Introductory EEG Reading

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CNS
Focal-onset seizures

- Primary reading epilepsy
- Benign childhood epilepsy with centrotemporal spikes
- Childhood epilepsy with occipital paroxysms
- Temporal, frontal, parietal or occipital lobe epilepsies - symptomatic - cryptogenic
- Chronic progressive epilepsy partialis continua of childhood
- Severe myoclonic epilepsy in infancy
- Epilepsy with continuous spike-waves during slow-wave sleep
- Acquired epileptic aphasia

1 year-old

- Childhood absence epilepsy
- Benign Neonatal Familial Convulsions
- Early Myoclonic Encephalopathy
- Early Infantile Epileptic Encephalopathy
- Benign Neonatal Convulsions
- Benign Myoclonic Epilepsy in Infancy

10 year-old

- Juvenile absence epilepsy
- Juvenile myoclonic epilepsy
- Epilepsy with grand mal seizures on awaking
- Epilepsy with specific modes of activation

Normal development and imaging

Developmental and/or imaging abnormalities

FIG. 1. Schematic diagram of the International Classification of Epilepsies and Epileptic Syndromes.

Nguyen The Tich S, Pereon Y. Epilepsia 1999;40:531
Learning Objectives

- Review the basic principles of EEG
- Describe normal EEG patterns across the age spectrum
  - Awake
  - Asleep
- Review principles, pearls and pitfalls of interpreting abnormal EEG patterns
- Review seizures when recorded on EEG
6 layer cortex
Pyramidal cells

- Main efferent neurons of cortex
  - Excitatory
  - Layers 3 and 5
  - Apical dendrites, deep axons
- Receive afferent input from thalamus and cortex
  - Excitatory post-synaptic potential (EPSP)
  - Inhibitory post-synaptic potential (IPSP)
Pyramidal cells and EEG

- Pyramidal cells are organized
  - Parallel to one another
  - Apical dendrites perpendicular to brain surface
- Each pyramidal cell has about 60,000 synapses
- Summation of organized electrical activity = surface EEG
Surface EEG is a measure of extra-cellular current flow associated with the summed activity of many individual neurons. Surface EEG mainly reflects the summed excitatory and inhibitory synaptic input upon pyramidal cells.
Neurophysiology – Key points

- Surface EEG is a useful (but very crude) tool
  - Always be aware of limitations
  - Precise localization is difficult
- Even very focal epilepsy reflects network-wide dysfunction
Brain to EEG display

- Brain generates electrical activity
  - Positive and negative charges
- EEG electrodes
  - Detect brain activity
  - Pairs of electrodes are linked (G1 – G2)
  - Activity of G1 – G2 delivered to differential amplifier
  - Series of electrode pairs displayed as montage
Brain to EEG display

- Differential amplifier
  - Differences bwt linked electrodes – amplified
  - Similarities bwt linked electrodes – suppressed

- Monitor
  - Results of differential amplification displayed as a waveform
  - Display is filtered
Display standards

- G1 negative – G2 positive: UP
- G1 positive – G2 negative: DOWN
Inter-ictal EEG
Polarity and surface EEG

A. Typical Dipole Layer  
B. Dysmorphic Layer  
C. Multiple Microfoci  
D. Quadrupole Layer
Localization with surface EEG

- Only accurate with “typical dipole”
- Inaccurate with any other generator

- About 6-10 cm² of cortical surface must synchronously generate electrical potentials to be recorded on scalp EEG
EEG Frequencies

- Delta = less than 4 hertz
- Theta = 4 to less than 8 hertz
- Alpha = 8 to 13 hertz
- Beta = greater than 13 hertz
- Age of patient
- Behavioral state
  - awake, drowsy, asleep
  - absolutely critical!
- Montage
- Screen display
- Filter settings
EEG interpretation - 2

- EEG background - awake
  - Frequency (hertz = cycles/second)
  - Amplitude (microvolts)

- Posterior dominant rhythm - relaxed and awake

- Frequency amplitude gradient - awake
  - Front of head – faster and lower
  - Back of head – slower and higher

- Sleep architecture

- Normal slowing and normal sharp EEG transients
EEG interpretation - 3

- Asymmetries
- Slowing
  - Focal
  - Excessive generalized (age dependent)
- Epileptiform abnormalities
  - Sharp waves and spikes
  - Generalized discharges
  - Seizures
EEG interpretation - 4

- Provocation procedures
  - Hyperventilation (HV)
  - Photic stimulation
Beware of artifacts
  always
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Relaxed wakefulness

- Posterior dominant rhythm (PDR) can only be assessed in relaxed wakefulness
  - Eye blinks
  - Not too much movement and muscle artifact
- Normal standards are age dependent
- Look for frequency-amplitude gradient
Stage 1 sleep (drowsiness)

- Decreased eye blinks, movement and muscle
- Slow, rolling, lateral eye movements
- Fragmentation of posterior dominant rhythm
- Bursts of slowing (often theta)
- Vertex sharp waves
- Increased beta activity
- Positive occipital sharp transients of sleep
  - POSTs
This isopotential map shows the potential field of the vertex wave illustrated in Figure 29b (open arrow).
Stage 2 sleep

- Vertex sharp waves
- Sleep spindles
  - central: 14 hz (range 12.5-15.5)
  - frontal: 12 hz (range 11-13.5)
- K-complexes
  - vertex sharp waves and sleep spindles
Stage 3 sleep

- Diffuse delta activity: 20-50%
- Sleep spindles may persist
Stage 4 sleep

- Diffuse delta activity: > 50%
REM sleep

- Rapid eye movements
- Lower amplitude, faster activity
  - Resembles waking EEG, but with rapid eye movements
Age groups

- Infants (1 – 12 mos)
- Toddlers (12 – 36 mos)
- Pre-school (3 – 5 yrs)
- Children (6 – 12 yrs)
Infancy (1 – 12 mos) - awake

- Posterior dominant rhythm
  - Must have relaxed wakefulness to assess
    - 3 – 4 mos: 3 – 4 hz
    - 5 – 11 mos: 5 – 6 hz
    - 12 mos: 6 – 7 hz

- Frequency - amplitude gradient
Infancy (1 – 12 mos) - sleep

- **Stage 1 sleep (drowsiness)**
  - Bursts of high amplitude rhythmic slowing
  - Vertex waves at 4-6 mos

- **Stage 2 sleep**
  - Sleep spindles at 1-2 mos
    - 12-15 hz, asynchronous, max in central regions
2 months – awake, asleep
4 months – awake, asleep
4 mos - awake
6 months – awake
9 months – awake
Toddlers (12 – 36 mos) - awake

- Posterior dominant rhythm
  - Usually 6-7 hz
  - Fragments of 8 hz PDR by age 3
  - Need relaxed wakefulness

- Much delta and theta in the background
Toddlers (12 – 36 mos) - sleep

- **Stage 1**
  - Bursts of high amplitude rhythmic slowing (hypnagogic hypersynchrony)
  - Prominent vertex waves

- **Stage 2**
  - Sleep spindles synchronous by 24 months
24 months – awake/drowsy transition
Pre-school (3 – 5 yrs) - awake

- Posterior dominant rhythm
  - At least 8 hz (often 9-10 hz)
  - Posterior slow waves of youth
  - Need relaxed wakefulness

- Much theta, some delta in background
GOOD EFFORT FOR HV

00:02:00 HV

200 mV

dec sec
Children (6 – 12 yrs) - awake

- Posterior dominant rhythm
  - 8.5 – 11 hz
  - Posterior slow waves of youth
  - Need relaxed wakefulness
- Still some theta in the background
10 years – awake/drowsy transition
Normal EEG - summary

- Systematic approach
- Beware and be honest about the behavioral state
- Do not overcall
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So what is abnormal?

- Review suspected abnormalities in multiple montages
  - AP bipolar
  - Transverse bipolar
  - Reference

- Do not overcall
Inter-ictal EEG
Guidelines for sharp waves

1) Artifact until proven otherwise
2) Definable electrical field
3) Usually surface negative in polarity
4) Followed by a slow wave
5) Deviate from background activity
6) Not a physiologic (normal) sharp wave

Maulsby RL, Am J EEG Technology 1971;11:3-16
1) Every sharp wave is an artifact unless there are one or more good reasons for suspecting otherwise.

- muscle
- EKG
- electrodes
- eye movements
10 yr old, school problems
2) Sharp waves of cerebral origin always occupy a definable electrode field on the scalp and should always be seen in 2 or more nearby electrode sites.
3) Clinically significant sharp waves are almost always surface negative in polarity.
4) Most clinically significant sharp waves are followed by a slow wave or a series of slow deflections.
WICKET WAVES

Age: 44 yrs (2-20-81)

FP1-F7
F7-T3
T3-T5
T5-O1
FP2-F8
F8-T4
T4-T6
T6-O2

40µV
1 sec
Wicket rhythm
Wicket rhythm
TYPICAL BSSS

Age: 66

F7-A1
F8-A2
T3-A1
T4-A2
T5-A1
T6-A2

Asleep

1 sec 50 μV
Guideline #5

5) Ignore sharp waves which can be logically explained by simple alterations in voltage of the existing background or by superimposition of several components in the background.
9 yr old, school problems
9 yr old, school problems
6) Several types of physiological sharp waves may be present, especially during drowsiness and sleep. These must be thoroughly familiar to the EEG reader.
Guidelines for sharp waves

1) Artifact until proven otherwise
2) Definable electrical field
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Maulsby RL, Am J EEG Technology 1971;11:3-16
F  Age: 13

Fp1-F7
F7-T3
T3-T5
T5-O1
Fp2-F8
F8-T4
T4-T6
T6-O2

50 µV
1 sec
Rolandic epilepsy of childhood

- aka “Benign focal epilepsy with centro-temporal sharps”
- Normal EEG background
- Sharp waves
  - Centro-temporal sharps
  - Often a frontal horizontal dipole
  - Activation with sleep
  - Possibly other focal or generalized sharps
10 year old, nocturnal seizures with facial twitching and speech arrest
10 year old, nocturnal seizures with facial twitching and speech arrest
10 year old, nocturnal seizures with facial twitching and speech arrest
Occipital epilepsy of childhood

- aka “Benign focal epilepsy with occipital sharps”
- Normal EEG background
- Sharp waves
  - Occipital sharps (or spike/wave)
  - activated by eye closure
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Approach to Clinical Seizure

- Seizure or not?
- What does the seizure look like?
  - Seizure semiology
- Partial or generalized?
  - Semiology, EEG, imaging
  - If partial, what side and what lobe?
- Etiology?
  - Epileptic seizures or provoked seizures?
  - Specific etiology?
- Syndrome?
The actual episode – history, history...

- Circumstances
- Progression of signs
  - Aura or prodrome
  - Eyes open or closed?
  - Eye flutter, facial automatisms
  - Focal, versive or lateralizing signs
  - Characteristics of motor movements
- Post-ictal state
Approach to an EEG seizure

- Have a beginning, middle and end
- Evolve in frequency, amplitude, morphology and/or spatial distribution

- Beware of artifacts
  - Monomorphomic
  - Often do not evolve
Age makes a difference in ...

- Semiology
- Terminology
- Ability to determine mechanism of onset clinically
- Lateralizing value
- Syndrome classification
Age-specific semiology summary

- **Neonates**
  - Only focal clonic and focal tonic seizures can be diagnosed clinically
  - Most seizures are subclinical
- **Infants less than 2 years**
  - Unique semiological terms are helpful
  - Seizure classification and lateralization are challenging clinically
- **Children 2-6 years**
  - Moving target
- **Children 6 years and up**
  - Largely resemble older children and adults
Infant (< 2 years) seizure semiology

- Astatic
- Behavioral arrest (hypomotor)
- Clonic
- Epileptic spasm
- Myoclonic
- Tonic
- Versive

Nordli et al. Epilepsia 1997;38:553
Lennox Gastaut - ILAE definition

Age 1-8 years
Tonic, atonic and absence seizures
EEG usually has abnormal background activity, slow spike-waves <3 Hz and, often multifocal abnormalities. During sleep, bursts of fast rhythms (~10 Hz) appear.
In general, there is mental retardation.
LGS Classic Triad

Multiple seizure types

Slow spike and wave on EEG

Delayed mental development
LGS: inter-ictal
LGS: inter-ictal
LGS: ictal
Infantile Spasms - EEG
3 mos old – hypomotor
3 mos old – Generalized tonic + hypomotor
3 mos old – Focal, subclinical
6 mos old – Focal, subclinical
Approach to an EEG seizure

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