The Normal EEG, Normal Variants, Artifacts

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I have no financial relationships to disclose that are relative to the content of my presentation.
Learning Objectives

- recognize normal EEG patterns
- recognize normal variants that may masquerade as abnormalities
- recognize common artifacts
Self assessment questions
Question 1

The pattern above represents

1) A seizure
2) Midline theta
3) Rhythmic temporal theta bursts of drowsiness (RTTBD)
4) SREDA
Question 2

The pattern above represents

1) A seizure
2) Midline theta
3) Rhythmic temporal theta bursts of drowsiness (RTTBD)
4) SREDA
Question 3

- The pattern above represents
  1) A seizure
  2) 14 and 6 Hz positive burst
  3) Wicket pattern
  4) RTTBD
Question 4

The pattern above represents
1) A seizure
2) 14 and 6 Hz positive burst
3) Wicket pattern
4) RTTBD
Posterior dominant rhythm

- Poorly visualized in ~¼ of normal adults, with very low voltage in 6-7%
- Voltage asymmetry of ≤ 50% is normal, usually greater on right
- Maximum frequency asymmetry < 1 Hz
- Slow and fast alpha variants may be seen representing subharmonic (one half) and harmonic (double) alpha frequencies. Transitions to regular alpha rhythm helps identification.
Slow alpha variant
Slow alpha variant reactivity
Fast alpha variant
Mu rhythm

- Arciform alpha frequency representing the resting rhythm of the rolandic cortex. May be asymmetrical and asynchronous
- Seen in about 25% of normal EEGs
- Blocks with contralateral movement of an extremity, or with the thought of movement.
Mu rhythm
Other rhythms

- Beta rhythm may be observed bifrontally. May attenuate with eye opening, alerting, movement.
- Beta activity is increased by benzodiazepines, barbiturates, chloral hydrate.
- Theta rhythms of 6 to 7 Hz theta appear during relaxed wakefulness maximally in the frontal or fronto-central regions. Theta can be facilitated by focused concentration and drowsiness.
- Temporal theta activity is normal in the elderly if less than 10% of the EEG.
- Lambda waves are occipital positive sharply contoured transients seen with visual scanning of complex images. They may be asymmetrical.
Lambda waves
Activation techniques

- Hyperventilation
  - 3-5 minutes
  - To be avoided in patients with severe cardiac or pulmonary disease, recent stroke, sickle cell anemia or trait.
  - Normally associated with increased theta and delta activity including intermittent generalized rhythmic delta activity (FIRDA or OIRDA)- resolves within one minute of end of HV

- Photic stimulation
  - produces rhythmic potentials at the frequency of stimulation or a harmonic/subharmonic thereof
  - "driving" may be asymmetrical
HV effect
Photic driving response

Fp1-Av
Fp2-Av
F3-Av
F4-Av
C3-Av
C4-Av
P3-Av
P4-Av
O1-Av
O2-Av
Photic driving response
Drowsiness

- Early drowsiness characterized by attenuation of muscle artifact, anterior expansion of occipital rhythm, and slow eye movements
- Stage 1b sleep characterized by disappearance of occipital rhythm, simple vertex waves, positive occipital sharp transients of sleep (POSTS)
Drowsiness
Vertex waves
Sleep

- Stage 2 sleep characterized by sleep spindles and K-complexes
- Slow wave sleep characterized by increasing 1-2 Hz delta activity
- REM sleep - lower voltage EEG with rapid eye movements
Stage 2 sleep
REM sleep
Sources of Erroneous Epileptiform Interpretation of nonepileptiform activity

- Artifacts
- Normal phenomena- Physiological rhythms can have a sharp configuration, particularly in transition to drowsiness
- Sharp transients of dubious significance (benign variants)
- Rhythmic non-ictal patterns
The misdiagnosis of epilepsy and the management of refractory epilepsy in a specialist clinic

D. SMITH, B.A. DEFALLA and D.W. CHADWICK

From the Walton Centre for Neurology and Neurosurgery, Liverpool, and Huddersfield Royal Infirmary, Huddersfield, UK

- 324 patients
- Misdiagnosis rate more than 25%.
- The two most important factors in misdiagnosis were
  - Incomplete history, particularly failure to obtain eyewitness description of attacks
  - EEG misinterpretation
Normal sharp activity in drowsiness

- Most common in the waking drowsy transition and with arousal
- Generalized or frontocentral sharp alpha-theta bursts
- Temporal sharp alpha
- Posterior alpha bursts
- Sharp vertex waves
Frontal Arousal Rhythm

- 7-10 Hz rhythmic activity occurring predominantly over the frontal regions
- There may be varying harmonics (7-20 Hz)
- Most common in children
- Disappears when the child is fully awake
- More common in children with minimal cerebral dysfunction
Normal sharp activity in sleep

- Vertex waves
- K-complexes
- Sleep spindles- subharmonics
- Lambdoids- POSTS
- Frontal mittens
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<th>Channels</th>
<th>Graphs</th>
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Asymmetrical POSTS
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**Frontal mittens**
Small Sharp Spikes (SSS)

- Also called “benign epileptiform transients of sleep (BETS)” and “benign sporadic sleep spikes (BSSS)”
- Occur mainly in adults
- Occur in 24% of normal subjects (White et al)
- Usually seen in drowsiness and stages I and II of sleep
- Usually decrease / disappear in slow wave sleep
SSS = BETS = BSSS

Features

- Generally of low voltage (<50μg), but amplitude may be higher in a long distance derivation
- Generally of short duration (<50msec)
- Simple diphasic morphology most common, with a steep slope of second phase. Aftergoing slow wave usually not prominent.
SSS = BETS = BSSS

Features

Field:

- prominent in temporal regions,
- often wide field,
- predominantly unilateral for an individual transient, but recorded from both sides if enough are recorded.
- Sometimes follows an oblique transverse dipole extending across the midline, with negativity in one hemisphere and positivity in the other hemisphere
Wicket Spikes

- A fragment of a temporal rhythm that resembles μ-like activity (third rhythm)
- Can be part of a breach rhythm with a skull defect
- Occur in wakefulness, drowsiness, or light sleep (more likely with bursts of arousal)
- Repetition: Single or in a train
- Morphology: Simple, symmetrical
Wicket spikes
Clinical and EEG features of patients with EEG wicket rhythms misdiagnosed with epilepsy  
Krauss et al, Neurology 2005

- 25 of 46 misdiagnosed patients (54%) had wicket rhythms misinterpreted as epileptogenic; all had nonepileptic clinical episodes.
- Within a single EEG, wickets may range in from single sporadic spikes to trains of arciform discharges.
- Trains **typically have a crescendo-decrescendo** envelope and can often be found bilaterally over temporal regions (not necessarily at the same time)
- Single wicket spikes are commonly misinterpreted as temporal sharp waves. Interictal sharp waves often have a following slow wave
- Patients who had single wicket spikes also had long runs of 6- to 11-Hz semirhythmic activity over the same temporal regions
Clinical and EEG features of patients with EEG wicket rhythms misdiagnosed with epilepsy

G.L. Krauss, MD; A. Abdallah, BA; R. Lesser, MD; R.E. Thompson, PhD; and E. Niedermeyer, MD
Clinical and EEG features of patients with EEG wicket rhythms misdiagnosed with epilepsy

G.L. Krauss, MD; A. Abdallah, BA; R. Lesser, MD; R.E. Thompson, PhD; and E. Niedermeyer, MD
Breach Rhythm

- Seen over skull defect from prior craniotomy/injury
- Includes beta over frontal region, sharply contoured mu over central region, wicket patterns (third rhythm) over temporal region
14 and 6 per second positive spikes

- Also called 14- and 6-Hz positive burst pattern, ctenoids
- Pattern begins to appear at 3-4 yrs, peaks at 13-14, then declines
- Incidence as high as 58% in normal teenaged boys.
- Prevalent in drowsiness and light sleep
- Field: -Unilateral, but shifting between the two sides
  -Most prominent over the posterior temporal regions
6-Hz spike-and-slow-wave pattern

- Also called phantom spike-wave or fast spike-wave
- Occurs mainly in young adults
- Occurs in bilateral widespread bursts lasting 1-2 seconds
- Tends to occur in drowsiness and disappear in sleep
- Amplitude low
- Predominate in the midparietal region
- Anterior predominance may have greater association with epilepsy
6-Hz spike-and-slow-wave pattern

Hughes described two forms:

- **WHAM** - Waking, High amplitude, Anteriorly predominant, in Males
  
greater probability of association with seizures

- **FOLD** - Females, predominantly Occipital, Low amplitude, in Drowsiness
  
low probability of association with seizures
Psychomotor Variant

- Also called “rhythmic temporal theta burst of drowsiness (RTTBD)” or “rhythmic midtemporal discharges (RMTD)”
- Trains of rhythmic notched waves with a frequency of 5-6 Hz, seen in drowsiness
- Maximal in midtemporal region, bilateral synchronous or asynchronous
- Mostly seen in young adults (2% of normals)
Focal rhythm over the midline region, most prominent over vertex with occasional spread to adjacent electrodes

Usually 5-7 Hz, monorhythmic, waxes and wanes

Seen in wakefulness and drowsiness- has variable reactivity

Occurs in a heterogeneous group of patients

May be more common in frontal lobe epilepsy if pathologic
Midline theta

First box shows posterior rhythm (9-10 Hz); second box is midline theta (6-7 Hz)
Subclinical Rhythmic Electrographic Discharge of Adults (SREDA)

- Seen mainly in the elderly
- Resembles an electrographic seizure discharge, but has no relationship to epilepsy
- Most often a train of rhythmic sharply contoured waves that merge into a sustained theta rhythm
- Predominates in the posterior head region
- Bilateral but often asymmetrical
- May last more than 1 minute
- May subside abruptly or gradually
Age: 52 yrs

No symptoms or clinical accompaniment

(continued)

Diabetes
Sources of Artifact

- Other physiologic activity
  - blinking and other eye movements
  - muscle/ chewing, swallowing, sucking, talking, hiccoughing/ tremor
  - movement
  - heart beat/ extrasystole/ pulse wave
  - perspiration
  - movements of the tongue & other oropharyngeal structures
  - dental restorations with dissimilar metals
Sources of artifact

- Interference
  - 60 Hz artifact
  - TV, radio paging, telephone ringing
  - cardiac pacemaker
  - movement of a charged body
  - IV drip

- Malfunctioning of the recording system
  - from electrodes, electrode terminal board, input cable, selector switches- ex: electrode pop
  - from the recording machine
Eye movement artifacts

- Combination of potentials from the eye and potentials from the muscles surrounding the eye
- Eye is electrically charged with the cornea positive relative to the fundus, so any movement of the eye results in potentials which can be recorded from anterior leads.
- These potentials can occasionally be mistaken for frontal lobe activity.
- May be asymmetrical (ex: enucleation)
Vertical eye movements

- Downward gaze results in the positive cornea moving away from the frontal lobe, so negativity is seen in frontal leads. The reverse is true for upward gaze. Since the eyes move up and down together, the potentials from the two sides are synchronous.

- Certain vertical eye movements have characteristic patterns, including eye blinks, eye opening, eye closure, eye fluttering.
Eye closure/ eye blink

- Eye closure results in Bell’s phenomenon, an upward deviation of the eyes. This will be associated with a positive deflection in the frontopolar electrodes. The reason that the tracing returns to baseline is the low frequency filter.

- An eye blink causes the same positive potential in the frontopolar regions, but the subsequent eye opening causes a negative deflection. The subsequent negative deflection distinguishes an eye blink from mere eye closure.
Lateral eye movements

- Lateral gaze results in the positive cornea moving toward the temple to the side of gaze. For example, left gaze results in positivity at the F7 electrode, whereas there is negativity at the F8 electrode. The differential effect of lateral gaze on the two sides makes for easy identification of this as a non cerebral potential.

- Lateral eye movements are often associated with lateral rectus spikes. Typical, the spike will be followed by a slower positive potential on the side to which the eyes moved.
Eye opening

- Eye opening results in a negative potential in the frontopolar electrodes plus alteration in the posterior rhythm.
  - The attenuation of the posterior rhythm with eye opening and reappearance with eye closing are good clues to the presence of vertical eye movements, although the technician should indicate this phenomenon along with other patient movements.

- Eye closure results in restoration of the posterior rhythm.
  - The posterior dominant frequency may be slightly faster immediately after closure. Therefore that should be measured a few seconds after eye closure.
**Muscle artifact**

- Very short/sharp potentials that tend to recur
- Most common from frontalis and temporalis muscles
- Can be helped by opening mouth slightly
- May be distorted by high frequency filter
- Paralysis may be indicated in some instances
- Specific patterns of muscle artifact may be seen in some movement disorders (ex: tremor, hemifacial spasm, myokymia)
Effect of filtering
ECG artifact

- usually has characteristic form and regularity
- may be confounded by arrhythmia
- problematic in brain death recordings
- most often detected by ear electrodes (recording from base of skull)
- short neck results in upward extension of field
- amplitude may fluctuate with respiration
- a dedicated ECG channel is recommended
Instrumental artifacts

- Amplifier noise: small random fluctuations in output - should be <2µV
- Junction boxes, contacts of switches, board contacts.
  - artifact from one electrode vs one channel
- Various mechanical problems
- Human error (filters, etc..)

EXAMINE CALIBRATION SIGNAL BEFORE EEG RECORDING
Electrode artifacts

- usually due to high impedance (impedance must be <5,000 ohms)
- most common is “electrode pop”, a spike-like discharge that reflects an abrupt change in impedance
- may give an appearance of irregular slow activity
Electrode artifact
Environmental artifacts

- most common in environments with uncontrollable externally induced currents (ex: ICU or OR)
- asymmetries in artifact amplitude may reflect impedance mismatch