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Is it a Seizure?
Diagnostic Limitations of EEGs

by Susan Agrawal

Most of the time, children do not have seizures that look like the prototypical convulsions seen on TV shows such as *House* or *ER*. These classic seizures, called generalized seizures, tonic-clonic seizures, or Grand Mal seizures, are usually simple to recognize and identify. Many children, however, have events that are much more subtle. A seizure could be as simple as a staring episode, a slight deviation of the eyes, smacking of the lips, a repetitive movement of an arm, or even a hallucination. The child may be conscious, unconscious, or have impaired consciousness. The following standard categorization of seizures shows how varied seizures can be:

Table 1: Types of Seizures[1]

I. Partial (focal) seizures
   - A. Simple partial seizures (remain conscious)
     1. With motor signs (such as head movements, eye movements, lip smacking, etc.)
     2. With sensory symptoms (including vision, hearing, taste, smell, pressure, temperature, vertigo, etc.)
     3. With psychic symptoms (including mood changes and hallucinations)
     4. With autonomic symptoms (including sensation in abdomen, paleness, flushing, eye changes, etc.)
   - B. Complex partial seizures (consciousness is impaired)
     1. Simple partial onset followed by impaired consciousness
     2. With impairment of consciousness at onset
     3. With automatisms (unconscious movements or speech)
   - C. Partial seizures evolving to generalized seizures

II. Generalized seizures of nonfocal origin (convulsive or nonconvulsive)
   - A. Absence seizures
     1. With impaired consciousness only
     2. With one or more of the following: atonic components (lack of muscle tone), tonic components (increased muscle tone), automatisms (unconscious movements or speech), autonomic components (flushing, paleness, etc.)
   - B. Myoclonic seizures
     1. Myoclonic jerks (single or multiple)

C. Tonic-clonic seizures (may include clonic-tonic-clonic seizures, or alternating loss of muscle tone with increased muscle tone)
D. Tonic seizures (increased muscle tone)
E. Atonic seizures (loss of muscle tone)

III. Unclassified epileptic seizures

With such a wide range of symptoms, how can you tell what is a seizure and what is not a seizure? There are many other conditions that can produce symptoms similar to those that occur during seizures. These nonepileptic events include, but are not limited to:

- Normal myoclonic or body jerks, especially when falling asleep
- Breath-holding spells that cause a child to pass out, particularly in toddlers
- Gastroesophageal reflux movements (Sandifer syndrome)
- Sleep disorders such as night terrors or narcolepsy
- Dystonia and other movement disorders
- Heightened startle reactions, especially in children with brain injuries or cerebral palsy
- Repetitive movements, especially in children with autism or developmental delays
- Migraines
- Syncope or fainting
- Tics such as from Tourette syndrome
- Dizziness or vertigo
- Hypoglycemia (low blood sugar)
- Daydreaming or inattention, especially in children with developmental delays
- Conversion disorders or psychogenic seizure-like events (psychiatric events), especially in teens
- Panic attacks, primarily in teens and adults
- Cardiac events, primarily in adults
- Masturbation in babies and toddlers[2]

Any child with repetitive or abnormal movements, staring spells, loss of consciousness, posturing, or other symptoms that could be indicative of a seizure should visit a pediatric neurologist. After a careful history, medical exam, and bloodwork, the doctor will often refer the child for an EEG (Electroencephalogram), a test that looks at brain activity for signs of seizures or other abnormal activity. This test is performed by placing electrodes on the head to detect electric activity within the brain.

In the majority of cases, an EEG will be able to confirm or deny a diagnosis of epilepsy. It is interesting, however, to note that a study on children experiencing paroxysmal events found that 46% of the children under age five, 25% of school age children, and 19% of teens had both seizures and other nonepileptic events such as those listed above.[3] These events were particularly common in children with developmental delays or other concurrent issues, making diagnosis somewhat difficult in this subgroup.

Just how accurate is an EEG? Can it miss seizures? According to one of the most widely used textbooks on neurology, “Characteristic interictal EDs [epileptiform discharges or

brain activity indicative of seizures] strongly support the diagnosis of epilepsy, but absence of [epileptiform discharges] does not exclude it. [Epileptiform discharges] are recorded on the first EEG in 30% to 50% of patients with epilepsy, and in 60% to 90% by the third EEG. Additional EEGs do not increase the yield further. Thus, 10% to 40% of patients with epilepsy will not have interictal discharges [seizure activity on EEG], even with repeated EEGs."[4] Another author reviewing the literature found that first EEGs identify 29-55% of seizures, with follow up EEGs catching 80-90%.[5]

This suggests that a large number of children, from 10-40%, may have seizures that do not show up during EEG testing. For some children, it is simply a matter of missing the seizure during testing. These children may benefit from prolonged seizure monitoring, such as a 24 hour (or longer) EEG with video, a sleep-deprived EEG since many types of seizures can be triggered by sleep deprivation, or attempts to induce a seizure through flashing lights or hyperventilation.

Electrodes on the scalp only pick up activity from about one third of the cortex.[6] This means that seizures originating from the sulci, basal regions, and interhemispheric regions of the brain are not picked up. Furthermore, approximately a 2.5 inch square of the cortex must be involved in generating a seizure for it to be detectable on EEG.

Though uncommon, some children may have seizures that are deep in the brain, such as in the amygdala or hippocampus, and cannot be detected by scalp EEGs.[7] In other words, the seizure activity is not able to be transmitted to the scalp where it can be picked up by electrodes.

Other children, particularly those who have severe brain injuries, brain tumors, large lesions in the brain, or other conditions that affect the brain or skull, may also have difficulty getting an accurate EEG. Pockets of brain tissue, scalp tissue, bone, or implanted metal may block transmission to the scalp, thereby blocking evidence of seizure activity.[8]

For these children, diagnosis can be extremely difficult. The following strategies may be helpful:

- Videotape events that are suspicious, whether you think they are seizures or not. A good neurologist or epileptologist can often recognize a seizure even without EEG evidence.
- Visit a pediatric epileptologist who specializes in pediatric seizures. These super-specialists have much more experience with pediatric seizures and may have access to more sophisticated testing and research.
- Try an anti-seizure medication and see if it reduces seizure activity. The difficulty with this proposition is that anti-seizure medications usually only treat certain types of seizures. Since you do not know the type of seizure due to a negative EEG, choosing a medication may be difficult. In addition, not all medications will work for all children, so multiple medications may need to be tried.

- Try more sophisticated testing. Using extra electrodes, such as nasal-pharyngeal or sphenoidal electrodes, can increase the ability to pick up more seizures.[9] Placement of these electrodes, however, can be difficult and painful for children and is rarely used. Another test, Magnetoencephalography (MEG), has been shown in some studies to reliably transmit more brain activity to the scalp as compared to EEG.[10] MEG, however, is very expensive and not widely available, and is typically only used for pre-surgical localization of seizures. Other tests that may help but are not particularly useful in most cases include PET and SPECT scans or Magnetic Resonance Spectroscopy (MRS).

For most children, seizures can be ruled out or diagnosed and treated relatively quickly using standard EEGs. But for some children, it may take years and several doctors to determine whether or not certain events are seizures. Compounding the problem is that both seizures and nonepileptic events have a tendency to change over time. In some cases, these changes actually may help confirm a diagnosis. Give it time, seek out expert opinions, and follow your gut instinct.

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[1] Adapted from Lewis P. Rowland, editor, *Merritt's Neurology*, 11th edition (Philadelphia: Lippincott Williams & Wilkins, 2005): 990, and adapted from Commission on Classification and Terminology of the International League Against Epilepsy. Proposal for revised clinical and electroencephalographic classification of epileptic seizures. *Epilepsia* 1981;22:489-501.

[2] See Prakash Kotagal, *et al*. Paroxysmal Nonepileptic Events in Children and Adolescents. *Pediatrics* 2002;110(e46):1-5. On masturbation, see Michele L. Yang, *et al*. Masturbation in Infancy and Early Childhood Presenting as a Movement Disorder: 12 Cases and a Review of the Literature. *Pediatrics* 2005;116(6):1427-32.

[3] Kotagal, 1-2.

[4] Rowland, 81, 998.

[5] Jyoti Pillai and Michael R. Sperling. Interictal EEG and the diagnosis of epilepsy. *Epilepsia* 2006;47(supp. 1):15-6

[6] Pillai and Sperling, 14.

[7] Pillai and Sperling, 14.

[8] Pillai and Sperling, 14.

[9] Pillai and Sperling, 17.

[10] See, for example, Pauly Ossenblok, *et al*. Magnetoencephalography Is More Successful for Screening and Localizing Frontal Lobe Epilepsy than Electroencephalography. *Epilepsia* 2007;48(11):2139-49.