The Paediatric EEG: Value and Abuses

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How can EEG help in epilepsy?

- **Diagnosis of epilepsy**
  - First Seizure
  - Distinction between focal and generalized seizure disorder
  - Identification of syndrome
  - Recognition of photic sensitivity

- **Management of epilepsy**
  - Assessing risk of recurrence after unprovoked seizure
  - Selection of medication
  - Likelihood of relapse if medication withdrawn-limited
  - Investigation of cognitive decline
  - Detection of nonconvulsive status
  - Identification of epileptogenic region in surgical candidates
Overview

- **Value**:  
  - Sensitivity and Specificity  
  - Syndromal Diagnosis  
  - First Seizure  
  - Comments on chronic epilepsy and drug withdrawal  
  - Other: PICU, Encephalopathy, Regression, Arrest, NICU

- **Potential Abuse**:  
  - Behavioural  
  - Autism  
  - Learning  
  - Febrile Convulsion  
  - Interpretation and access
THE EEG

EEG most important test in diagnosis and management of epilepsies and first seizure

In the patient with a seizure disorder what does one look for in the EEG?
Interictal epileptiform discharges are associated with epilepsy

Pattern Recognition
THE EEG

Sensitivity.

Relatively low 25-56%
The Request

Please do an EEG to exclude epilepsy.
In a patient with a seizure disorder a routine EEG may be normal in 50% of recordings.

This information must be carefully explained to a carer.
- The diagnosis of epilepsy is based predominantly on clinical features.
- EEG adds collateral information.
Prevalence of Interictal Epileptiform Discharges in Epileptic Patients

- Problem of varying methodologies in studies
- EEG protocol
- Spectrum of seizure burden in series
- Adult epilepsy centre: serial eegs (4), IEDs: 80-90%
The yield of IEDs can be increased by activation methods and other factors:

**sleep** (most epileptiform activity (IED) in first 20 mins of sleep or immediately before waking, less prominent in deep sleep) J Clin Neurophysiol 1984,1,83

**sleep deprivation**
repeat EEG: 20% second,< 10% after fourth Epilepsia 1987;28, 331

**hyperventilation**

**photic stimulation**

**timing** (within 24 hours of seizure IED 51% compared 34% later) Lancet 1998;352:1007-11

**increased coverage**

**co-medication**

**prolonged sampling**
The Value of Partial Sleep Deprivation as a Routine Measure in Pediatric Electroencephalography.

Quantifying Effect of Sleep Deprivation

- **Sleep deprivation increases yield, weighted decision** *Pediatrics: DeRoos 2009*
  - Randomized blinded comparison of routine EEGs vs sleep-deprived EEGs in 206 children, 0-18 years
  - > 1 seizure or first seizure (83%) or unclear spell (17%)
  - Primary outcome: proportion of normal EEGs
  - Sleep deprivation, not sleep gave modest increase in yield. To identify one additional child with epileptiform activity (EA) – 11 sleep deprived EEGs.
  - Highest yield >3 years with seizures.

- **The diagnostic yield of a second EEG after Partial sleep Deprivation: Prospective Study in Children with Newly Diagnosed Seizures. Epilepsia 38(5):595-599, 1997.**
  - Standard EEGs showed EA in 309 (56%) and Repeat EEGs with partial age dependent sleep deprivation added 61 (11%). In about half EA only in sleep.
  - Note EEG methodology – second EEG was longer recording.
Optimizing Electroencephalographic Studies for Epilepsy Diagnosis in Children With New-Onset Seizures
(Arch Neurol 2010;67(11):345-49)

- Cohort of 92 children, 2-16 years presenting to ED with new onset seizures. All had early and subsequent sleep deprived EEG
- Early EEG (24 hours) and sleep-deprived EEG (48 hours to 4 weeks) studies have a similar yield of epileptiform abnormalities
- Background abnormalities are more frequent in early EEGs
- The EEG and clinical picture led to electroclinical syndrome diagnosis in 50%
Photic Stimulation Induces IEDs in 10% of Epileptic Patients

- Juvenile Absence Epilepsy
- Epilepsy with Grand Mal on Awakening
- Juvenile Myoclonic Epilepsy
- Eyelid Myoclonia with Absences
- Severe Myoclonic Epilepsy of Infancy
Why Do Some Patients Have No Interictal Epileptiform Discharges?

- **Sampling:** limitations
- **Scalp coverage:** basal and mesial hemispheres not covered
THE EEG

Specificity.

78-98%
The EEG is not 100% specific for epilepsy

Interictal epileptiform discharges (focal spikes or sharp waves) occur in 1.9% non-epileptic children [Eeg-Olofsson et al., 1971] Other authors up to 3.5%.

- Incidence increases substantially in cerebral pathologies. (10-30%)

Findings must be interpreted in the light of the clinical picture. Treat the patient not the EEG
The common interictal patterns (illustrated in the following EEGs) seen in non-epileptic children are:

- Centrotemporal (1.9 - 3.5% normal children) [Cavazutti et al., 1980; Eeg-Olofsson et al., 1971]
- Generalised spike and wave particularly if strong family history
- Photoparoxysmal discharges - 63% of IEDs in subjects without epilepsy

Only a subset of children with centrotemporal spikes have the syndrome of Benign Rolandic Epilepsy (8.8%) [Luders et al., 1987]
Morphology: Centrotemporal Spikes

Fp2-F8
F8-T4
T4-T6
T6-O2
Fp2-F4
F4-C4
C4-P4
P4-O4
Fz-Cz
Cz-Fz
Fp1-F3
F3-C3
C3-F3
P3-O1
Fp1-F7
F7-T3
T3-T5
T5-O1
Generalised spike and slow wave

Interictal: Generalised
Photic Paroxysmal Response at 18 Hz
EEG in Syndromal Diagnosis
The EEG

Syndromal Diagnosis of Epilepsy.

Role of the EEG is to establish an accurate diagnosis.

This is valuable!
The Interictal EEG Provides Information In Syndromal Diagnosis:

- Juvenile Myoclonic Epilepsy
- "Childhood Absence Epilepsy"
- Epileptic spasms
- Lennox Gastaut Syndrome
- Benign Rolandic Epilepsy
- Benign Occipital Epilepsy
- Partial epilepsies
A child of 12 years presents with tonic clonic seizure on waking.

History reveals myoclonic seizures early morning.

Latter are aggravated by sleep deprivation.
Early morning - awake
Intractable partial epilepsy.
Aged 9 years.

- 18 months: prolonged febrile seizure.
- 4 years: onset of seizures with epigastric aura, staring, a dazed appearance and lip smacking.
Interictal: Temporal
Intractable Complex partial seizures in boy of 12 years

Visual distortion

Altered awareness

Eyes to right
Interictal-active L occipital focus
EEG IN FIRST SEIZURE

Valuable
Learning Package Overview

This online training will discuss the approach to a first unprovoked seizure in childhood.

The diagram outlines the structure of the training.

Each module in this training will address a part of this structure, from initial paroxysmal event through to management of unprovoked seizure.

Click Next to continue.
EEG studies after first unprovoked seizure
Shinnar et al: Pediatrics 1990,85,6;1076-1085)

- EEG, 30 min recording, following partial sleep deprivation, activation studies – HV, PS

- EEG most important predictor of recurrence: genetic

<table>
<thead>
<tr>
<th>EEG</th>
<th>1 year</th>
<th>2 years</th>
<th>3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal</td>
<td>41 %</td>
<td>54 %</td>
<td>56 %</td>
</tr>
<tr>
<td>Normal</td>
<td>15%</td>
<td>23 %</td>
<td>26 %</td>
</tr>
</tbody>
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Epileptiform 62/81) and nonepileptiform 22/81, slowing predominantly)
Practice Parameters: Evaluation of First Non-Febrile Seizure in Childhood

- Routine EEG recommended (Class I evidence) to predict recurrence, classify seizure and syndrome

  This is critical

- Inclusion of both an awake and sleep tracing, hyperventilation and photic stimulation are recommended by American EEG society
Royal College of Pediatrics and Child Health asserted: “There is no need for an EEG following a first simple afebrile seizure” (Arch Dis Child 2004;89: 278-280)

Arguments against based on: level of prediction of recurrence, reticence to treat after first seizure, quality of EEG interpretation and access

Arguments for based on: potential of syndromic diagnosis and patient/family entitlement to specific diagnosis and impact on counselling.

Recommendation: diagnosis of seizure, type, syndrome should be primarily based on clinical grounds and EEG not routinely requested without purpose. If requested should answer specific question, to aid diagnosis of epilepsy. Quality of report be considered, in doubt ask expert.

NICE Guidelines 2012: emphasis on clinical evaluation. Discusses EEG.
Chronic Epilepsy

- **Limited value**
  - “Not every 6 months”
  - Weak association between amount of IED and seizure frequency and antiepileptic medication has variable effect on IEDs.

- **Define the question**
  - Wrong diagnosis
  - Review of syndrome
  - New symptoms unexplained eg worsening seizures/cognition
Prognostic Role of EEG After Withdrawal of Anti Epileptic Drugs

- Conflicting data. Abnormal EEG associated with increased risk of relapse but should not be used as sole basis in decision of withdrawal. (Neurology 1994;44:601-8; Epilepsia 1992;33(4) 681-6)

- Evolution of EEG in drug withdrawal correlates with final outcome especially IGE. (Seizure 1993; 2: 213-220)

- Syndromal diagnosis and Aetiology maybe critical determinants.
Other valuable uses of the EEG

- Encephalopathy
- Regression
- Nonconvulsive status: confusion
- Status Epilepticus management
- Arrest
- Neonatal Asphyxia
Nonconvulsive seizures are common in critically ill children:

- Electrographic seizures: 46/100,
- 32/46 (70%) only nonconvulsive seizures
- Majority detected in 24 hours of monitoring.
- Risk factor: younger age
- Significant percent < one year
- Other authors emphasize young age < 1 year (Epilepsia 47, 1504-09, 2006)
14 month infant who fails to wake after prolonged seizure with fever and minor illness
Following 36 hours aggressive anticonvulsant treatment
Acute Encephalopathy with Subcortical white matter Diffusion changes. Influenza A and HHV6 identified. Excitatory insult.
Neonatal EEG valuable in predicting outcome in neonates with hypoxic ischemic encephalopathy.

- 89-100% of those with normal or mildly abnormal EEG at 1-7 days have a normal outcome.

- Inactive background (<5µV) or low-voltage plus theta(<15µV): outcome is death or significant neurodevelopmental disability in 89% to 100%

- Burst suppression pattern: 80-100% die or have severe neurodevelopmental disability but variation in definition

- Normal sleep-wake cycle in first 6-24 hours associated with good outcome.
Abuses

- When not to order an EEG?

- 534 children
  - Clinical seizure
  - Epilepsy
  - ADHD
  - Headache
  - Syncope
  - Learning Disabilities
  - TIC Disorders
  - Sleep Disorders

Epileptiform activity rarely found in patients without epilepsy. Interictal EEG overused in nonepileptic conditions. Decrease waiting times.
Misconceptions about the diagnostic capability of standard EEG in pediatrics are common.

44% (total: 109) standard EEG requests were inappropriate e.g. febrile convulsions, funny turns.

Appropriate requests were highly correlated with EEG results that were contributory to clinical management:
- Definite, probable epilepsy/seizure
- New diagnosis
- Status epilepsy
- Established epilepsy-subclinical EEG changes leading to symptoms
- Non-epilepsy: encephalopathy, neurodegeneration, organic brain disturbances
Can sodium valproate improve learning in children with epileptiform bursts but without clinical seizures?

Devel Med Child Neurol 2000, 42, 751-55. Ronen et al

- Randomized double-blind, single-crossover trial carried out with VPA or placebo on 8 participants with learning/behavioural problems. Exclusion criteria – known epileptic encephalopathies. No clinical seizures.

- Abundant generalized or focal bursts of spike/slow wave on repeated EEGs.

- Clinically none of the children improved. No consistent EEG change.

- Children on valproate were more distractible on formal testing, increased delay in response time, showed lower memory scores.

- Data did not support use of valproate.
Autism, EEG and Regression.

Treatment

- Seizure occurrence: 5-39%

- Epileptiform abnormalities: 6-60% with the higher incidence with epilepsy, lower IQ and with regression

- No data to support routine EEG screening in Autism. (J Child Neurol, 2005). Look at clinical phenotype-age, language regression or global, fluctuation, seizures.

- No evidence epilepsy/epileptiform abnormalities cause autistic regression or that treatment of seizures or interictal abnormalities impact language or social deficits
Abuses: Skill Base
There are Problems with EEG Interpretation

- Artefact
- Reporting: Who reports - e.g. benign variant
- Access to reading by paediatric neurologist
- Payment and availability of good technicians
6-year old girl, POSTS
6-Hz SPIKE AND WAVE
Inter-rater reliability of the EEG in patients with childhood idiopathic epilepsy
Epilepsy Research 66 (2005) 195-198

- To access level of agreement by experienced readers.

- 3 trained electroencephalographers examined 21 EEG records each (21 wake, 6 sleep)

- Moderate agreement on majority of features of wake and sleep EEG.
  - Unsatisfactory for background activity.
  - Ictal discharges, distribution and location more easily identified.
  - Interictal discharges suboptimal agreement (distribution and location)
Conclusions

- EEG most important test in diagnosis and management of epilepsies provided:
  - Experienced technician and reporter AND interpreted in clinical setting
  - Access
  - The EEG is a valuable test for an appropriate question.

- Interictal epileptiform discharges are highly correlated with epileptic seizures. It has limitations. Sensitivity and Specificity.

- The EEG has in general no role in headache, syncope, learning and behavioural disorders
Should be interpreted in clinical context.
Landau-Kleffner Syndrome

- Verbal Auditory Agnosia
- Focal epileptiform activity, sleep activation
- Seizure disorder common but not always
- Onset: 18 months to 13 years
- Previously normal development
Prognosis Role of EEG After a First Epileptic Seizure

Majority of series have shown EEG abnormalities are associated with an increased risk of seizure recurrence
Interictal Epileptiform Discharges in Non-Epileptic Patients

Children (2.2-3.5%)
Adults (0.2-0.5%)

Patterns seen: (majority)
Centrotemporal
Generalised
Photoparoxysmal

TREAT THE PATIENT NOT EEG
Spike Frequency: Activation and Reactivity

Awake

Drowsy
Incidental independent bilateral centrotemporal spikes (patient has not had seizures)
Role of EEG in Assessing Cognitive Decline

- Dementia or language regression
- Non convulsive status presenting as confusion, subtle motor events
First Unprovoked Seizure EEG

- A routine EEG is recommended [Hirtz et al., 2000] to:
  - Classify the seizure and syndrome
  - Predict recurrence

  **This is critical**

- Inclusion of both an awake and sleep tracing, hyperventilation and photic stimulation are recommended by American EEG society however an awake EEG with provocation testing often gives valuable information.
THE EEG

In a patient with a seizure disorder a routine EEG maybe normal in 50% of recordings.
The EEG

Localisation Tool in Epilepsy Surgery
EEG Abnormalities

♦ Background abnormalities: significant asymmetries and/or degree of slowing inappropriate for clinical state or age

♦ Interictal abnormalities associated with seizures and epilepsy
  - Spikes
  - Sharp waves
  - Spike-wave complexes

♦ May be focal, lateralized, generalized
EEG: Hypsarrhythmia
EEG: Slow Spike and Wave
EEG: Paroxysmal Fast Activity
POSTS
Reactive Occipital Epiletiform Act.
8-year old child – trains in wakefulness, drowsiness and sleep