Traps and Pitfalls Leading to Misinterpretation of Normal EEG Variants and Variation of the Background Activity

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Additional electrodes



- The lower temporal line is measured from the external auditory canal to the lateral canthus of the eye.
- The line is divided by three.
- T1 and T2 are marked at onethird from the external auditory canal.
- TA1 and TA2 are marked at one-third from the lateral canthus of the eye.
- The electrodes are placed one centimeter above these points.
- T1 and T2 are the zygomatic electrodes.
- TA1 and TA2 are the anterior lower temporal electrodes (Temporal Anterior).



The Context of Recording EEG

Frequency (Hz)	Normal	Abnormal	
0.0 - 0.5 (Infraslow activity)	Artifacts	Ictal onset focal seizures	
0.5 - 3.5 (Delta)	PSWY, HV, N3 Sleep, elderly	Encephalopathy, white matter lesion	
>3.5 - <8.0 (Theta)	Drowsiness, children, elderly	Encephalopathy, white matter lesion	
8 – 13 (Alpha)	PDR, mu rhythm, "third" rhythm	Ictal rhythm in seizure, alpha coma	
13 – 30 (Beta)	Medication (i.e., barbiturates & benzodiazepines, drowsiness	Breach rhythm, drug overdose, ictal rhythm	
30 – 80 (Gamma)*	Voluntary motor movement, learning & memory	Ictal onset focal seizures- intracranial EEG	
80 – 250 (Ripples)*	Cognitive processing & memory consolidation	Ictal onset focal seizures, possibly reflects epileptogenesis	
250 – 500 (Fast ripples)*	?	Ictal onset focal seizures- intracranial	
500 – 1000 (very fast ripples)*	Acquisition of sensory information	Ictal onset focal seizures- research	

* = Expanded frequencies currently under investigation; HV= hyperventiliation; PSWY= posterior slow waves of youth; PDR= posterior dominant rhythm. Adapted from Tatum WO, Freund B, Feyissa A. EEG in Epilepsy September2023. <u>https://www.medlink.com/articles/eeg-in-epilepsy</u>

Rules and recommendations

First rule: When the alpha rhythm is ample, all physiological and unusual waveforms are accordingly ample.

 \rightarrow First recommendation: When the alpha rhythm is ample, electroencephalographers must not be misled by the EEG pattern's unusual amplitude.

Second rule: Absence of slow after-wave in the majority of normal variants and variation of the background activity.

→ Second recommendation: If there is no wave after the spike, electroencephalographers should be suspicious of artifacts and normal EEG variants/variations of the background activity.

Third rule: Normal EEG variants display a single non-evolving rhythm. The morphology is stable with repetition of the same pattern throughout the entire EEG recording and subsequent EEGs.

→ Third recommendation: Electroencephalographers should be suspicious of possible EEG variants when the pattern appears monomorphic and repeats itself identically throughout the recording

Fourth rule: Phase reversals merely indicate localization, not epilepsy.

→ Fourth recommendation: The phrase "phase reversal" in an EEG report should be only used to describe the localization of the pattern and should not imply epileptogenicity or abnormality.

Fifth rule: Interictal epileptiform discharges and EEG variations differ in their EEG reactivity patterns

→ Fifth recommendation: EEG patterns that react similarly to the alpha rhythm correspond to alpha-harmonic or posterior slow waves of youth.

Sixth rule: Drowsiness and NREM sleep facilitate the occurrence of IEDs.

→ Sixth recommendation: When the activity decreases or stops at drowsiness or sleep onset, electroencephalographers need to be vigilant to artifacts, variations of the background activity and Ciganek's rhythm.

Seventh rule: Wicket spikes are best identified during sleep.

→ Seventh recommendation: Obtain an EEG that includes sleep stages in case of doubt and difficulties.

Eighth rule: REM sleep is relatively protective against interictal epileptiform discharges and epileptic seizures.

→ Eighth recommendation: Electroencephalographers should be suspicious of EEG variants when activity increase in REM sleep or when rhythmic discharges are observed without arousal.

Ninth rule: Seizures usually disrupt sleep patterns.

→ Ninth recommendation: Consider electrode artifact, RMTD, and SREDA when the discharge occurring at drowsiness or during sleep is strictly subclinical.

Tenth rule: Epilepsy is and must remain a clinical diagnosis.

→ Tenth recommendation: EEG must stay a tool used to confirm clinical hypotheses.



- "Most spike or sharp wave discharges of clinical import are followed by a slow wave or series of slow deflections.
- If it does not have a slow after-wave, be more suspicious of artifact or of a sudden alteration in voltage of physiological background rhythms".

Maulsby RL. Some guidelines for assessment of spikes and sharp waves in EEG tracings. Am J EEG Technol 1971; 11:3-16. http://dx.doi.org/10.1080/00029238.1971.11080808

Second rule: Absence of slow-after wave in the majority of normal variants and in normal variation of the background activity

Normal EEG variants



"Most spike or sharp wave discharges of clinical import are followed by a slow wave or series of slow deflections."

Wicket spikes

TA2 T4	mmMMmMMM
T2 T6	mmMullulu

14- and 6-Hz burst

Typical spike-waves









Posterior slow waves of youth

- Bilateral
- Intermixed with the alpha rhythm
- Blocked when eyes are open
- Disappear at drowsiness
- Increase during hyperventilation

Superposition of alpha rhythm and posterior slow waves of youth (underlined)

Posterior slow waves of youth





Superposition of alpha rhythm and posterior slow waves of youth (underlined)

Posterior slow waves of youth share the same reactivity with the alpha rhythm. They are blocked when eyes are open and disappear at drowsiness

Background activity: children versus adults

9-year-old child Hyperventilation

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Alpha rhythm intermixed with slow posterior slow waves presenting sharplycontoured waves that interrupt the sinusoidal pattern of the alpha rhythm. Posterior slow waves are significantly enhanced by hyperventilation

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43-year-old woman

Note the reactivity of the alpha rhythm upon eye opening and eye closure

Slow alpha variant

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49-year-old woman

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ECG

Alpha.

Slow alpha variant



Slow alpha variant shares the same reactivity with the alpha rhythm. It is blocked when eyes are open and disappear at drowsiness

© ☺ ☺ Slow alpha variant ☺	
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52-year-old woman

The rhythm disappears upon eye opening

Slow alpha variant









Mu rhythm

- Observed during resting wakefulness but can also be observed during sleep, especially REM sleep.
- Mu rhythm commonly occurs over the central region at 7-11 Hz.
- Mu rhythm blocks unilaterally upon contraction of the contralateral hand, or upon movement of the contralateral foot if the rhythm is near the vertex.



Mu rhythm

12-year-old woman. Migraine

Patient is asked to clench her fists Epilepsy Unit, Montpellier, FRANCE Fp2 F4 mmmm MMMMM F4 C4 MMM C4 P4 MAA P4 02 Fp2 F8 www.while. WWWWWWWWWW F8 T4 With Children with mathematic for the side with a strate with a strate with and Manuf Manual Manufal Manuf Manufal Man т4 т6 т6 02 MMWWWWWWWWWWWW TA2 T4 T2 T6 Fz Cz Cz Pz TA1 T3 WINNING AN NAMATINA MANAMATINA MANAMATINA T1 T5 Fp1 F3 F3 C3 C3 P3 mmm P3 01 Fp1 F7 F7 T3 warm Marin Marin war and the second ТЗ Т5 with William mound of the well of the way of the and the many and the WM NOW MANNAMAN and market for an and the market and the second of the sec walter Walter T5 01 70 µV R. Delt 1 sec L. Delt Mu rhythm Eyelid movement artifacts

Patient is asked to clench her fists

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Same EEG panel at an EEG speed of 15 mm/s

L. Delt

Mu rhythm in REM sleep Rapid eve movements

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Mu rhythm



Midline theta rhythm (Cigánek rhythm)

- Observed during wakefulness or drowsiness.
- Sinusoidal or arciform
 4-7 Hz activity.
- This rhythm occurs predominantly over the vertex (Cz).
- Sometimes, this rhythm resembles mu rhythm but it is not similarly reactive.



Midline theta rhythm (Cigánek rhythm)



Awake Eyes open

Midline theta rhythm and mu rhythm in the same patient Awake Eyes open

18-year-old woman.

Parasomnia

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Midline theta rhythm This rhythm may resemble to mu rhythm but it is not similarly reactive and occurs on the vertex region at 4-7 Hz.

Mu rhythm

Note the topographic distribution of the mu rhythm. To test the reactivity, it would have been necessary to have the patient move her right feet due to its localization near the vertex



Midline theta rhythm (Cigánek rhythm)

Midline theta rhythm while she was reading on her tablet.

15 mm/s 100 μV/cm

Eyes open. No cognitive task. She was looking up at the ceiling.



Lambda waves

- Lambda waves are observed during wakefulness when individuals are visually scanning a picture in a well-illuminated room.
- They are often associated with saccadic eye movements.
- They occur in the occipital regions.
- Lambda waves are often bilateral.
- Lambda waves disappear when the patient stares at a point and when the room is not as bright.



Eyes open. She was reading a book

Lambda waves

40-year-old woman. Left left lateral temporal lobe epilepsy



Same EEG panel at an EEG speed of 15 mm/s

Lambda waves

40-year-old woman. Left lateral temporal lobe epilepsy



Same patient Comparison when she was reading a book and reading on her tablet with a powerful activation of lambda waves and inversion of polarity.

Lambda waves

40-year-old woman. Left lateral temporal lobe epilepsy



A. Patient reading a book. Typical lambda waves. The predominant phase is positive in occipital electrode O2 and O1.

B. Patient reading on tablet. Di- or triphasic lambda waves. The predominant phase is negative in occipital electrode O2 and O1.

Gélisse P, Crespel A. Powerful activation of lambda waves with inversion of polarity by reading on tablet. Epileptic Disord. 2024. doi: 10.1002/epd2.20197. OPEN ACCESS

Lambda waves



Lambda waves

Reading a book

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Lambda waves

37-yearold woman Positive occipital sharp transients of sleep (POSTs)

- POSTs occur, either symmetrically or not, on the occipital areas.
- POSTs are frequent in adolescents and young adults, and have no pathological significance.
- They are monophasic or diphasic
- POSTs generally occur in stage N2 and they may persist in stage N3.
- They disappear during REM sleep.



30 mm/second

37-year-old woman with left temporal lobe epilepsy



19-year-old woman with juvenile myoclonic epilepsy



27-year-old woman with cryptogenic left temporo-parieto-occipital junction epilepsy.







POSTS
- Monophasic arciform waves.
- Occur over the temporal regions either bilaterally or independently.
- Occur generally during drowsiness and light sleep and disappear during deep sleep and reappear in REM sleep.





Typical morphology of diamond or lozenge-shaped

30 mm/second

WS appear most often in bursts, but occasionally singly, in which case they resemble an epileptiform spike activity.





WS appear most often in bursts, but occasionally singly, in which case they resemble an epileptiform spike activity.

Second recommendation: If there is no wave after the spike, electroencephalographers should be suspicious of artifacts and normal EEG variants/variations of the background activity.





70-year-old woman with REM sleep behavioral disorder



70-year-old woman with REM sleep behavioral disorder



NREM sleep.

Isolated wicket spike which can be mistaken for an "epileptic" abnormality. REM sleep. Wicket spikes over the right temporal region.

70-year-old man, left lateral temporal lobe epilepsy Stage N2 sleep Epilepsy Unit, Montpellier, FRANCE Fp F8 F8 T4 Т4 Т6 Fp2 **T**6 Т4 Т6 02 Te www ТА Т4 TA2 T2 T6 Т2 Т6 Cz Pz Wicket Spikes TA1 MAM T1 T5 Fp1 F3 Fp1 F7 \sim F3 C3 C3 P3 F7 T3 P3 01 ТЗ Т5 F7 ТЗ Т5 т5 01 T5 mmmm ECG 1 sec

Fast epileptic rhythm

42-year-old woman with right temporal lobe epilepsy

Stage N2 Sleep

REM Sleep



42-year-old woman with right temporal lobe epilepsy

Stage N2 Sleep

REM Sleep



NREM sleep



- 51-year-old woman
- Onset of seizure at age 30 with GTCS in the awakening period

Idiopathic (genetic) generalized epilesy

49-year-old woman referred for episodes of loss of consciousness



49-year-old woman referred for episodes of loss of consciousness



a theta-like morphology.

 $\mathbf{01}$

Stage N2 sleep

- Lipman and Hughes (1969): rhythmic midtemporal discharge.
- Pattern: theta burst over the mid-temporal regions.
- Mostly seen during drowsiness and usually cease in deeper sleep but reappear in REM sleep.

18-year-old man with syncope



Rhythmic temporal theta burst of drowsiness

16-year-old woman with Idiopathic (Genetic) Generalized Epilepsy

Drowsiness

→ Stage N1 Sleep

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Rhythmic temporal theta burst of drowsiness

V waves

16-year-old woman with Idiopathic (Genetic) Generalized Epilepsy

Drowsiness Stage N1 Sleep Ninth rule: Seizures usually disrupt sleep patterns. Ninth recommendation: Consider electrode artifact, RMTD, and SREDA when the discharge occurring at drowsiness or during sleep is strictly subclinical. MAWW I3 MMMMMMM

Rhythmic temporal theta burst of drowsiness

V waves



Rhythmic mid-temporal theta (burst) of drowsiness and mu rhythm in REM sleep



Small Sharp Spikes

- Low-voltage diphasic spikes which occur singly over the anterior or midtemporal regions.
- SSS generally occur as a unilateral waveform, but can occur bisynchronously or independently.
- They are mainly seen during drowsiness and at the onset of light sleep.



Small Sharp Spikes



Small sharp spikes

43-year-old man

Fourteen and 6-Hz positive bursts

- As indicated, these bursts occur at a rate of 6 Hz and/or 14 Hz.
- They consist of short trains of low-voltage arch-shaped waveforms.
- They occur during drowsiness and light sleep but are mainly seen during REM sleep.
- They appear in children after 3-4 years, are maximally expressed in the adolescents and young adults, and then progressively decrease in adulthood.



30 mm/second

Fourteen and 6-Hz positive bursts

A new approach for the detection of the fourteen- and six-Hertz positive bursts (6–14 Hz): The lower temporal line

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Table 1

Showing age distribution of the 50 patients with fourteen- and six-Hertz positive bursts seen in our epilepsy center from 2 January 2004 to 15 July 2010.

Age groups (In years)	Number of cases
5-10	2
11-14	3
15-20	21
21-25	10
26-30	4
31-40	5
41-50	4
51-55	1
Total	50

Fourteen and 6-Hz positive bursts during REM sleep in an adult

19-year-old man with psychogenic seizures



14- and 6-Hz positive burst during REM sleep

Fourteen and 6-Hz positive bursts during REM sleep in an adult

18-year-old woman with idiopathic (genetic) generalized epilepsy



14- and 6-Hz positive burst during REM sleep

Fourteen and 6-Hz positive bursts



Fourteen and 6-Hz positive bursts during NREM sleep in an adult

18-year-old woman with idiopathic (genetic) generalized epilepsy

 T4
 F

 T6
 F

 T2
 F

 T4
 F

 T5
 F

Asynchrony of some waves between the left and right hemisphere



14- and 6-Hz positive burst during NREM sleep

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA)

- SREDA first described by Naquet et al. (1961) using the term of "paroxystic discharges of the parietal and posterior temporal regions"
- Onset is abrupt or the onset involves a built-up of slow waves gradually occurring at shorter intervals.
- Pattern frequency at 4-7 Hz is sustained, lasting from a few seconds to a few minutes
- Occur during wakefulness, may be activated by hyperventilation, or photic stimulation. May be observed in NREM and REM sleep
- Occur several times in a single standard EEG

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in NREM sleep stage 2



Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge

NREM sleep 30 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in NREM sleep stage 2

49-year-old woman with psychogenic seizures



Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge

NREM sleep 15 mm/s

Same EEG panel at an EEG speed of 15 mm/s

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T1 T5	and the second of the second o	Marian P
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F7 13		
13 15		
15 01		
ECG1+ECG1-	10 - March and a start was a strategic and a s	war Van

Pay attention to the K complex present inside the discharge

End of the discharge No arousal

NREM sleep 15 mm/s

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T5 O1	washered to an and the second of the second	MANN MANNIE MANNE	
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End of the discharge No arousal

NREM sleep 15 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in REM sleep

49-year-old woman with psychogenic seizures. Same patient.





Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge

REM sleep 30 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in REM sleep Rapid eye

49-year-old woman with psychogenic seizures. Same patient.

Fp2 F4 ware and the second of the second and the second of the second second second and the second F4 C4 and a second a second a second a second a second a second second second as a second C4 P4 man when and the second of the P4 O2 Fp2 F8 aller a superior of the second second second second second second second second ways and the first second man a man a second a F8 T4 T4 T6 T6 O2 TA2 T4 and and the second of the seco t2 T6 Fz Cz Cz pZ Third recommendation: Electroencephalographers my my ta1 T3 should be suspicious of possible EEG variants when and a prover a property of the second T1 T5 hand have a start and have a start a strand and the start and the start and the strand and the strand and the st men Ampania Fp1 F3 the pattern appears monomorphic and repeats itself F3 C3 mound of the second of the second of the second sec identically throughout the recording. C3 P3 have have a support of a support of the support of P3 O1 had all and a provide the provident and a second second Fp1 F7 F7 T3 a prove a second and the second and and a second where the second and a second and the second second second and the second T3 T5 and an and a second T5 O1

Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge

Same EEG panel at an EEG speed of 15 mm/s

No arousal

movements

REM sleep 15 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in REM sleep Rapid eye

49-year-old woman with psychogenic seizures. Same patient.

Fp2 F4 and the second and the second of the second F4 C4 man when the second of the sec C4 P4 P4 O2 Fp2 F8 man and the second F8 T4 T4 T6 T6 O2 TA2 T4 t2 T6 Fz Cz Ninth rule: Seizures usually disrupt sleep patterns. Cz pZ more hand ta1 T3 Ninth recommendation: Consider electrode artifact, and many many many many m T1 T5 m Amphania RMTD, and SREDA when the discharge occurring at Fp1 F3 F3 C3 hours of the second second and the second se drowsiness or during sleep is strictly subclinical. C3 P3 Marian power and a contraction and the contraction of the P3 O1 Fp1 F7 F7 T3 man and a second and the second and and the second of the T3 T5 and and the second and the T5 O1

Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge

Same EEG panel at an EEG speed of 15 mm/s

No arousal

movements

REM sleep 15 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA)

37-year-old woman with right temporal lobe epilepsy



Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge Eyes open 30 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA)

37-year-old woman with right temporal lobe epilepsy



Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge Eyes open 30 mm/s
Subclinical Rhythmic Electrographic Discharges in Adults (SREDA)



Slow waves appear on the right posterior region at gradually shorter interval until there is a continuous discharge

Eyes open 15 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA)

37-year-old woman with right temporal lobe epilepsy

Fp2 F4	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
F4 C4	www.www.www.www.www.www.www.www.www.ww
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P4 O2	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
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T6 O2	ware and the second ware and the
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T1 T5	an and a second a second a second a second and a second a secon
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ECG1+ ECG1-	
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EMG2+ EMG2-	
	Murhythm

Another example of SREDA in the same patient but without build-up of slow waves gradually occuring at shorter intervals Eyes open 30 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in REM Sleep

37-year-old woman with right temporal lobe epilepsy



Same patient. Slow waves appears bilaterally in REM sleep at gradually shorter intervals until there is a continuous discharge

REM Sleep 30 mm/s

Subclinical Rhythmic Electrographic Discharges in Adults (SREDA) in REM Sleep

37-year-old woman with right temporal lobe epilepsy

Same EEG panel at an EEG speed of 15 mm/s



Same patient. Slow waves appears bilaterally in REM sleep at gradually shorter intervals until there is a continuous discharge

REM Sleep 15 mm/s

Temporal lobe seizure in NREM sleep

Same patient. One focal subclinal seizure during NREM sleep.



37-year-old woman with right temporal lobe epilepsy.



Temporal lobe seizure in NREM sleep

37-year-old woman with right temporal lobe epilepsy. Same patient



This patient had both SREDA and temporal lobe epilepsy. Compare the evolution of the EEG pattern in both situations.

NREM Sleep 30 mm/s

Six-Hz Spike-and-Wave bursts (Phantom Spikeand-Wave bursts)

- Consist of brief bursts of spikes in very low amplitude with a repetition range of 5 to 7 Hz but usually occurring with a rate of 6 Hz.
- They are said to be "phantom" because of the low amplitude of the spike in contrast to the slow-wave component that follows and the more widespread distribution of the slow wave.
- This pattern usually occurs bilaterally, generally synchronous during relaxed wakefulness, drowsiness or light sleep.



Breach rhythm

- A breach rhythm is an increase in high-voltage activity of alpha, beta, mu rhythm or other elements such as wicket spikes nearby the breach which occur in persons with a skull defect.
- Breach rhythm occur in wakefulness, and is persistent throughout all sleep stages.

Fp2 F4	must have a support and a support
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Fp1 F7	man for the second and the second s
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ТЗ Т5	www.www.www.www.www.www.www.www.www.ww
T5 01	Marine
ECG	"

Breach rhythm

Awake. Eye open

49-year-old woman.

5 years after surgery for a right cavernous sinus meningioma

Typical breach rhythm with sharplycontoured waveforms that resemble to wicket-spikes

The morphology is stable with repetition of the same pattern throughout the entire EEG recording (Recommendation IV)

POSTS	Stage N2 sleep	Rapid eye	REM sleep
ECG		-A- BCGA	And <u>isec</u> A
55 mmmmmm	man Manutan many	much 55 mount mount	
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F7 martin	man man man man man and a second and the second sec	marking F7 may marking marking	
Fp1 MMMM	man	man Pp1 mg	m manufacture and a second sec
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FP2		Epilepsy Unit, Montpellier, FRANCE	

movements

Tenth rule: Epilepsy is and must remain a clinical diagnosis

Tenth rule: Epilepsy is and must remain a clinical diagnosis

When the EEG makes things more difficult! Typical spike-waves in subjects without epilepsy

3-year-old boy with a typical vasovagal syncope





- These spike-waves are characteristic for self-limited epilepsy with centrotemporal spikes formerly known as benign Rolandic epilepsy or benign epilepsy of childhood with centrotemporal spikes but this child had no seizure.
- In this child, the spike-waves observed on the EEG evoke age-dependent functional spikes. They can be observed in children who do not display epilepsy. Beaussart (1972) reported that, in a cohort of 315 children with rolandic spikes, 16% were not epileptic. Cavazzuti et al. (1980) reported rolandic spikes in 2.3% if 3,726 children.
- The changes disappear at puberty.

19-year-old woman with a typical vasovagal syncope



19-year-old woman with a typical vasovagal syncope

- The EEG pattern evokes an genetic (idiopathic) generalized epilepsy but the patient had no seizure (generalized tonic-clonic seizure, myoclonic or absence seizure).
- Her antiseizure medication was stopped after the EEG. But she had a genetic predisposition to genetic generalized epilepsy. She was advised to avoid sleep deprivation and alcohol abuse.
- This example indicates how important the clinical context is when interpreting an EEG. The presence of spike-wave does not necessarily indicate that a patient has epilepsy. There should not have been an EEG.





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