Electroencephalography and Epilepsy

Speaker Donald L. Schomer, M.D.

Lecture outline
EEG recording in patients with suspected seizures and/or epilepsy
A. Generalized (Genetic) Epilepsy
B. Symptomatic Generalized Epilepsy
   1. Hypsarrhythmia
   2. Lennox-Gastaut syndrome
   3. Neurodegenerative disorders
C. Focal or partial seizures and/or epilepsies
   1. Classical temporal lobe seizure
   2. Occipital lobe seizure
   3. Limbic, sub-temporal seizure
   4. Symptomatic focal seizure
D. Other EEG findings of unclear significance
E. Other useful ancillary recording techniques

EEG - overview of use in epilepsy
Routine and telemetric EEG

- Routine Electroencephalogram
  - Standard recording
  - Standard recording using activation procedures
  - Standard recording with special electrodes
  - Prolonged in-lab recordings
- Telemetry-based recording
  - Hospital based
    - Standard or non-invasive recordings
    - With invasive electrodes
  - Ambulatory
    - With or without audio/video recording

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EEG-overview of use in epilepsy
Routine EEG

Routine Electroencephalogram

- Standard recording
  - Subject's head is measured for identification for the placement of standardized electrodes
  - Electrodes are attached using paste or glue
  - Standard electrode connections are used for recordings (montages)
  - Recordings are preformed for 30 to 60 minutes understand conditions
    - Eyes open on request
    - Eyes closed on request
    - Subject will hyperventilate for up to 3 minutes, if clinically appropriate (HV)
    - Subject is allowed to fall asleep, if tired
    - Subject is stimulated with a photic stimulator using standardized protocols (IPS)

EEG-overview of use in epilepsy
Routine EEG (2)

EEG-overview of use in epilepsy
Routine EEG (3)
Fundamentals of recording EEG
Routine activating techniques - hyperventilation

- Hyperventilation is usually done for 3 minutes during the course of a routine EEG.
- As shown on the right hand side of the slide, partial pressures of $pO_2$ and $pCO_2$ are graphed along the time course of the procedure.
- Time course and magnitude of absolute $pCO_2$ and $pO_2$ changes with 3 minutes of hyperventilation in nine normal adult subjects are demonstrated.
- The error bars are 1 standard deviation.
- A transcutaneous heated membrane technique was used for the blood gas measurements.
- Note the late changes in these values, which do not normalize for up to 10-12 minutes after the exercise is discontinued.

EEG-overview of use in epilepsy
Routine EEG - hyperventilation

- See request to start hyperventilating.

EEG-overview of use in epilepsy
Routine EEG – hyperventilation (2)

- See request to cease hyperventilating.
During the course of a routine EEG, intermittent photic stimulation (IPS) is performed under standard conditions.

The subject is first told that IPS will be obtained and how the procedure is done.

A photic stimulator is placed directly in front of the relaxed and resting subject at a distance of 1 meter.

The subject is asked to keep their eyes closed during this portion of the study.

They are told that a bright flashing light will be used.

The technologists then trigger the stimulator to flash at a set frequency for approximately 10 seconds.

The subject then has 10 seconds without stimulation.

The stimulus is repeated at different frequencies.

Usually frequencies of 1, 2, 3, 4, 6, 8, 10, 15, 20, 25, 30 and 35 Hz are used, although some frequencies may be repeated or given for a slightly longer duration.

If there is a discharge that occurs, the technologists are trained in the decision making about repeating the stimulus or stopping the procedure.

In some seizure disorders, the IPS may trigger an overt convolution.

This procedure may be repeated using colored light filters.
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Fundamentals of recording EEG
Routine - intermittent photic stimulation

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EEG recording in suspected seizures/epilepsy
Routine activating techniques - sleep

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Fundamentals of recording EEG

Additional electrodes

- An additional set of electrodes can be applied further down (caudal) to the lateral array over what would be considered the posterior portion of the anterior part of the temporal lobe; This corresponds to the anterior portion of the middle temporal gyrus. These electrodes have standardized positions and are referred to as T1 and T2. Very similarly positioned electrodes are over the zygomatic prominences.

- An additional entire array of electrodes may be placed further caudal to the lateral temporal array; These electrodes are called sub-temporal electrodes and together are called the sub-temporal chain. They record from middle and inferior temporal gyri and more inferior aspects of the lateral occipital lobes.

- Sphenoidal electrodes require a physician to place them. They are placed such that they either approach to foramen ovale or reside slightly deeper into the masseter muscles from the T1 and T2 electrodes. These are shown in a later slide.

- Naso-ethmoidal electrodes are rarely used. They are firm metallic electrodes that are placed into the nasal passages, directed upward and rest on the cribiform plate. These electrodes allow the recording to be extended to cover more frontal polar regions and potentially anterior and inferior frontal regions. An example is also shown on the next slide.

- Naso-pharyngeal electrodes are also shown on the next slide but are currently used in very few centers worldwide because of their tendency to be very artifact prone.

Fundamentals of recording EEG

Special electrodes - NPs and NEs

Naso-pharyngeal electrodes

Naso-ethmoidal electrodes

Fundamentals of recording EEG

Special electrodes - sphenoidal electrodes

- The more anterior placed sphenoidal electrode is placed by a trained physician, under local anesthesia, close to the foramen ovale shown on the left.

- The more posterior placement, shown on the left, has never actually become popular due to the rather significant amount of discomfort associated with its placement.

- Often an AP or base view skull x-ray is required to insure accurate placement. The fine silver wire variant of this electrode can often be left in place for several days of recording for monitoring purposes.
Fundamentals of recording EEG
Special electrodes - sphenoidal electrodes (2)

- Phantom image of the head showing a 22-gauge carrier needle entering the skin (concentric target lines, S) at the front of the condylar process of the mandible, passing under the zygomatic arch (2) and through the mandibular notch (MN), en route to V3 emerging from the foramen ovale (FO, seen on the edge). PP denotes the pterygoid plate. The SE that is mounted on the superior surface of the needle is not shown.


EEG - overview of use in epilepsy

Telemetry-based recording
- The purpose of prolonged EEGs is to capture the EEG on the subject while they are having clinical symptoms
  - Ambulatory
    - Subject has a recording device attached and usually goes home with it for a variable period
    - The recorders can be attached to audio/video recording equipment to link those signals to the EEG

EEG recording in suspected generalized seizures/epilepsy genetic and/or symptomatic based
- Seizures or epilepsy syndromes that are generalized are often genetically based or related to disorders that affect the neurons of the brain in a diffuse manner, which may be acquired or genetic in origin. The later condition is referred to as a symptomatic state.
- If a patient has “symptomatic” epilepsy, the routine EEG often demonstrates other abnormalities, in addition to the markers for the seizures themselves. This may take the form of diffuse or multifocal abnormalities in the background rhythms, abnormal responses to hyperventilation or intermittent photic stimulation.
- The electrical phenomena, in either situation tend to be seen over all or most regions of the brain, when they occur.
- There are situations where both generalized and focal abnormalities can be present in the same subject.
Absence epilepsy
With generalized-synchronous spike-slow wave discharge
With a frequency
At the onset of 3.0 Hz
That slows to about
2.5 Hz near the end
Of the discharge.
The enormous amplitude
Of the discharges necessitates
Considerable lowering
Of the display gain. The frontal
Voltage maximum is evident;
Also note gradual decline
Of the spike component
At the end of event

Juvenile Myoclonic Epilepsy (JME) is also associated with sudden, high amplitude generalized discharges, similar to Absence Epilepsy. However, these discharges tend to be somewhat faster, with a frequency
Of 4-6 Hz and have polyphasic discharges as demonstrated above

Jeavon’s Syndrome is associated with somewhat similar discharges to the JME Syndrome. Patients with this condition have eye-closure related activation of their discharges, causing eye-lid myoclonus and occasional generalized myoclonus and more rarely generalized tonic-clonic convulsions

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Patients with generalized tonic-clonic seizures have an onset as noted here; there is often a discharge at the onset, followed by EEG desynchronization, followed by a buildup of generalized rhythmic activity associated with the clinical behavior.

EEG recording in suspected seizures/epilepsy
Generalized seizure disorders

- Generalized convulsion can occur in infancy. Such a pattern is shown here in "Early Infantile Myoclonic Encephalopathy." This 3-month-old patient has burst-suppression-like activity that alternates with mixed slow background activity some of which is intermingled with slow and spike discharges and stretches of background flattening.


- In the slightly old infant, the "Infantile spasms" are seen with the EEG pattern called "hypsarrhythmia." In this 8-month-old patient, please note the high-voltage characteristics of the background and posterior voltage maximum of the spikes.


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EEG recording in suspected seizures/epilepsy
Generalized seizure disorders - Lennox-Gastaut syndrome

A run of rapid spikes in a 19-year-old patient with the Lennox-Gastaut syndrome. This often follows a patient who had a hypsarrhythmia EEG pattern associated with clinical spasms. Note anterior maximum of the discharge; a few slow spike-wave complexes are also seen in the right temporal occipital region.

EEG recording in suspected seizures/epilepsy
Generalized seizure disorders - Lennox-Gastaut syndrome

Common EEG findings

EEG recording in suspected seizures/epilepsy
Symptomatic seizure disorders - Niemann-Pick disease

A genetic disorder with a deficiency of acid sphingomyelinase and the intraneuronal accumulation of sphingomyelin. Patients develop a progressive loss of function with changes in intellect and progressive myoclonic seizures.

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**EEG recording in suspected seizures/epilepsy**

**Symptomatic seizure disorders - Retts syndrome**

Female disorder of early childhood with a subacute mental and physical decline with elementar, loss of motor skills and severe seizures. Shown here is a case with severe background slowing and multifocal interictal discharges.


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**EEG recording in suspected seizures/epilepsy**

**Symptomatic seizure disorders - Angelman’s syndrome**

Most cases of this disorder are due to a gene deletion that effects GABAa receptor function. The EEG pattern is similar to hypsarrhythmia pattern with severe background abnormalities and multifocal interictal discharges.


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**EEG recording in suspected focal onset seizures**

**“Partial” seizure disorders**

- “Partial” seizures or the “Partial Epilepsy Syndromes” are synonymous with focal onset seizures;
- Since the seizures have origin in a specific area or focal of the brain, the first signs or symptoms of the event itself often suggest the area where the seizure starts. This is a very helpful clue regarding the possible area of origin;
- Focal seizure may remain focal, spread to other areas or regions of the brain or evolve into generalized convulsions. These issues are dealt with extensively in later talks;
- It is important to remember that there are significant limitations to routine EEG or routine EEG monitoring. Some seizures may come from regions of the cortex that have little or no representation in the routine recordings or even with the addition of special electrodes.

Those cases will also be discussed in later talks.
EEG recording in focal seizures
Partial seizure - interictal discharges

- Partial seizures with often have markers for their presence in the form of focal interictal discharges.
- Shown here is a patient with an age related focal epilepsy called "Benign Rolandic Epilepsy".
- This tracing shows the coexistence of Rolandic interictal spikes and physiological vertex waves in light sleep in an 8-year-old boy with attacks of abdominal pain.
- Right centroparietal spikes with occasional spread to the left are marked with an "X" and typical examples of a vertex wave are marked with an "O".

Computer algorithms are also frequently employed to detect interictal discharges, as demonstrated in this page of computer detection on a patient with right temporal lobe onset epilepsy.

EEG recording in suspected focal seizures
Partial seizure - interictal discharges

Computer algorithms are also frequently employed to detect interictal discharges, as demonstrated in this page of computer detection on a patient with right temporal lobe onset epilepsy.

EEG recording in suspected focal seizures
Partial seizure - interictal discharges (2)

Computer algorithms are also frequently employed to detect interictal discharges, as demonstrated in this page of computer detection on a patient with right temporal lobe onset epilepsy.
EEG recording in focal seizures
Partial seizure - focal temporal onset

Onset – phase reversals at F7

EEG recording in focal seizures
Partial seizure - focal occipital onset

Occipital onset seizure – Maximum activity at O1

EEG recording in focal seizures
Partial seizure - focal subtemporal onset

Onset – phase reversals at T10
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EEG recording in focal seizures
Symptomatic seizure – mitochondrial encephalopathy with lactic acidosis (MELAS)

EEG recording in suspected seizures/epilepsy
Other findings of unclear significance

Psychomotor Variant - Med temporal, bilateral and independent, young to middle age
6 Hz. Spike and wave burst - Highest amplitude frontal-central, drowsiness and light sleep, children and adults
Mu rhythm - Central location, resting rhythms of motor-sensory cortex, blocked with contra-lateral hand movements
Small sharp spike, benign epileptiform transients of sleep - Anterior and mid-temporal, mainly adults, small and very sharp
Wickets - Temporal location, 6-11 Hz, adults
14-6 Hz discharges - Posterior temporal, 14 or 6 Hz discharges, mainly children
Midline theta (Ciganek rhythm) - Midline (Cz, Fz) and parasagittal, 4-7 Hz, children and adults
Subclinical rhythmic EEG discharges in adults (SRED) - Temporal and parietal regions, older adults, many last seconds to minutes, without obvious clinical effect

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EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - psychomotor variant

A short run of 6/sec spike waves, posterior type, recorded in a 52-year-old woman with a history of head injury 2 years earlier and subsequent headache, dizziness, and memory loss. There was computed tomography (CT) scan evidence of cortical atrophy.

EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - 6 Hz. spike and wave

EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - Mu rhythm
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EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - small sharp spikes

- Small sharp spikes (51-year-old patient). Note the subtle character and moderate voltage of the discharge. Also note its predominance in the left nasopharyngeal lead. There is evidence of spread into T3, as well as into the right nasopharyngeal lead. The left section was recorded in the waking state (transition to earliest drowsiness); the middle and right sections were recorded in sleep.

EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - Wickets

- Examples of 14/sec and 6/sec positive spikes (underlined). Note posterior predominance for this pattern and shifting asymmetry. Also note the sometimes blurred distinction between the 14 and 6 components, due to notch formation. The recording was obtained from a 12-year-old patient; montages to ipsilateral ear.

EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - 14-6 Hz. discharges

- Examples of 14/sec and 6/sec positive spikes (underlined). Note posterior predominance for this pattern and shifting asymmetry. Also note the sometimes blurred distinction between the 14 and 6 components, due to notch formation. The recording was obtained from a 12-year-old patient; montages to ipsilateral ear.

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EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - midline theta

EEG recording in suspected seizures/epilepsy
Other findings of unclear significance - SREDA

EEG recording in suspected seizures/epilepsy
Other findings - cardiac rhythm changes

Recording shows a patient going from an atrial-based arrhythmia to ventricular tachycardia
EEG recording in suspected seizures/epilepsy
Other findings - cardiac asystole

Patient had a brief clinical epileptic seizure followed by cardiac asystole for 35 seconds that was associated with diffuse changes on the EEG. The patient had spontaneous resumption of their cardiac rhythm.

SaO₂ abnormalities

This is a compressed EEG. The patient experienced a brief seizure noted above. This occurred early in the recording. The patient then went on to become profoundly hypoxic with SaO₂ saturations down from normal of 94% to the mid-60s. All the while, he was relatively unaware of this phenomena.

Summary and conclusions

- Routine EEGs are for 30 or more minutes in duration and include opening and closing the eyes on command, hyperventilating for approximately 3 minutes and intermittent photic stimulation.
- Additionally, EEG may be done or hours or days in an attempt to capture EEG during epileptic seizures.
- The EEG is useful in correlating behavioral events with the brain's electrical activity. The EEG may give additional information about the presence of localized or widespread abnormalities that may be of clinical significance.
- Non-EEG physiological recordings may prove useful; too. Cardiac or respiratory disorders may mimic seizures or encephalopathies.
- When recording EEGs in the diagnosis or management of patients, there are markers for the epileptic potential which can be recorded. These asymptomatic phenomena are called "interictal" discharges.
- Interictal discharges can be relatively diagnostic in some cases, but are more commonly a predictor of inherited versus acquired and/or idiopathic forms of epilepsy.
- Symptomatic recordings show "ictal" changes. These changes can vary significantly depending on the biology of the underlying seizure disorder and can be predictive of the patient's clinical behavior.
- Many non-epileptic EEG phenomena may masquerade as epileptic events to the non-trained and experienced clinician.
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