prévisibles et donc de peu de valeur pour un clinicien d'expérience. Dans l'épilepsie, ce test "ancien" demeure rempli de surprises.

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Hans Berger introduced electroencephalography (EEG) as a tool for assessing brain disorders in 1929.[1] A huge number of publications have documented the type and frequency of EEG abnormalities in many different childhood disorders. In most Canadian jurisdictions, any licensed physician may request an EEG for assessment of any patient. In Nova Scotia in 1998, we estimate that about 4500 routine EEGs were carried out in children and adults.

Most people with epilepsy show interictal EEG abnormalities that assist in syndrome classification.[2] Comatose patients may show special abnormalities that add to diagnosis and management, such as continuous spike-wave, paroxsymal lateralized epileptic discharges or important background abnormalities. On the other hand, children with learning disorders, migraine or behaviour disorders have a high rate of minor nonspecific abnormalities that cannot be used to enhance or refute the clinical diagnosis. It is unclear how often EEG adds to the precision of a clinical diagnosis. Because EEG is so widely used, we have studied how predictable the results are in children presenting for an initial routine EEG and then tried to judge the impact of "surprise" results. We began with the premise that if a test result is predictable, then the test is unnecessary. This paper

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is not meant as an attack on EEG, but rather an attempt to explore the diagnostic categories where it has the greatest utility.

METHODS

EEG recordings for study were all carried out at the IWK Grace Health Centre in Halifax, Nova Scotia. This is the only tertiary pediatric centre for the Maritimes, however, EEG recordings for children in Nova Scotia are also carried out in Sydney. In 1998, there were about 1000 EEGs for children at the IWK Grace Health Centre and 250 in Sydney. This study reports results only from the IWK Grace EEG laboratory. This laboratory accepts requests from any licensed physician in the province. Recordings are carried out using paper output from 16 channel EEG machines with the 10-20 electrode system and paste contact for electrodes. All recordings during the study period were carried out by three experienced pediatric registered EEG technologists and all interpretations were by two pediatric neurologists with one (PRC) reporting 95%. All pediatric neurology services for the province are located at the IWK Grace Health Centre.

Requests for EEG are accompanied by a written requisition. The EEG technician briefly interviews the family immediately before the recording (usually about five minutes or less) and adds additional history to the requisition. The report of the EEG is then printed on the back of the requisition. Requisitions are then filed in consecutive order. If a child has had a previous EEG, the previous requisitions/reports are brought forward and attached to the most recent one.

We reviewed 250 consecutive EEG requisitions from 1993 and 250 from 1996. The two time periods were selected arbitrarily and for convenience. We are unaware of any interventions that would have altered EEG requests between these two time frames. If a child had more than one EEG, only the first one was studied in order to avoid the bias of knowing the result of the first EEG in predicting subsequent abnormalities. In addition, if the investigators were familiar with the patient, the record was excluded. To enter data, the requisition was first read and then coded. Data collected were: age of the child, category of ordering physician (family practitioner, type of specialist), geography of patient's residence (urban vs rural), reason for EEG request (as seen in Table 1) and prediction of EEG result. All predictions of the results were made by one of the authors (PRC) without discussion with anyone else. The requisition was only then turned over and the actual result was recorded. Predicted and actual EEG results were coded as seen in Table 2. If there was a difference between the predicted and actual result of the EEG, both investigators reached a consensus about how important this result might be in clinical practice. The predicted versus actual results were coded as identical, not important difference, possibly important difference, or quite important difference. An example of a "not important" difference was the failure to find hypnagogic spike wave in a child with febrile seizures, especially if the child did not sleep. An example of

Table 1: Reason for EEG request and Discrepancy

Reason for EEG N=480*		Number without significant discrepancy between predicted and actual result *	
Classification of epilepsy	n=141	83	(59%)
Likely nonepileptic event such as syncope or breath-holding	n=158	152	(96%)
Staring spells, unlikely to be absence epilepsy	n=27	23	(85%)
Headache	n=28	27	(96%)
Acute encephalopathy – neonatal	n=25	18	(72%)
Acute encephalopathy – non-neonatal	n=25	17	(68%)
Behaviour disorder	n=25	24	(96%)
Febrile seizure	n=24	21	(88%)
Chronic encephalopathy	n=12	12	(100%)
Acute life threatening event	n=8	8	(100%)
Learning disorder	n=4	4	
Attention deficit disorder	n=1	1	
Other	n=2	1	
		Total 391/480	(82%)

* Excluded are 14 patients where the results could not be interpreted because the children were too restless for satisfactory recording and six patients where the reason for the recording could not be ascertained from the requisition.

Table 2: Predicted EEG results compared with actual results

EEG Result	*Predicted result Correct prediction		**Actual result Correct prediction	
Normal	321/353	(91%)	325/363	(90%)
Diffuse background >mild	16/27	(62%)	12/19	(63%)
Focal slowing, no spikes	5/10	(50%)	4/9	(44%)
Unifocal spikes, not rolandic	17/33	(52%)	11/21	(52%)
Rolandic spikes	14/21	(67%)	15/16	(94%)
Focal spikes plus focal slowing			0/2	
Multifocal spikes	1/5	(20%)	1/8	(13%)
Focal spikes, 2ary generalisation			1/1	
Generalized spikes and wave ≥ 3 Hz	6/14	(43%)	7/23	(30%)
Slow spike and wave	0/2		0/0	
Absence seizures	3/5	(60%)	5/6	(83%)
Electrographic seizures	4/5	(80%)	6/9	(67%)
Hypnagogic spike and wave	4/5	(80%)	4/4	
Total	391/480	(82%)	391/480	(82%)

- in each cell the number of patients correctly predicted is divided by the total number in that category
- * The number predicted to have a given EEG result is the demoninator with the number correctly predicted in that category as numerator
- ** The number with an actual EEG result in a given EEG category is the denominator with the number correctly predicted in that category as numerator.

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"quite important" difference was the finding of focal epileptic discharge in a child thought to have syncope and predicted to have a normal EEG.

Data entry and analysis were carried out using EpiInfo version 6.0. Statistical comparisons were with chi-squared or t-tests.

Results

A total of 500 cases was studied. The average age of the children at the time of the EEG recording was 71.2 months (range 1-198) with 22% less than age one year. Pediatric neurologists requested 45% of the EEGs, pediatricians 32%, family physicians 17% and other specialists 6%. The family lived in the urban Halifax area in 86% or in a rural area in 13%. A sleep recording was obtained in 56.8% and 97.2% of recordings were sufficiently technically satisfactory to be interpreted. (Occasional children were so restless during EEG recording that muscle and movement artefact precluded interpretation). In addition to the 14 children with uninterpretable recordings, there were six patients where we were unable to understand the reason for the EEG request. Therefore, there were 480 patients for study.

For 367 of the 480 (76%) patients, the actual EEG results were exactly correctly predicted. For 24 patients there was a difference between the prediction and actual results, which was judged to be clinically unimportant. These two groups (total 391) were combined to form a "correct prediction" group (81% of the total series). In 46 patients, the discrepancy between prediction and actual result was judged to be possibly important and for 43 the difference seemed quite important (total 89, 19% of the overall series). These two groups were combined to a "discrepancy" group.

Reasons for the EEG request and rates of correct prediction are listed in Table 1. The highest rate of correct prediction was in the group with nonepileptic, paroxysmal disorders. Children in this category were virtually always (157 of 158) predicted to have a normal EEG – correct in 96% of patients. On the other hand, the results for children with suspected epileptic disorders were correctly predicted in only 59% of patients (comparison of prediction for paroxysmal vs epileptic disorders, $p<0.0001$ chi squared).

Table 2 lists the predicted and actual EEG results. Overall, 81% of those with interpretable results were correctly predicted. The highest rate of success (91%) was for the prediction of a normal EEG.

The high rate of discrepancy for suspected epileptic disorders (41%) had several explanations. For 56 of these patients, the prediction was for a normal EEG, which was correct in 38 patients (68%). For the 16 predicted to be normal but with a discrepant result, the results were in eight other EEG categories. For 64 patients, the prediction was for a focal EEG abnormality (spikes and/or focal slowing) which was correct in 37 patients (58%). Four of those predicted to have focal EEGs had generalized spike-wave with no focal features. For 21 patients, a generalized epileptic discharge was predicted which was correct in only nine (43%).

The category of physician ordering the EEG did influence the rate of discrepant results. The rate of discrepancy for neurologists was 24% compared with 14% for the other physicians ($p<0.005$). Neurologists were much more likely than other physicians to order EEGs for epilepsy disorders (104/150 vs 46/150 $p<0.00001$).

The age of the child did not effect the rate of congruence.

Conclusion

This study suggests that routine pediatric EEG recordings often give predictable results. While EEG recording has little obvious harm, the cost is substantial both to the health care system and to the family who may miss work for a test that often takes several hours for small children. We judged the reason for the EEG request from the written requisition since this is usually the only form of communication available in routine practice. EEG results were especially predictable for nonepileptic, paroxysmal disorders, such as vasodepressor syncope, pallid syncope or cyanotic breath holding attacks.[3] A variety of motivations have been suggested for requesting "inappropriate" laboratory investigations in general.[4,5] We think that there are some special reasons that lead to EEG requests for paroxysmal, nonepileptic disorders. First, some clinicians may use the normal result to be more certain of the diagnosis and to exclude epilepsy. This reassurance is false since a small percent of children without any neurologic disorder have "significant" EEG abnormalities[6] and, as illustrated in this paper, children with epilepsy may not show interictal EEG abnormalities.[7] Second, physicians might try to convince parents that their concerns are taken seriously by carrying out a "serious" investigation. The EEG laboratory and equipment are impressive to the nonexpert. Current culture may require such investigations in order for some physicians to be "taken seriously". A third reason may be a lack of understanding of the limits of EEG recording and interpretation. Current Canadian medical school curriculae do not set aside time for EEG and it is likely that students have little exposure to settings where EEG can be critically assessed. The fact that a high proportion (60%) of requests for EEG for non-epileptic paroxysmal events came from family physicians and pediatricians does not explain why 40% came from neurologists. Informal discussion with our neurology colleagues suggests that many of these EEGs were to satisfy a request from the referring family physician or pediatrician. Finally, EEG requests were generated by neurologists for children who were travelling a long way for consultation. When the referring note did not suggest a clear diagnosis, the EEG was scheduled just before a neurology consultation.

EEG does not appear to be very useful in a variety of other disorders. In our study, there were modest numbers of children with headache, learning disorders, behaviour disorders, chronic encephalopathy, nonepileptic staring spells and febrile seizures but taken together, there was a striking predictability to most of these EEGs – 85-95% were predicted correctly (usually normal). It is of interest that an attempt to provide guidelines to physicians for appropriate EEG use may not alter their practice.[4]

Investigation of epileptic disorders seemed more fruitful. In about 40% of patients, the EEG result was predicted incorrectly from the clinical history. Since the EEG is crucial for the diagnosis of many epileptic syndromes, these discrepancies are important. The only EEG phenomenon associated with an epilepsy type that was accurately predicted (94% correct) was the typical spike discharge of benign epilepsy of childhood with

centro-temporal spikes.[2] The other area where the EEG appeared more useful was for acute encephalopathy in the newborn or older child. In seven of 23 with acute encephalopathy, we predicted a normal EEG but there were important abnormalities, indicating that the cerebral insult was more severe than the short history suggested. EEG background has been shown to be a consistent predictor of outcome following neonatal hypoxic-ischemic encephalopathy.[8]

Our study has limitations. First, we stopped assessing patients after 500 because the results for the second 250 patients were identical to the first 250, which meant insufficient numbers of patients in many subcategories for analysis. For example, there were only 26 patients with behaviour disorder. The literature on each of these subcategories points in the same direction – significantly, abnormalities on EEG are infrequent and rarely diagnostic.[9] Second, we predicted the EEG results based only on the brief history on the requisition. Our predictions might have been more accurate with the complete clinical history. Third, it is unclear what frequency of unpredicted abnormality mandates EEGs for all children with a given suspected diagnosis. For example, there is a current controversy about the rate of epileptic discharge in children with autism.[10] Since there is a possible beneficial treatment to be offered to those with epileptic discharge, a low rate of positive tests might be justifiable. There is, however, no clear therapeutic advantage to finding an EEG abnormality in a child with headaches. Fourth, we have not evaluated the predictability of repeated routine EEG recordings in patients with evolving disorders. Finally, we did not directly interview the physicians ordering the EEGs or assess the impact of various findings on management. The relief of family anxiety may still occasionally warrant a test with predictable results.

Our experience may not be the same as other centres; however, based on the number of EEGs that we perform in comparison to the population of Nova Scotia, it is likely that other centres have an even greater need to assess the value of routine EEG. In Ontario, it has been estimated that there are about 130,000 EEGs performed annually (Dr. G. Bryan Young, personal communication 1999). We do not know if we are any more (or less) skilful at predicting EEG abnormalities than other child neurologists – a comparable study in another setting would be welcome.

We conclude that there are many unnecessary routine EEG recordings in children. Investigation of epilepsy and acute encephalopathies appear to be the most valuable indications for routine pediatric EEG. Finding a way to reduce EEG requests while retaining the autonomy of a physician's clinical judgement is not straightforward. Once an EEG has been requested, the effect of cancelling the test may be to undermine the patient's confidence in their physician. Physician education seems more palatable although one study suggested that circulation of guidelines had little impact.[11] This study was very different from ours. The authors attempted to alter physician practice by issuing guidelines for EEG requests. the details of the guidelines were not noted in the paper and the appropriateness of the EEGs was assigned by one of the authors without explicit criteria. Appropriateness of laboratory tests of all kinds is a controversial subject.[4,5] Routine pediatric EEG now joins this controversy.

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