Rhythmic and Periodic EEG patterns. When to sound the alarm?

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Disclosure

- I have nothing to disclose.

- The majority of the content in this lecture was obtained from the ACNS's Standardized Critical Care EEG Terminology: 2012 version, published in the JCNP and from the Handbook of ICU EEG Monitoring, edited by Suzette M. LaRoche, and Hiba Arif Haider, Springer Publishing Company, 2018.

Objectives

- Basic terminology
- Periodic pattern and main clinical relevance
- Rhythmic patterns and main clinical relevance
- Ictal –interictal continuum
- Non-convulsive status epilepticus
- Post anoxic brain injury and burst suppression/attenuation

Main terms:

- Main term 1 (Location):
- Generalized (G):
  - Bilateral and **symmetric/synchronous**.
  - Predominance can be frontal, midline, or occipital.

- Lateralized (L):
  - lateralized to one hemisphere or a focal region (in one hemisphere). Can be seen bilaterally but **asymmetric** (i.e., clearly prominent on one side).
  - Can be localized to a region if that it was more involved that others (F,T,P,O) or to the whole hemisphere if not able to specify.

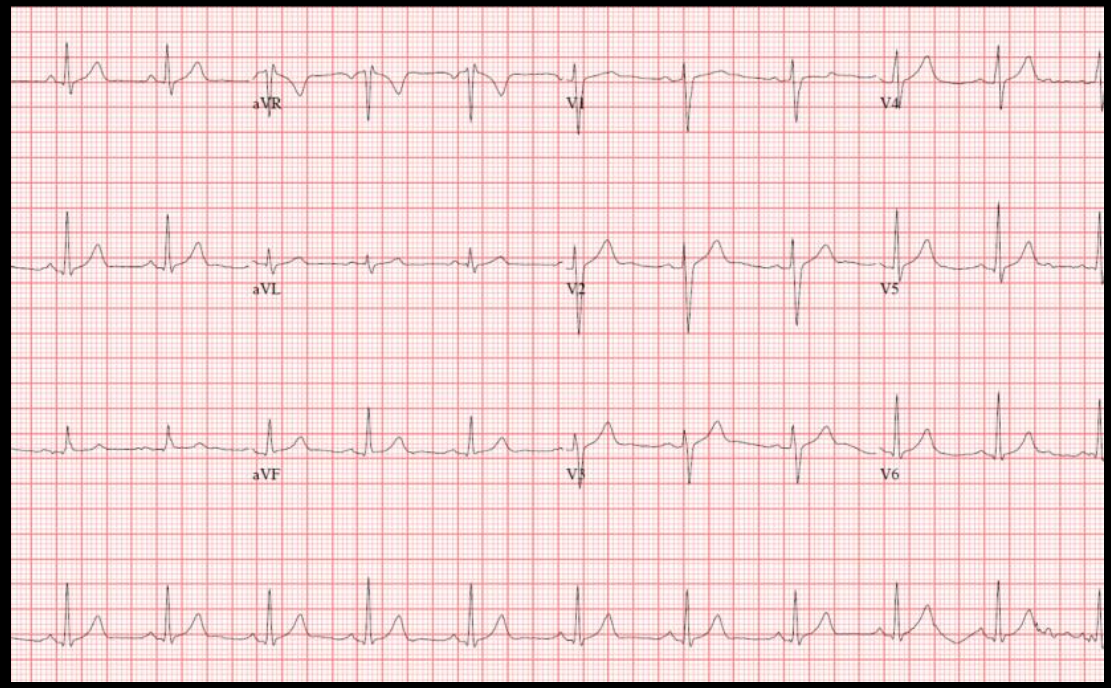
- Bilateral-independent (BI):
  - Asynchronous hemisphere/focal (F,T,P,O), occur independently over both hemispheres.
  - Symmetric or not?, different frequency?

- Multifocal:
  - Independent in 3 regions of the brain

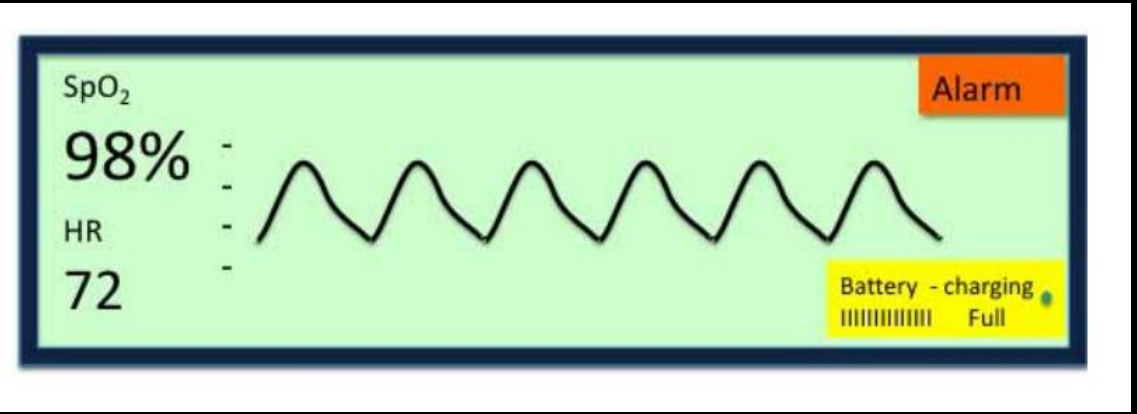
AND

  - Both hemispheres are involved

- Main term 2 (morphology,type): (PD, RDA, SW)
- Periodic discharges:
  - uniform morphology, relatively regular intervals
  - 3 or less phases, or any waveform ≤0.5 sec regardless of phases. (Does not include bursts >0.5 sec and have at least 4 phases)
  - Identifiable intervals, and have <50% variability



- Rhythmic delta activity (RDA):
  - Repetition of a waveform, uniformed in morphology and duration
  - NO intervals between waveforms.
  - Per the ACNS guidelines, for any pattern to be defined as rhythmic, it must recur regularly for at least six cycles in duration; for example, 1 per second for 6 seconds or per second for 3 seconds.



- Spike and wave, sharp and wave (SW):
  - Spike/polyspike/sharp and wave followed by a slow wave
  - Regular pattern

WHO, patient's safety guide, 2011

How to describe the pattern?

- Combination between term 1+term 2: Location+ morphology/type

- Generalized periodic discharges (GPDs)
- Lateralized periodic discharges (LPDs)
- Bilateral independent periodic discharges (BiPDs)
- Generalized rhythmic delta activity (GRDA)
- Lateralized rhythmic delta activity (LRDA)

Modifiers

- Frequency: <0.5, 0.5, 1, 1.5, ……up to 4 Hz.
- Amplitude: very low, low, medium, high
- Prevalence:
  - Continuous: >90%
  - Abundant: 50-89%
  - Frequent: 10-49%
  - Occasional: 1-9 %
  - Rare: <1 %
- Duration

- Number of phases
- Sharpness
- Polarity
- **Stimulus induced** (ex: activity after suction in ICU), stimulus terminated, spontaneous
- Evolving : at least 2 changes in: frequency (at least 0.5/sec), morphology or location (2 electrode locations) at least 3 cycles. < 5 mins long.
- Fluctuating: ≥3 changes, no more than 1 min apart in freq, morphology, location), without evolution.

Plus modifiers: (more ictal)

- Used with PD and RDA but not with SW.
  - PD: +F (fast activity),+R (rhythmic or quasi-rhythmic delta activity), and +FR
  - RDA: +F (fast activity), +S (sharp, spike activity, or sharply contoured activity), or +FS

- Triphasic morphology: Waveforms with two or three phases, each phase longer than the previous, with the highest amplitude seen in the positive phase
- Anterior–posterior lag: Defined by a delay of more than 100 ms from the most anterior to the most posterior derivation, seen in both bipolar and a referential montage.

Association with increased risk for seizures

- LPDs and LRDA. (+ modifier → increased risk)
- GPDs+ (not GPD w/o +)
- Higher frequencies → increased risk

- GRDA was not associated with seizures.

TERM #1
Generalized (G)
Lateralized (L)
Bilateral Independent (BI)
Multifocal (Mf)

TERM #2	PLUS MODIFIERS (ADD ONLY IF PRESENT WITH PATTERN AND NOT IN BACKGROUND)	
Periodic Discharges (PDs)	+ F	Superimposed **FAST** activity; use with PDs or RDA only
	+ R	Superimposed **RHYTHMIC** activity; use with PDs only
	+ FR	Use for PDs if both subtypes apply
Rhythmic Delta Activity (RDA)	+ F	Superimposed **FAST** activity; use with PDs or RDA only
	+ S	Superimposed **SHARP** waves or Spikes; use with RDA only
	+ FS	Use for RDA if both subtypes apply
Spike Wave (SW)	No + modifiers	

Main terms and modifiers of the ACNS Critical Care EEG Monitoring Research terminology. ACNS Standardized Critical Care EEG Terminology. Abbreviated version. ACNS, American Clinical Neurophysiology Society; PDs, periodic discharges; RDA, rhythmic delta activity; SW, spike-wave.

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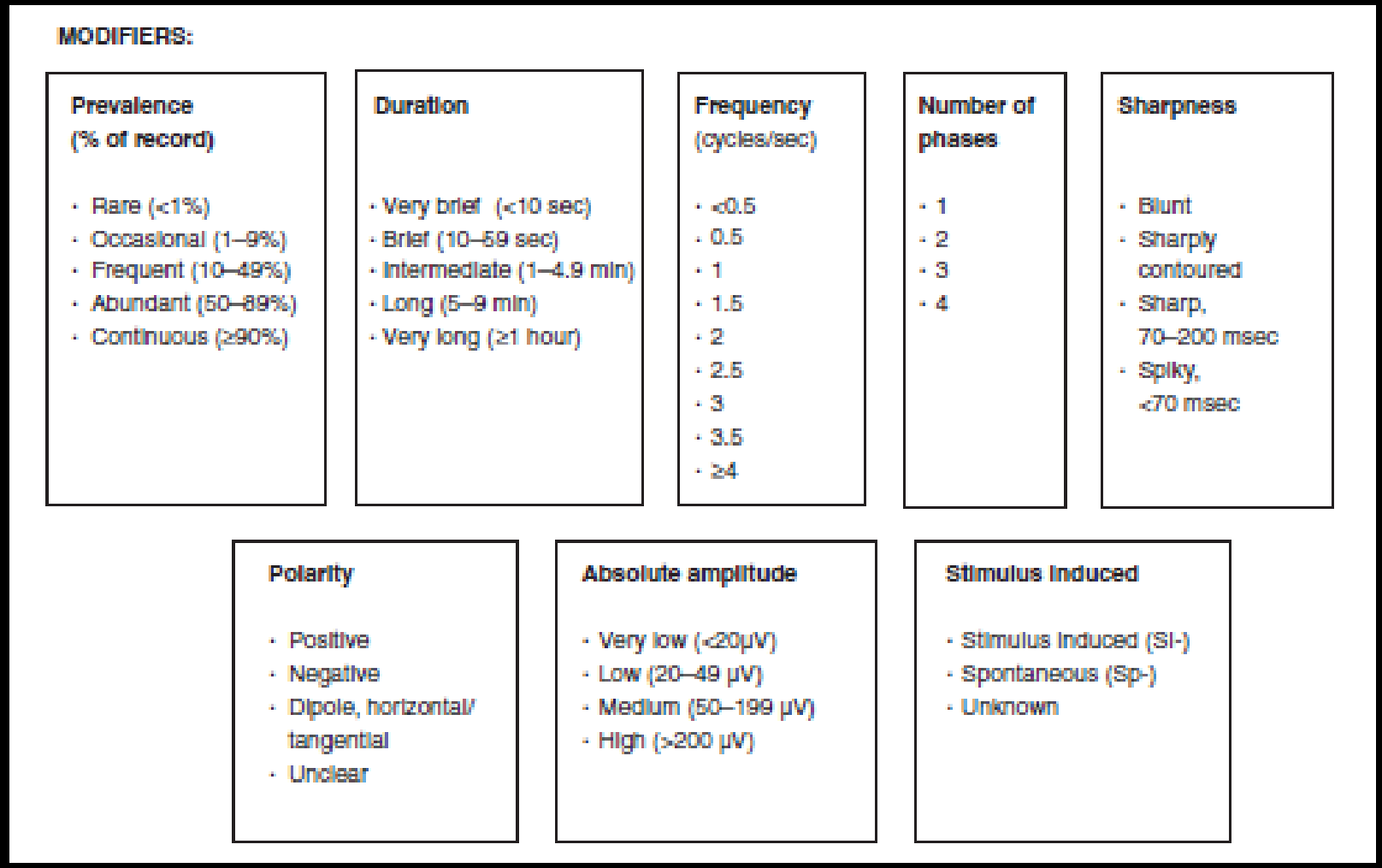

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LPDs

- Frequently associated with structural lesions involving the cortex.
- In adults: Most commonly stroke. Other associations: viral/autoimmune encephalitis (HSV), brain tumors, ICH, anoxic injury.
- Clinical seizures may occur in the majority of pts with LPDs
- LPDs are highly associated with NCS on continuous EEG.
- Ruiz et al. 44% of 802 cEEG with LPDs contained electrographic seizures, the majority of which were nonconvulsive. Of all periodic or rhythmic patterns, LPDs had the highest association with seizures
- LPDs+ significantly increased the risk.
- Clinical manifestations could be subtle if located in noneloquent cortex or could be motor if located in motor cortex.

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LPDs, Right temporal

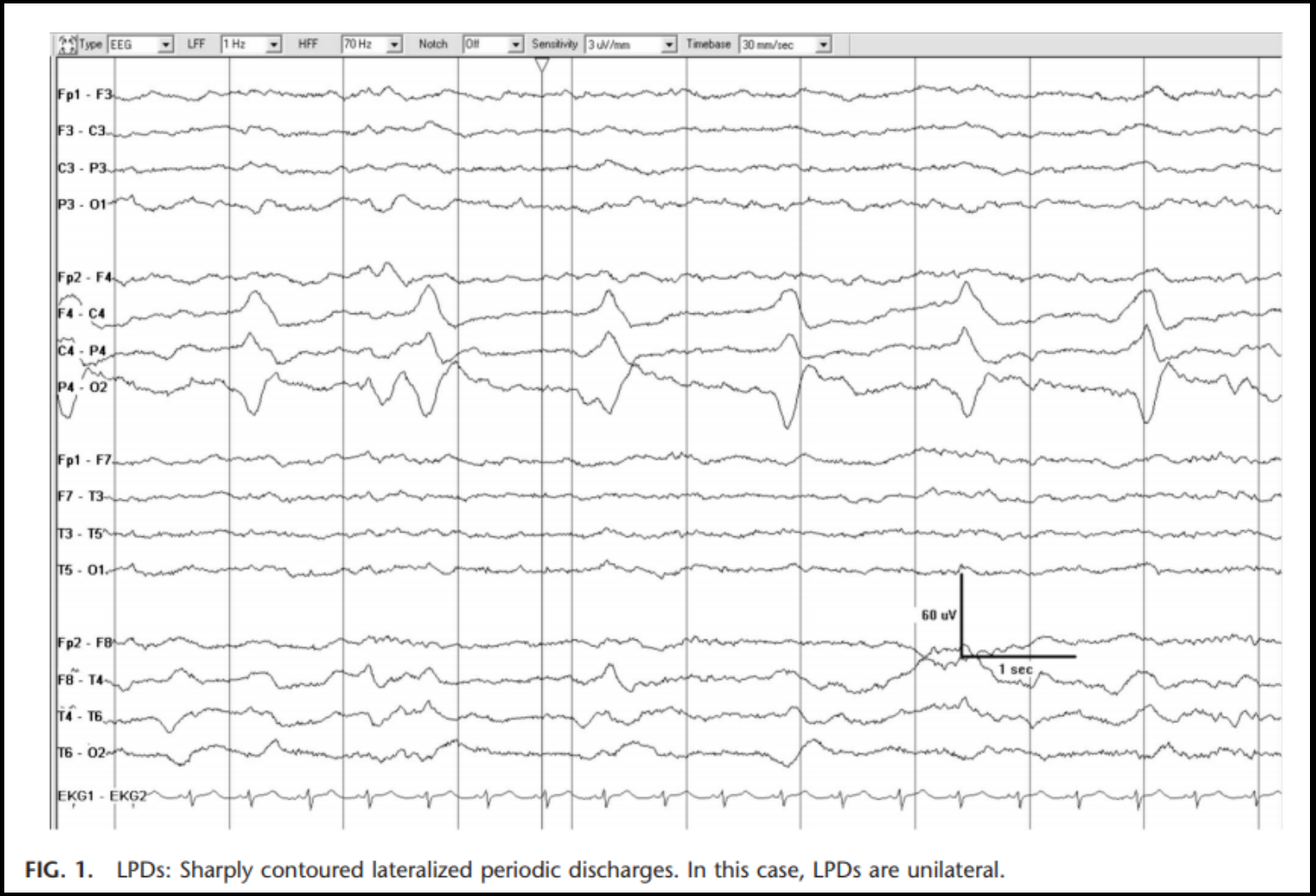


FIG. 1. LPDs: Sharply contoured lateralized periodic discharges. In this case, LPDs are unilateral.

Hirsch LJ et al, JCNP, ACNS Standardized Critical Care EEG Terminology: 2012 version

LPDs, asymmetric

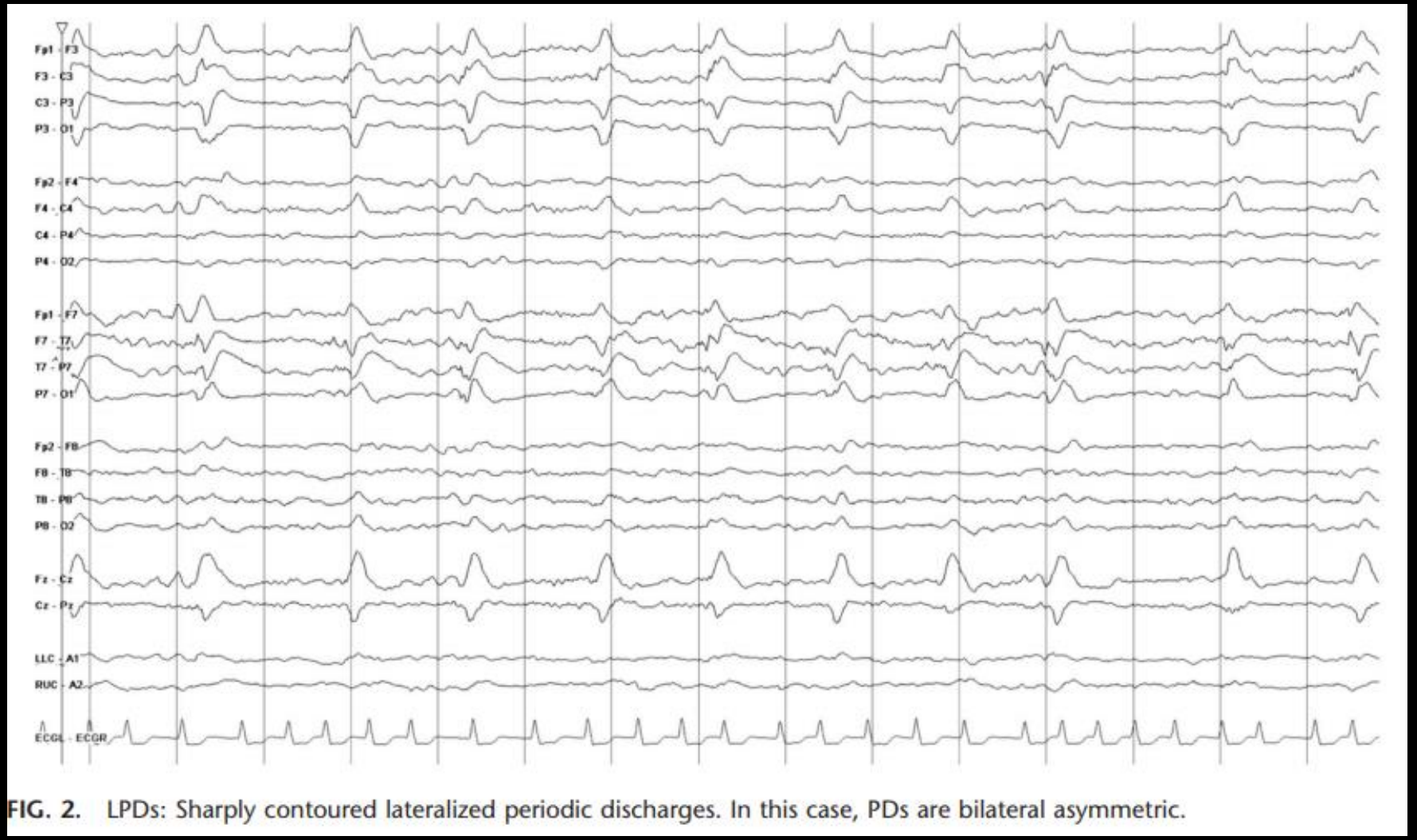
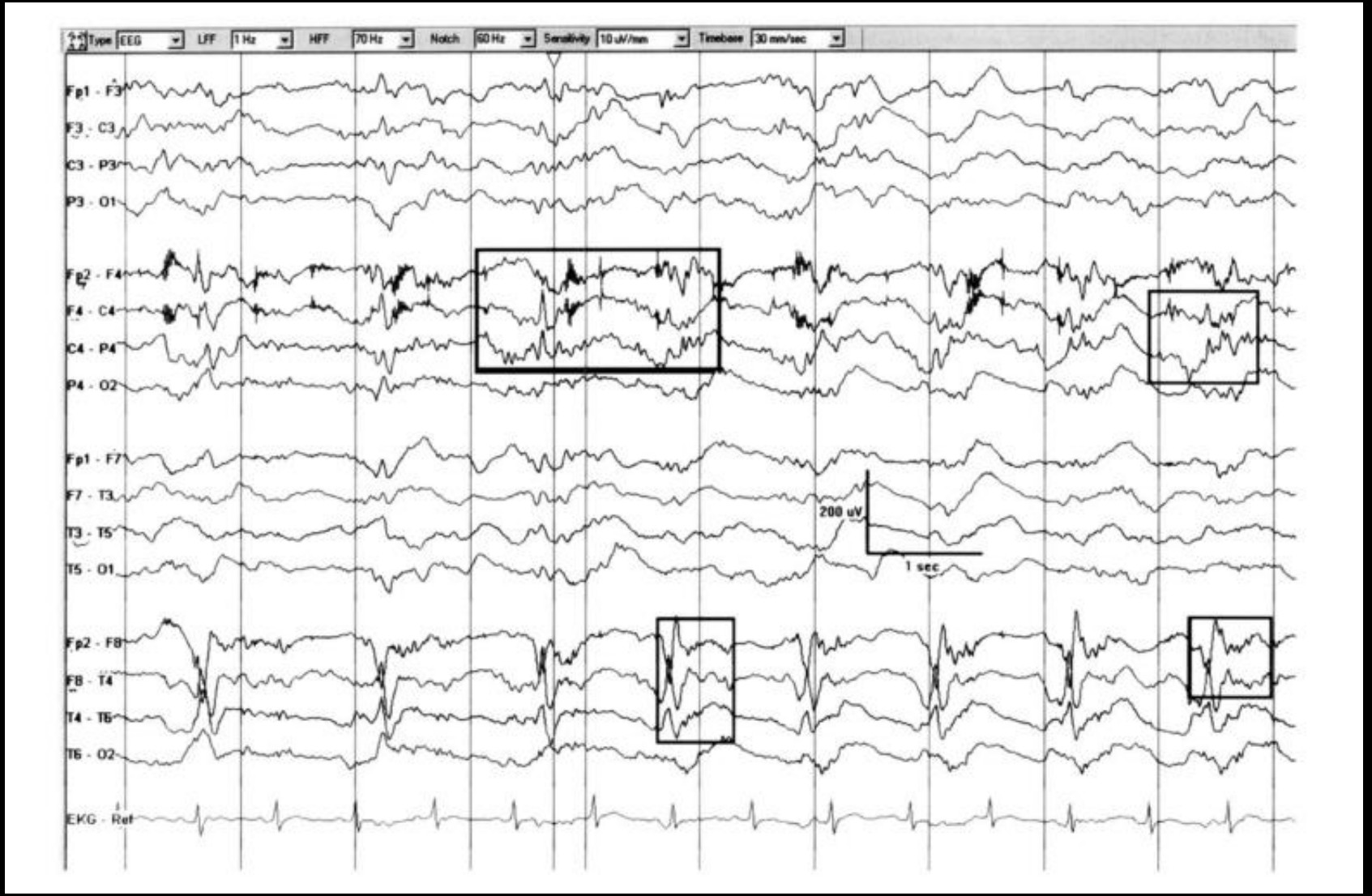


FIG. 2. LPDs: Sharply contoured lateralized periodic discharges. In this case, PDs are bilateral asymmetric.

Hirsch LJ et al, JCNP, ACNS Standardized Critical Care EEG Terminology: 2012 version

LPDs+F



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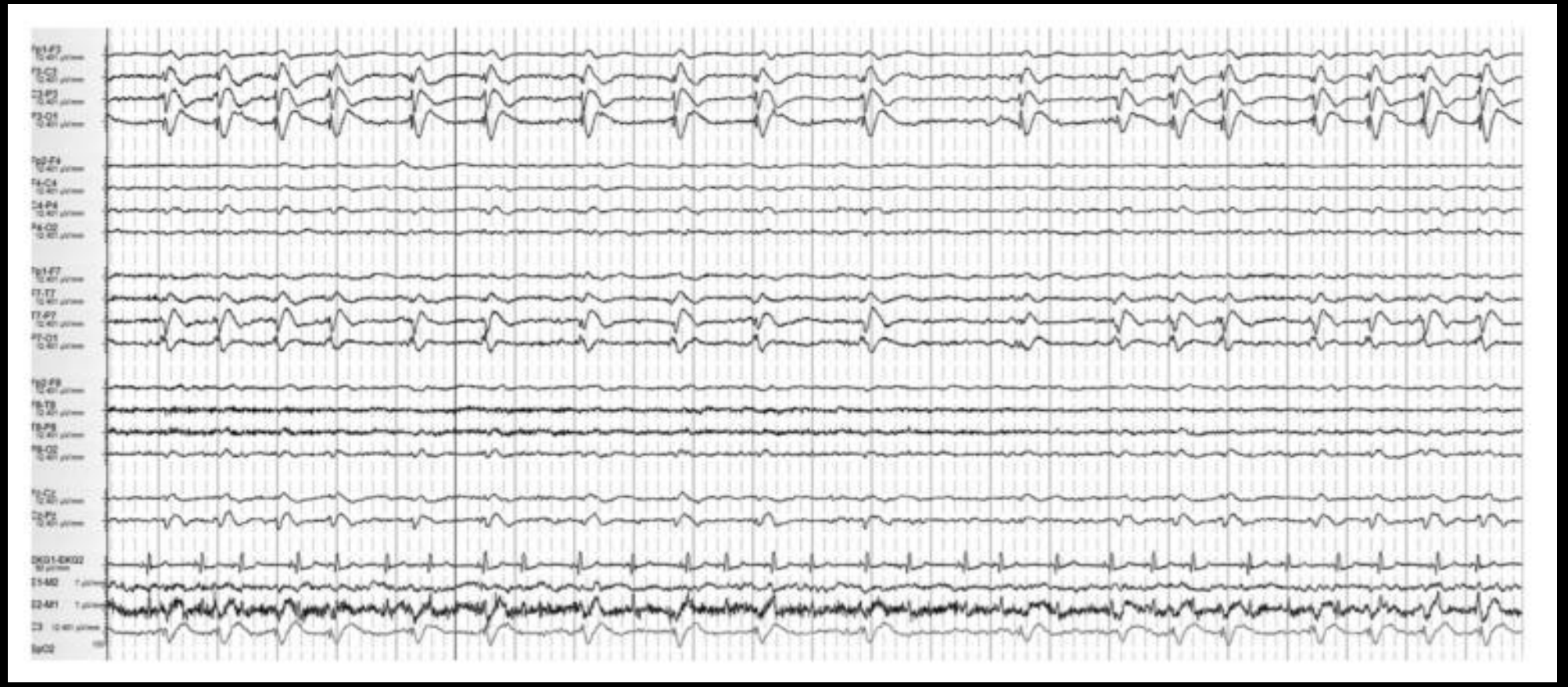
Fluctuating LPDs



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GPDs

- Associated with brain dysfunction
- Patients with GPDs experienced seizures more commonly than controls without GPDs.
- Nonconvulsive seizures were seen in 27% of those with GPDs
- 23% of those with GPDs had nonconvulsive seizures that occurred after the first 24 hours of cEEG monitoring. Mainly more than 48 hours after EEG began.
- GPDs with “Plus” features, sharper morphology, or higher frequency may increase the probability of developing seizures on cEEG.

GPDs

TABLE 19.1 Common Etiologies of GPDs

CATEGORY	ETIOLOGY OF GPDs
Neurovascular	• Hypoxic/anoxic encephalopathy • Acute ischemic stroke
Inflammatory or infectious	• Sepsis • Herpes encephalitis • Subacute sclerosing panencephalitis • Steroid-responsive encephalopathy with antithyroid antibodies, or Hashimoto's encephalopathy • Systemic lupus erythrematosus (children)
Trauma	• Traumatic brain injury
Systemic illness	• Hepatic encephalopathy • Uremia or renal failure • Hyponatremia/hypernatremia • Hypoglycemia • Hypothyroidism
Epilepsy	• Epileptic encephalopathy • Terminal phase of status epilepticus
Neurodegenerative	• Creutzfeldt–Jakob disease • Alzheimer's disease
Toxicity	• Withdrawal from barbiturates, benzodiazepines, or propofol • Phencyclidine (PCP) or ketamine • Baclofen • Lithium • Naproxen • Cefepime and other cephalosporins • Tiagabine (children) • Cyclosporine (children)

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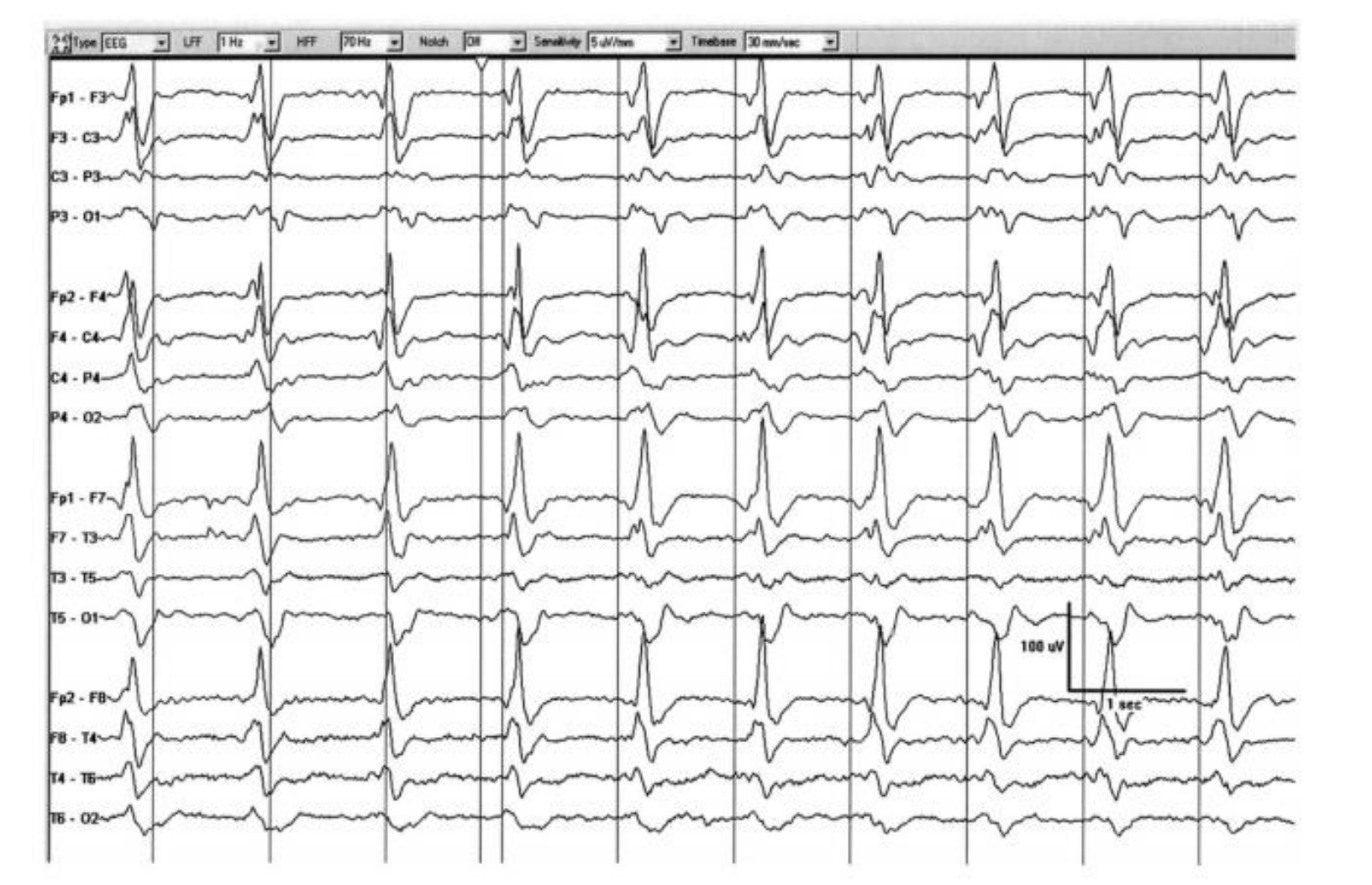
GPDs



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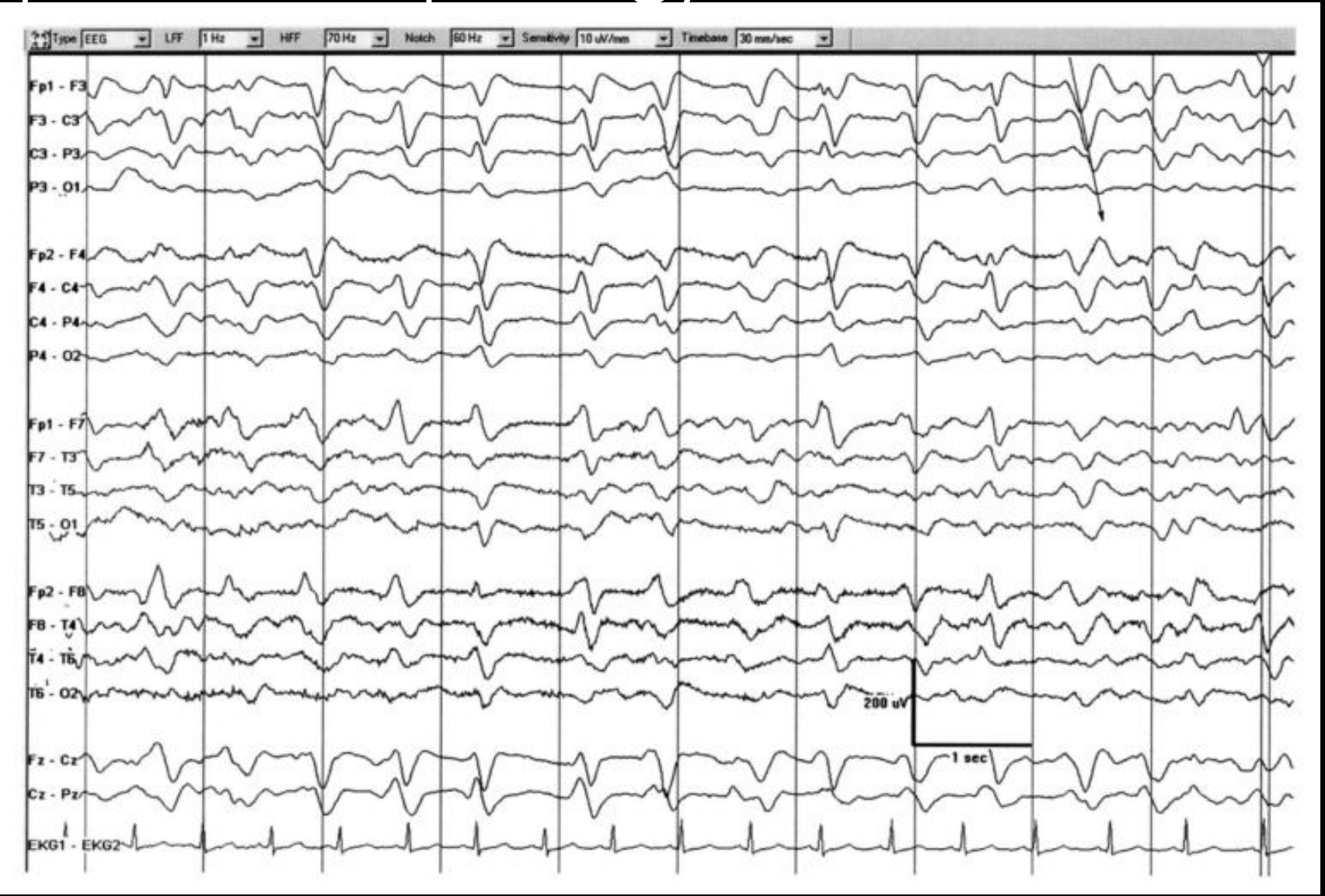
GPDs +Triphasic morphology



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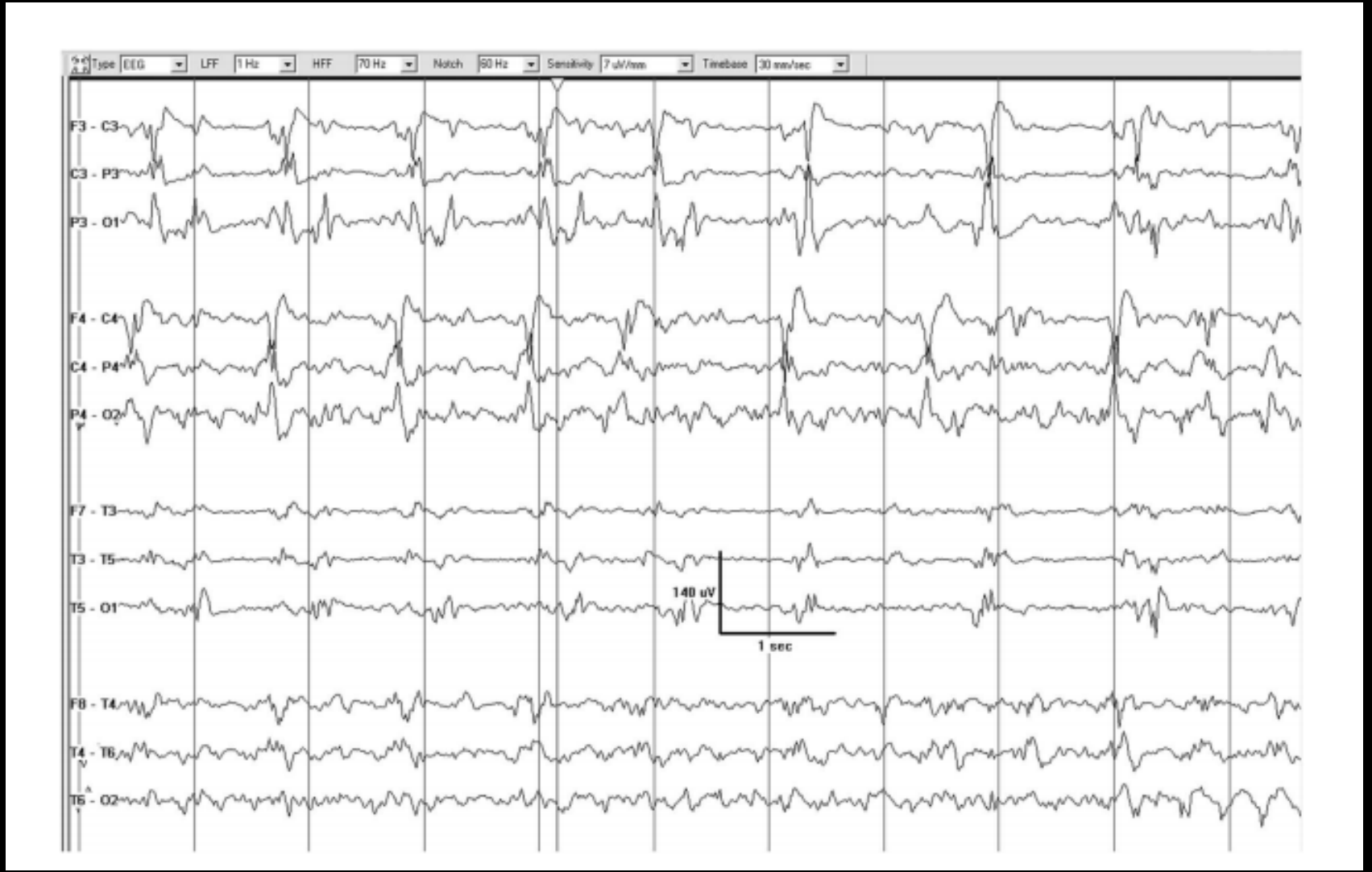
BiPDs

- Less common than LPDs
- Reflects severe diffuse or multifocal brain injury
- Sz were less common in general with BiPDs, but when etiology was infectious it was found to be high.
- Mortality was higher (likely related to etiology).
- Can be seen with PRES

BiPDs+F



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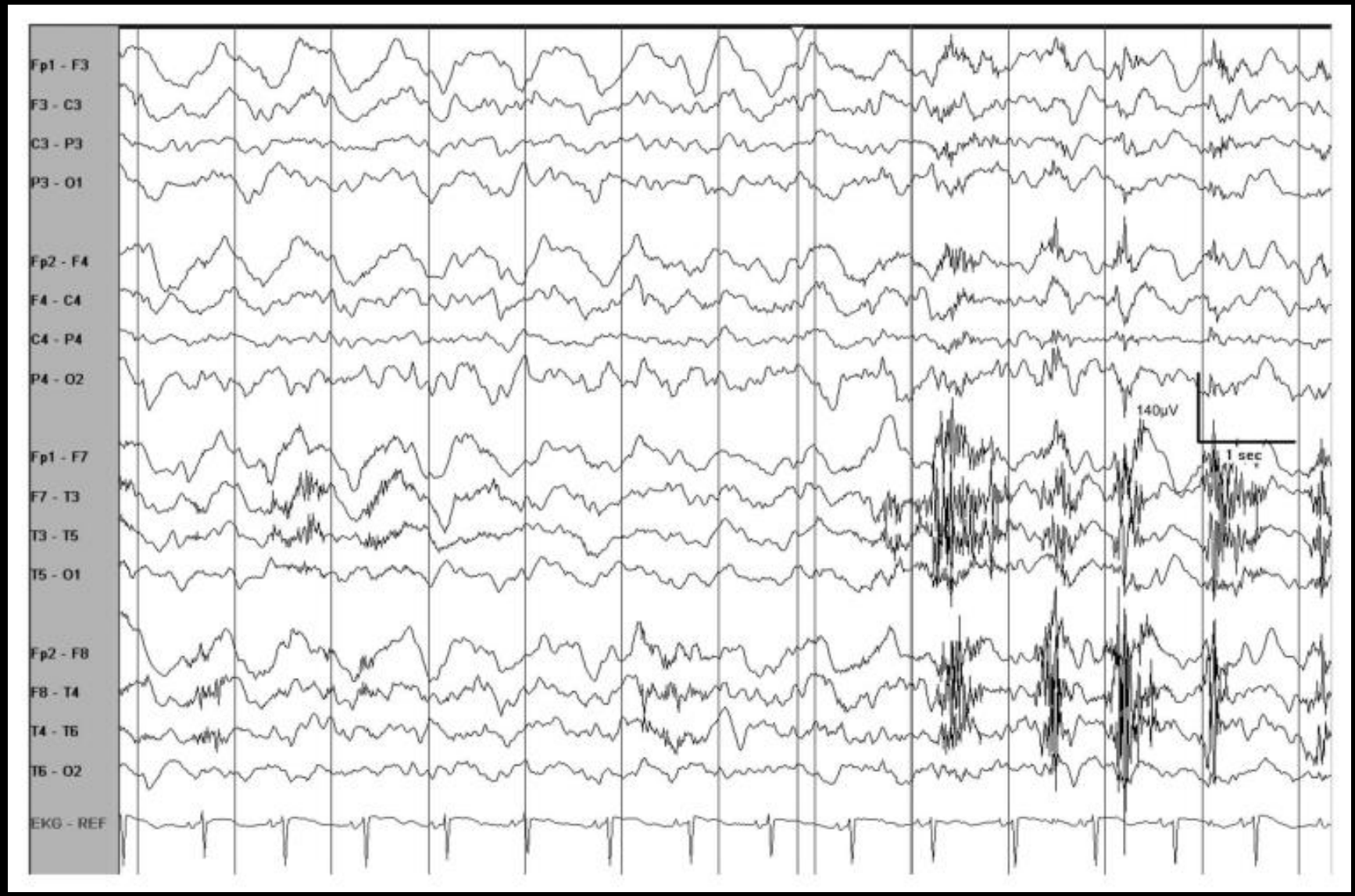
GRDA

- GRDA is defined as bilateral, bisynchronous, and symmetric rhythmic activity of 4Hz or less. It is most commonly intermittent and predominant in the frontal regions.
- One of the most common patterns
- Prolonged runs of GRDA lasting up to several hours without clear evolution are also seen in many patients with anti–*N*-methyl-D -aspartate receptor encephalitis.
- Generally it is a **benign** pattern

GRDA



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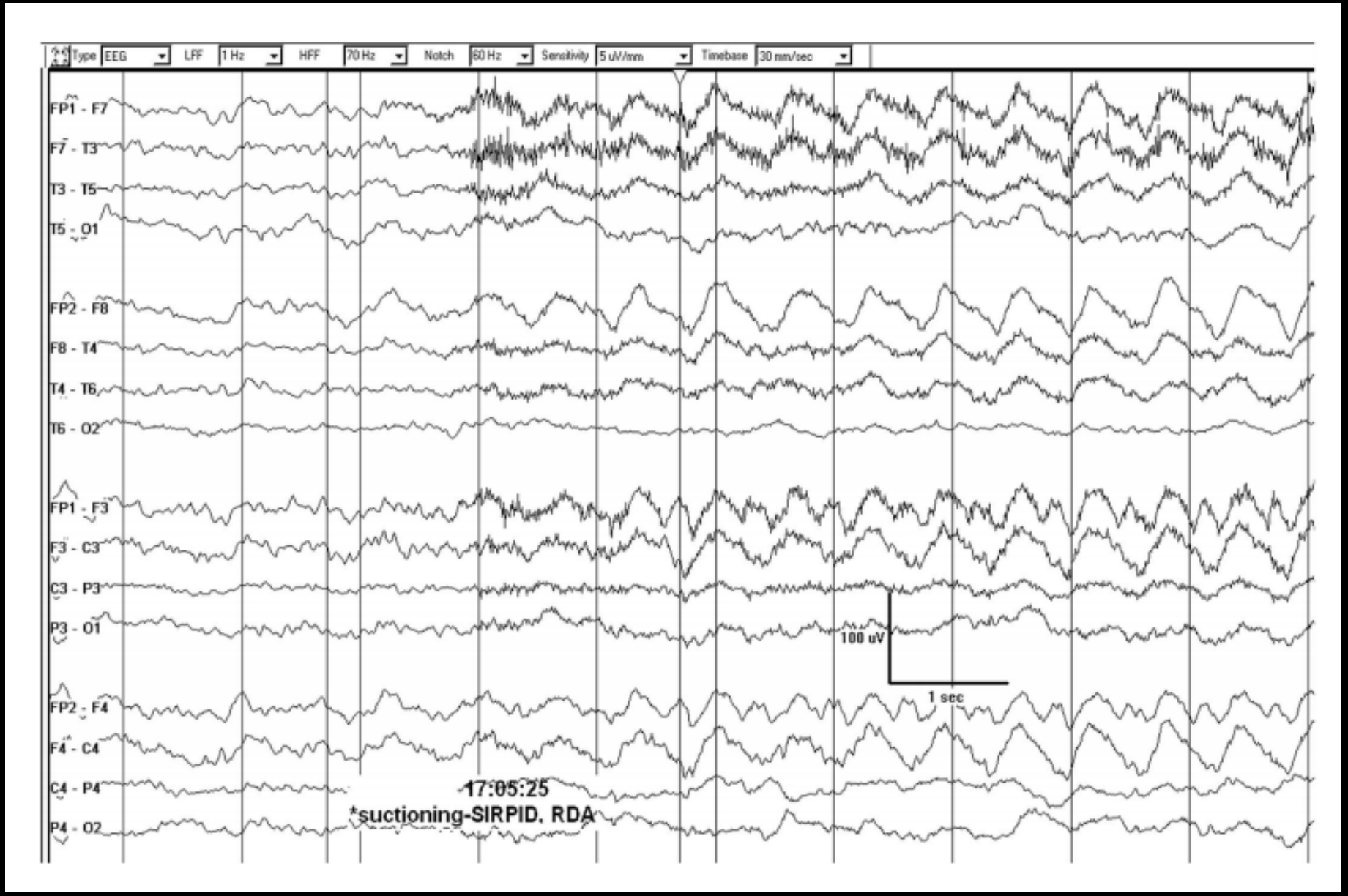
SI-GRDA

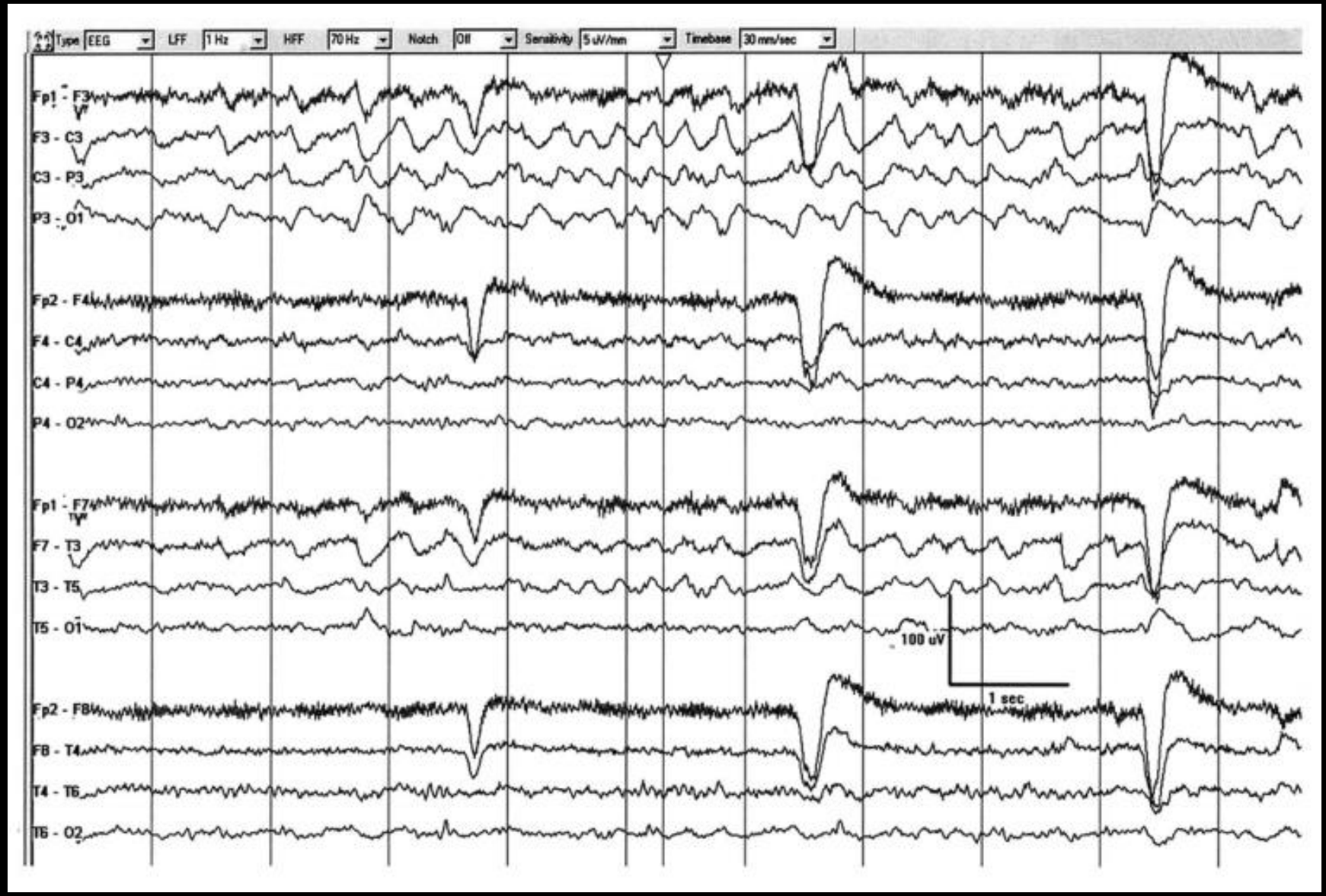


Hirsch LJ et al, JCNP, ACNS Standardized Critical Care EEG Terminology: 2012 version

LRDA

- Similar to GRDA but lateralized
- Two of the **most common causes** are: 1. acute brain injury and 2. chronic seizure disorder.
- There is some evidence from simultaneous intracranial recordings that timelocked intracranial periodic discharges or bursts may coincide with LRDA seen on scalp EEG
- LRDA and LPDs can commonly coexist in up to 44% of cases. Patients with both patterns showed an even higher risk of acute seizures.

LRDA



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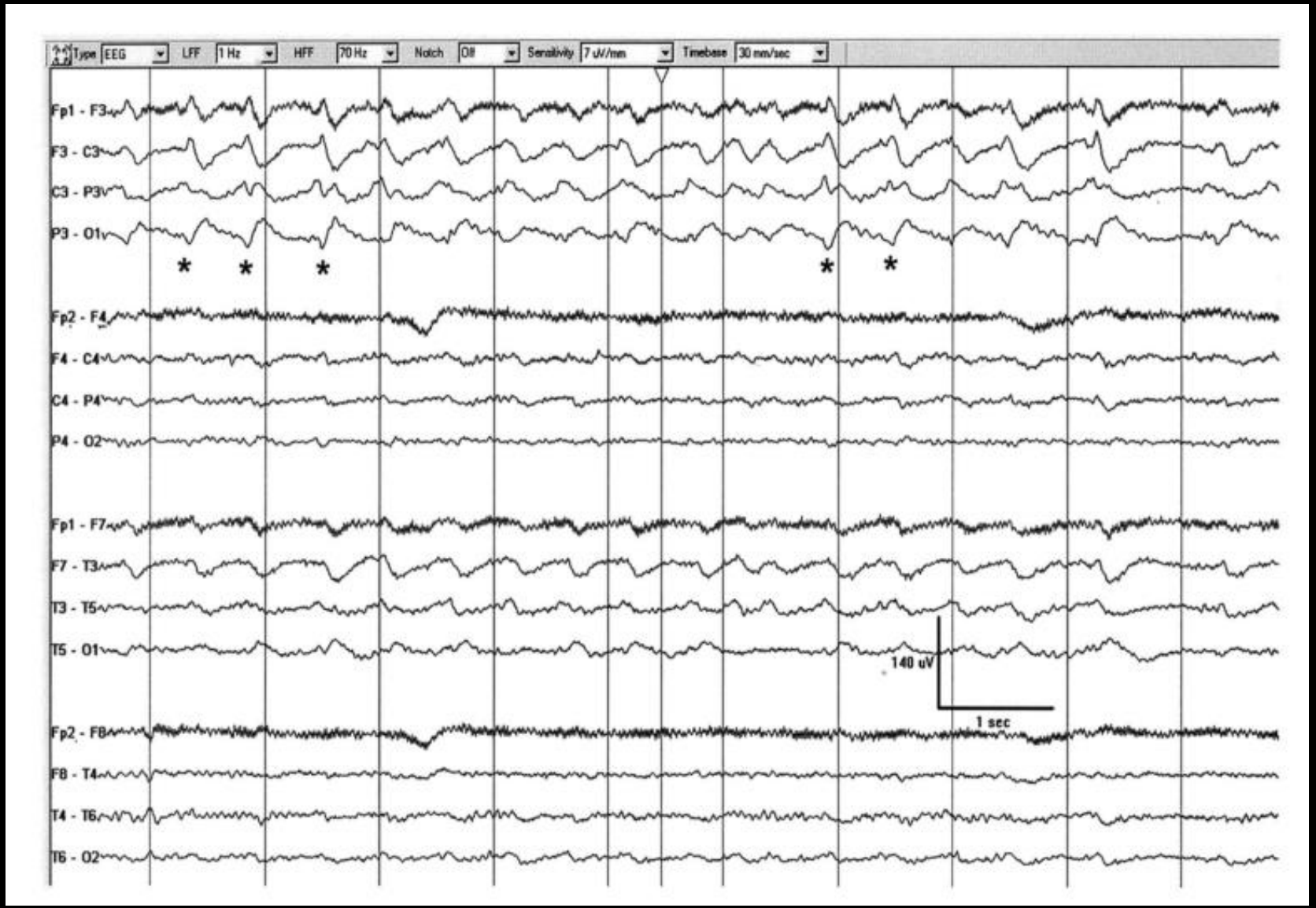
LRDA+S



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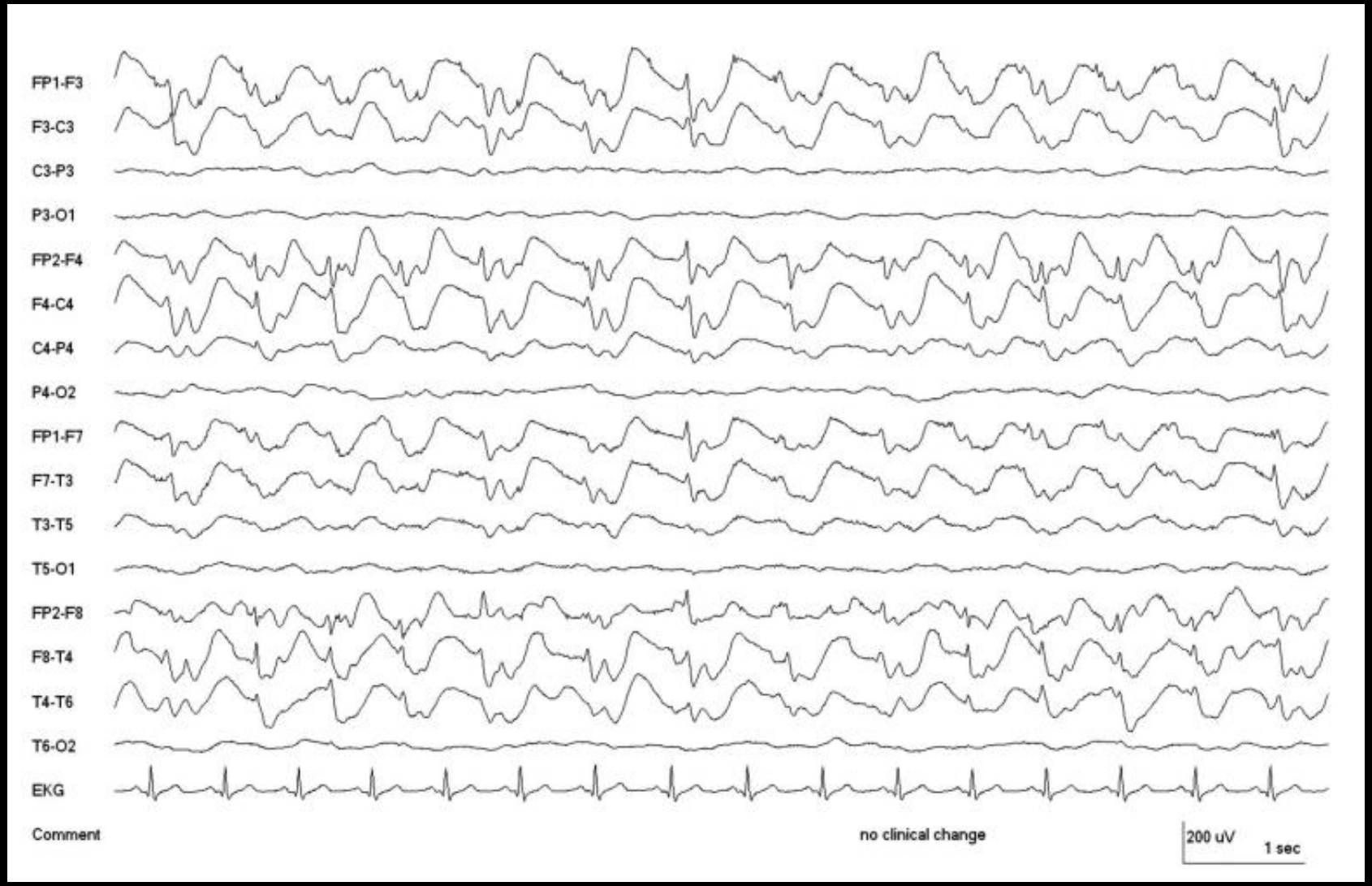
GSW



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Brief ictal rhythmic discharges (BIRDs)

- Very brief (<10 seconds; most often <4 seconds), of more than 4 Hz focal or generalized rhythmic discharges.
- Most patients with B(I)RDs have an acute cerebral injury or a chronic seizure disorder
- 75% experience seizures, which are mostly nonconvulsive. In almost all cases, B(I)RDs precede the onset of electrographic seizures.

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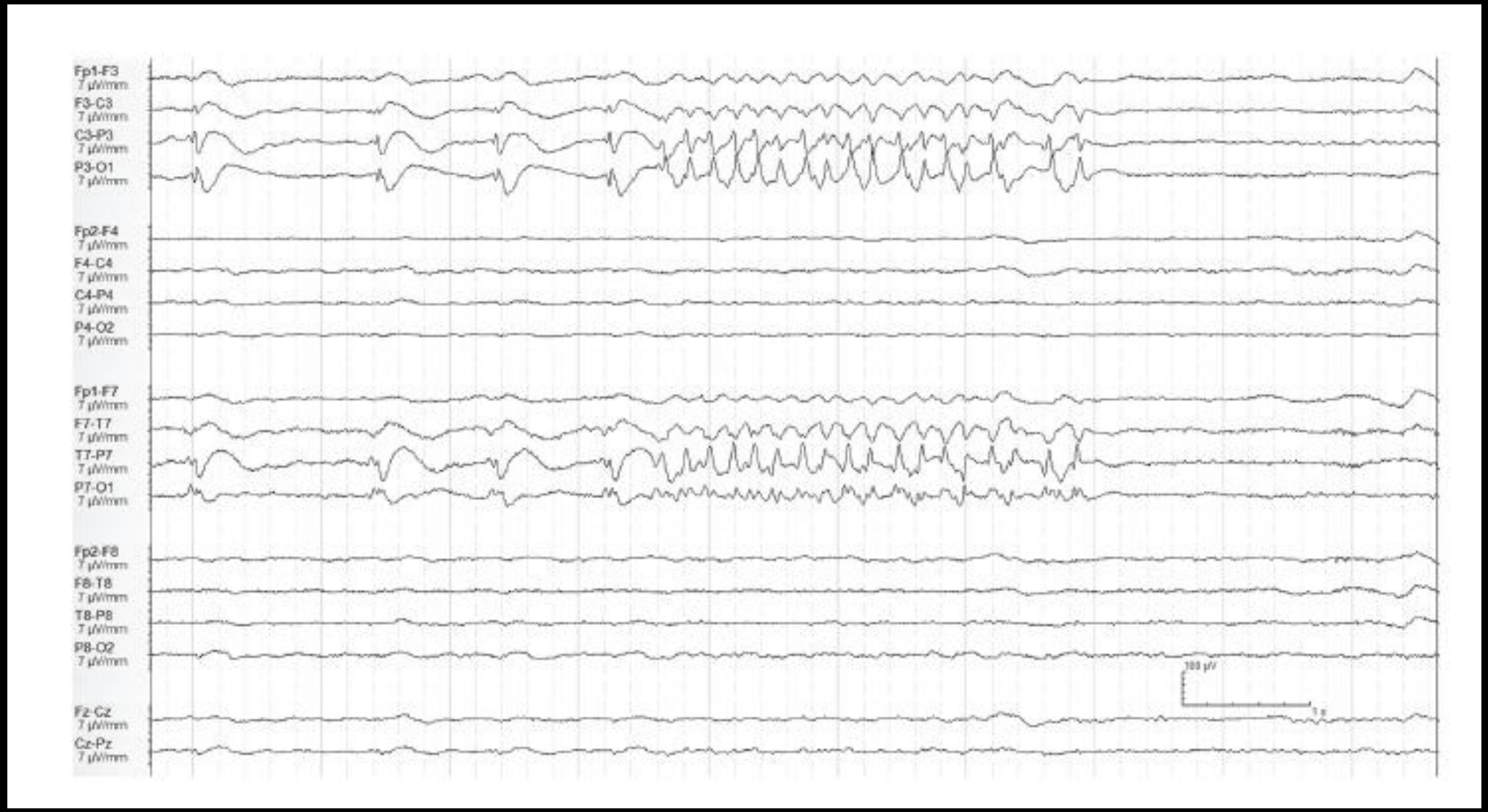
BIRDs



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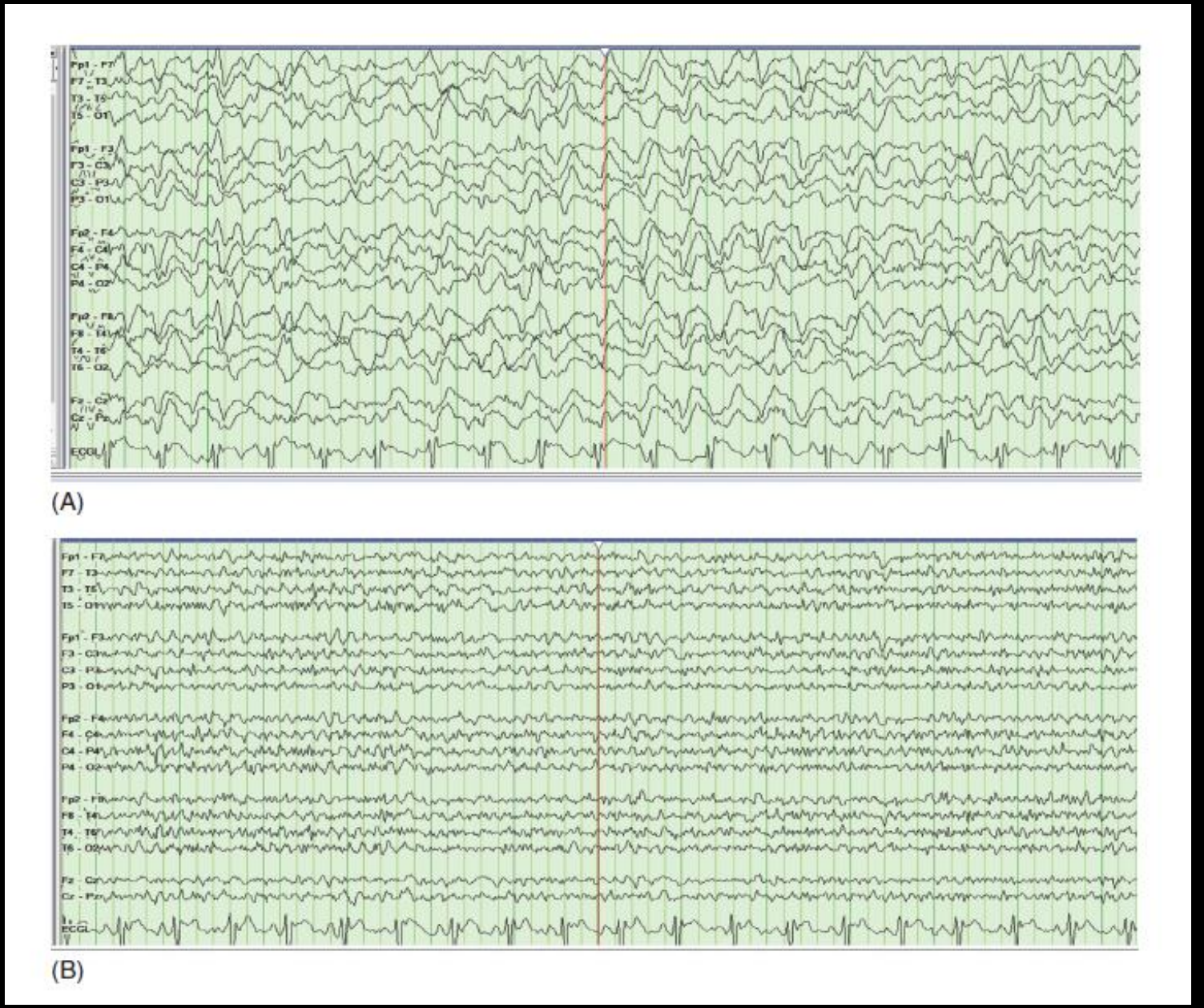
Ictal-interictal continuum (IIC)

- Suspicious of ictal activity, but do not meet criteria for an electrographic seizure.
- No specific pattern forms IIC (at times, may transition)
- GPDs
- LPDs
- GRDA
- LRDA
- Stimulus-induced rhythmic periodic or ictal discharges (SIRPIDs)

- With IIC:
  - Consideration for medication trial if: PDs+, PDs >2Hz in frequency
  - No treatment but monitor 24-48 Hrs if: GPDs
  - PDs without + <2 Hz in frequency.

IIC

- **IIC pattern secondary to anesthetic withdrawal.**



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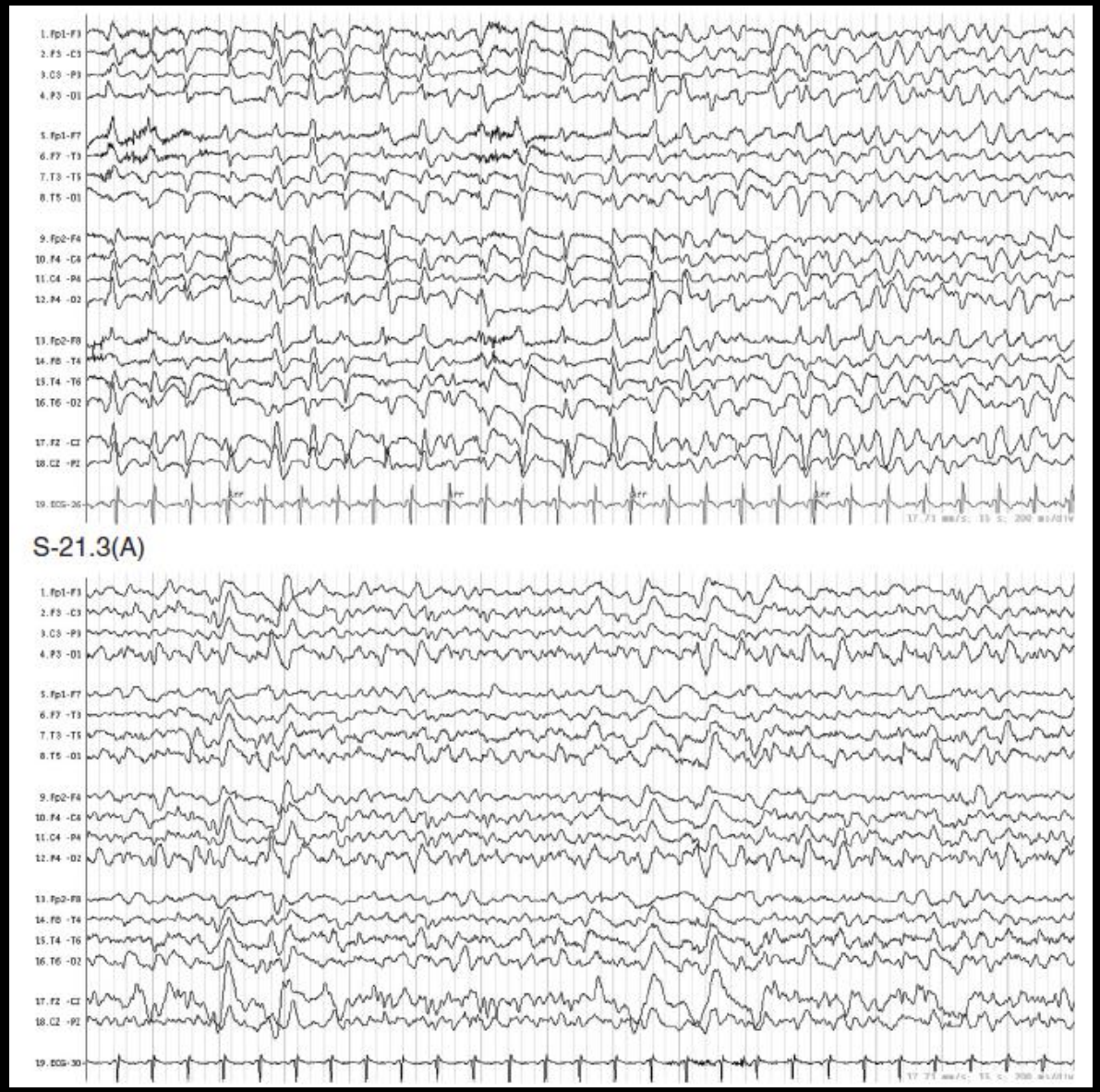
IIC

- GPDs TW



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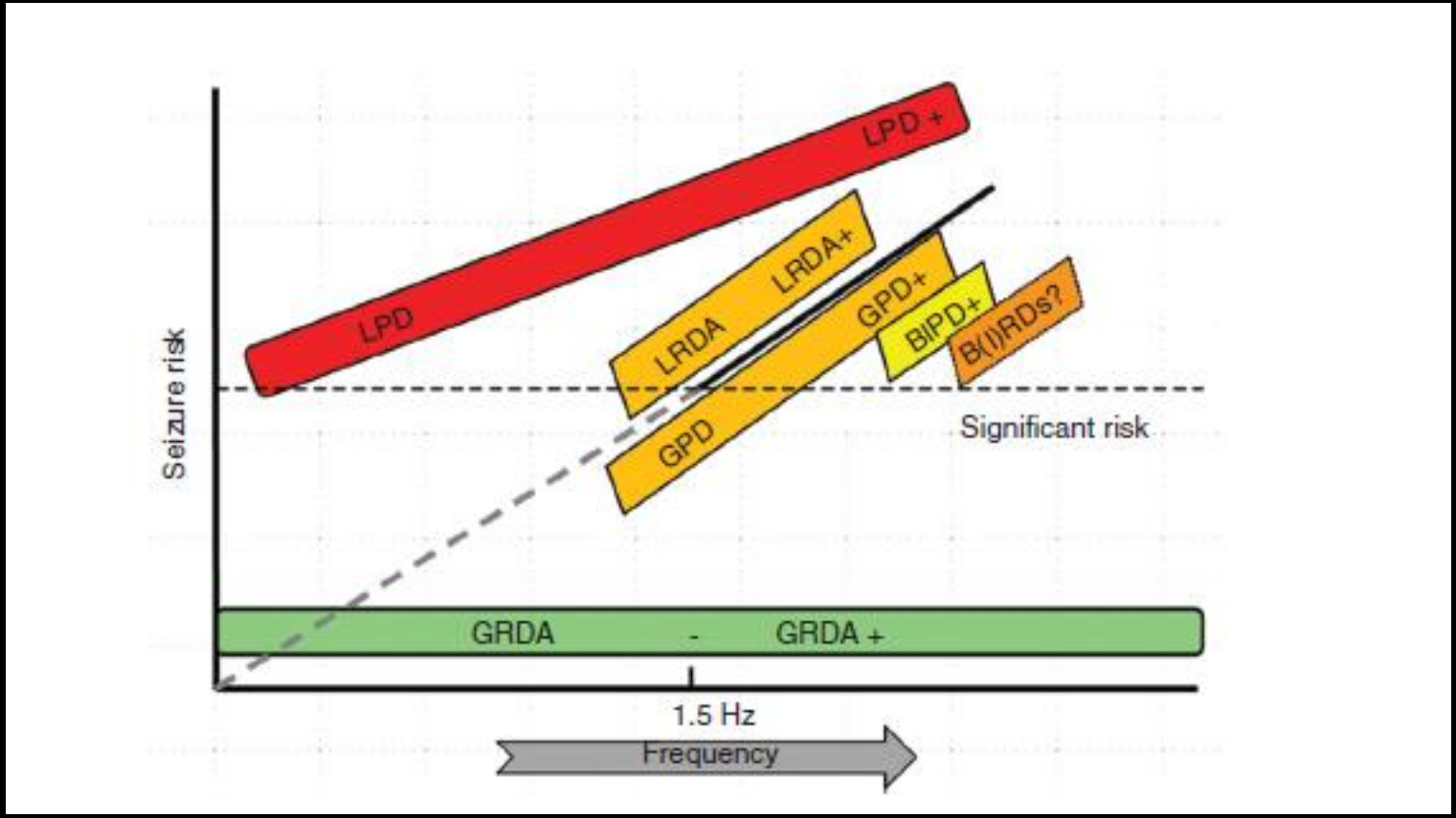
Risk for seizures with these patterns:



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Non convulsive status epilepticus:

- **High suspicion in** patients who just had a clinical seizures without signs of recovery after 20-30 mins.
- Also, in patients with acute brain injury (stroke, bleeds) with unexpected and unexplained decline in neuro exam. Impaired mentation with myoclonus or nystagmus, aphasia without structural lesion.

- NCSE has an estimated prevalence between 5% and 48% in comatose patients, and accounts for at least one third of all cases of SE.

- NCSE persists in around 20% of patients after cessation of clinical seizures
- Recurrent NCSE is common (first 24 hours) and when weaning off meds.

Non-convulsive seizures/SE

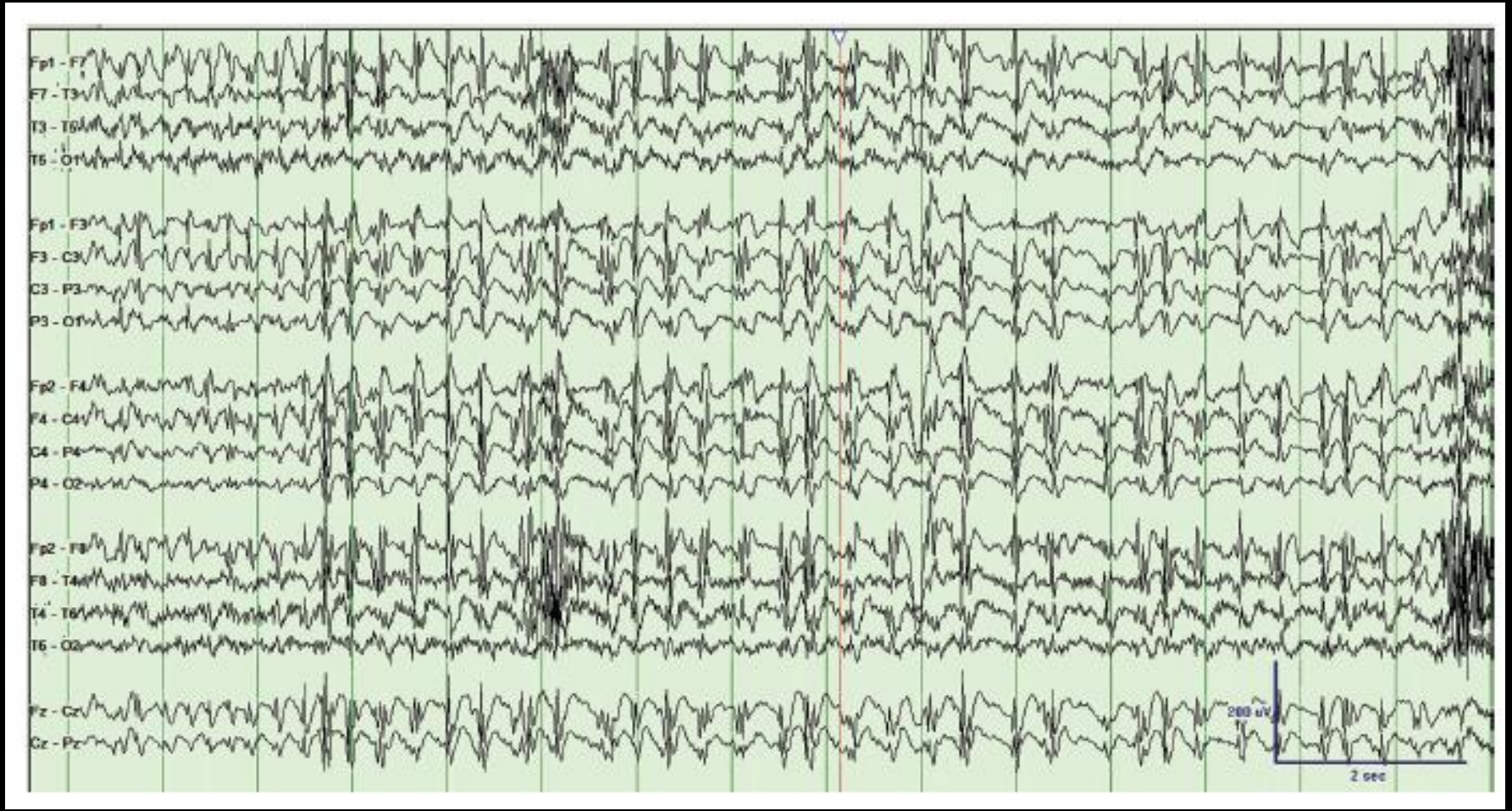
- Salzburg criteria in patients w/o known epileptic encephalopathy:
  - Epileptic discharges (EDs) at freq >2.5 Hz

  Or
  - EDs of ≤ 2.5 Hz (or rhythmic delta/theta activity >0.5), AND one of the following:
    - subtle clinical ictal manifestation time locked to the pattern
    - Typical spatiotemporal evolution
    - EEG and clinical improvement following anti-seizure drug use.

How long should we monitor with cEEG?

Typically, it’s appropriate to monitor for at least 24 hours in non comatose patients and 48 hours if coma existed, PDs or when tapering meds off.

Absence NCSE



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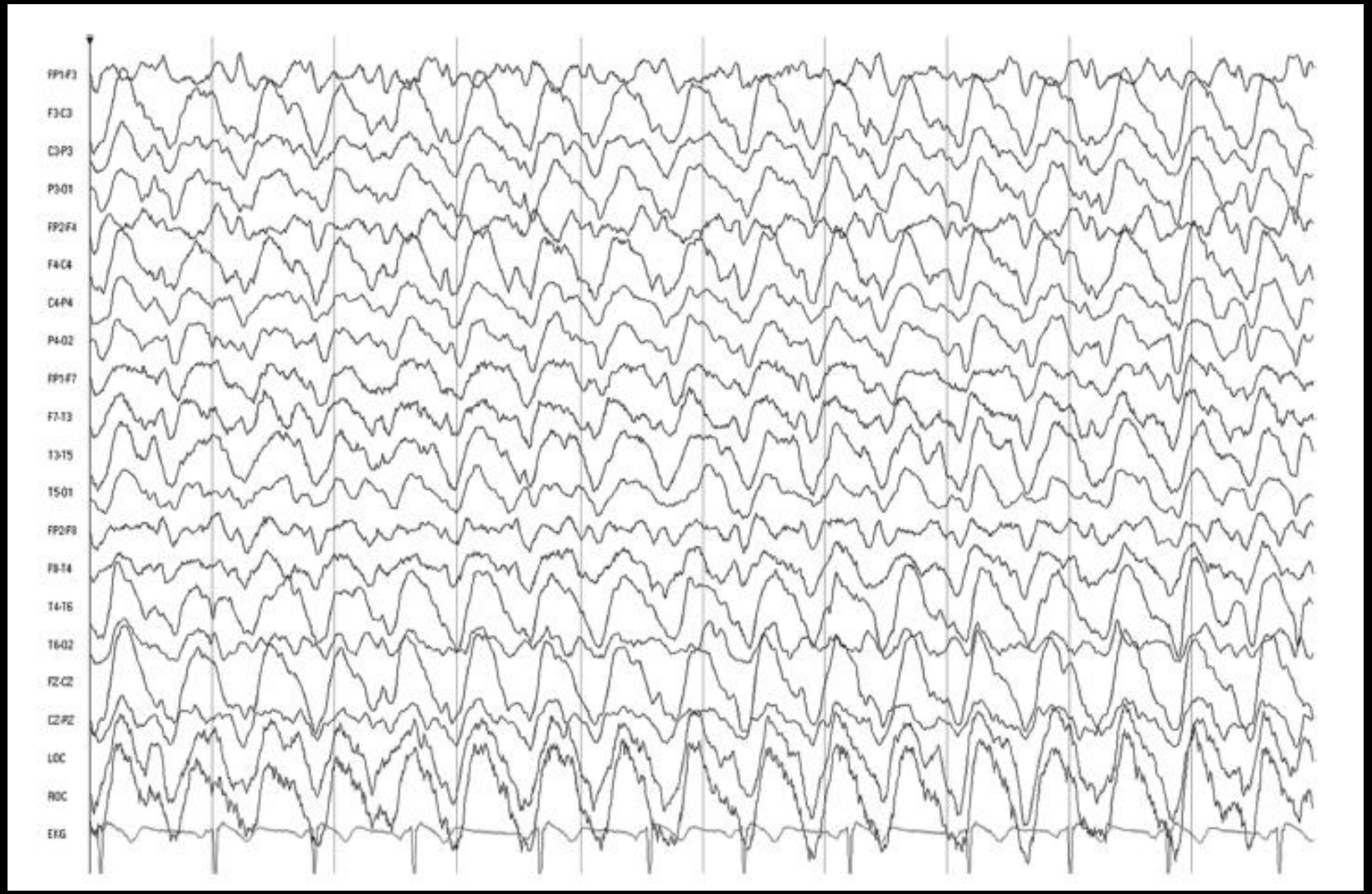
Secondarily generalized NCSE.



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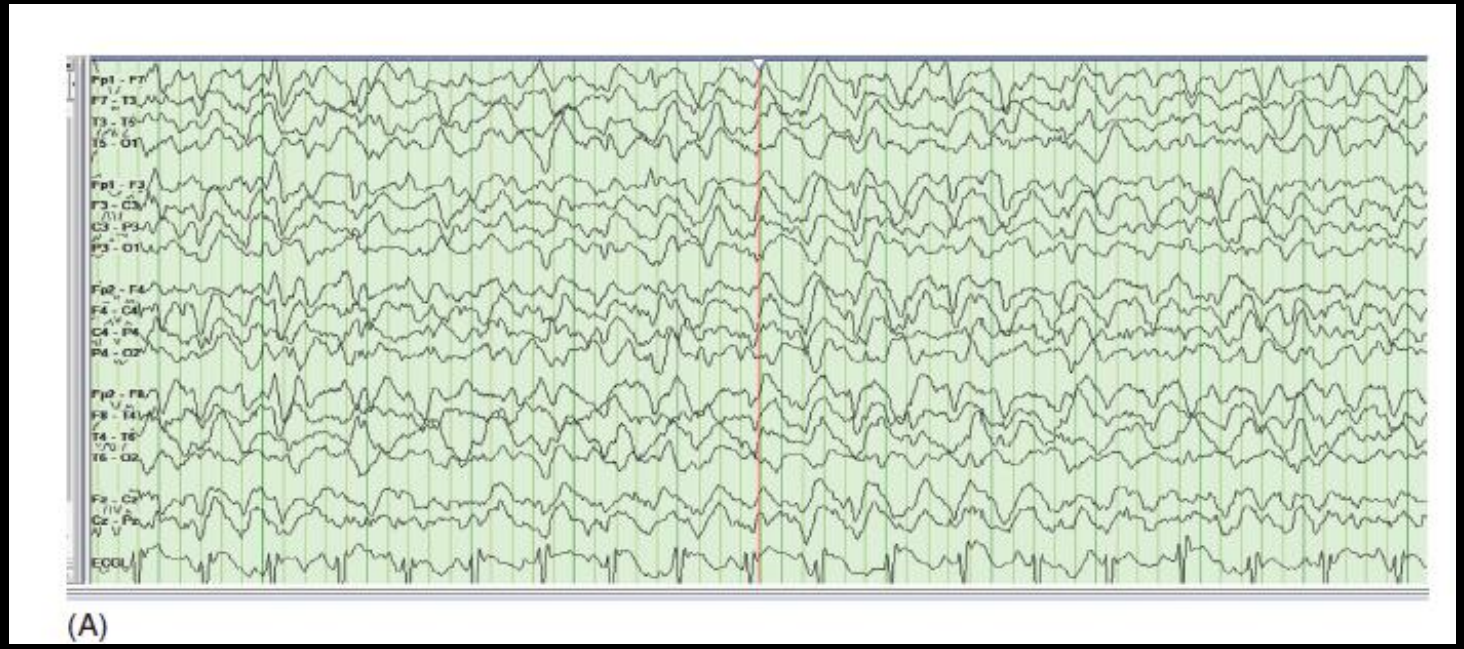
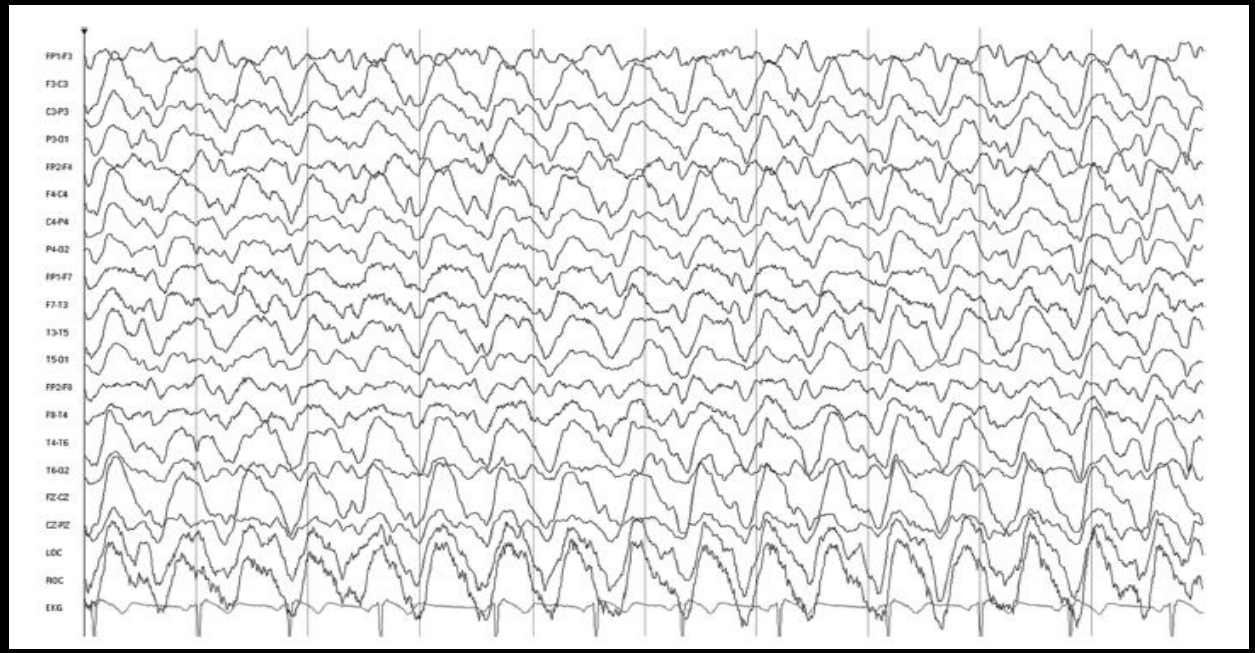

Fp1 - F7
F7 - T3
T3 - T5
T5 - O1
Fp1 - F3
F3 - C3
C3 - P3
P3 - O1
Fp2 - F4
F4 - C4
C4 - P4
P4 - O2
Fp2 - F8
F8 - T4
T4 - T6
T6 - O2
Fz - Cz
Cz - Pz
ECGL

(A)


FP1-F3
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C4-P4
P4-O2
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F7-T3
T3-T5
T5-O1
FP2-F8
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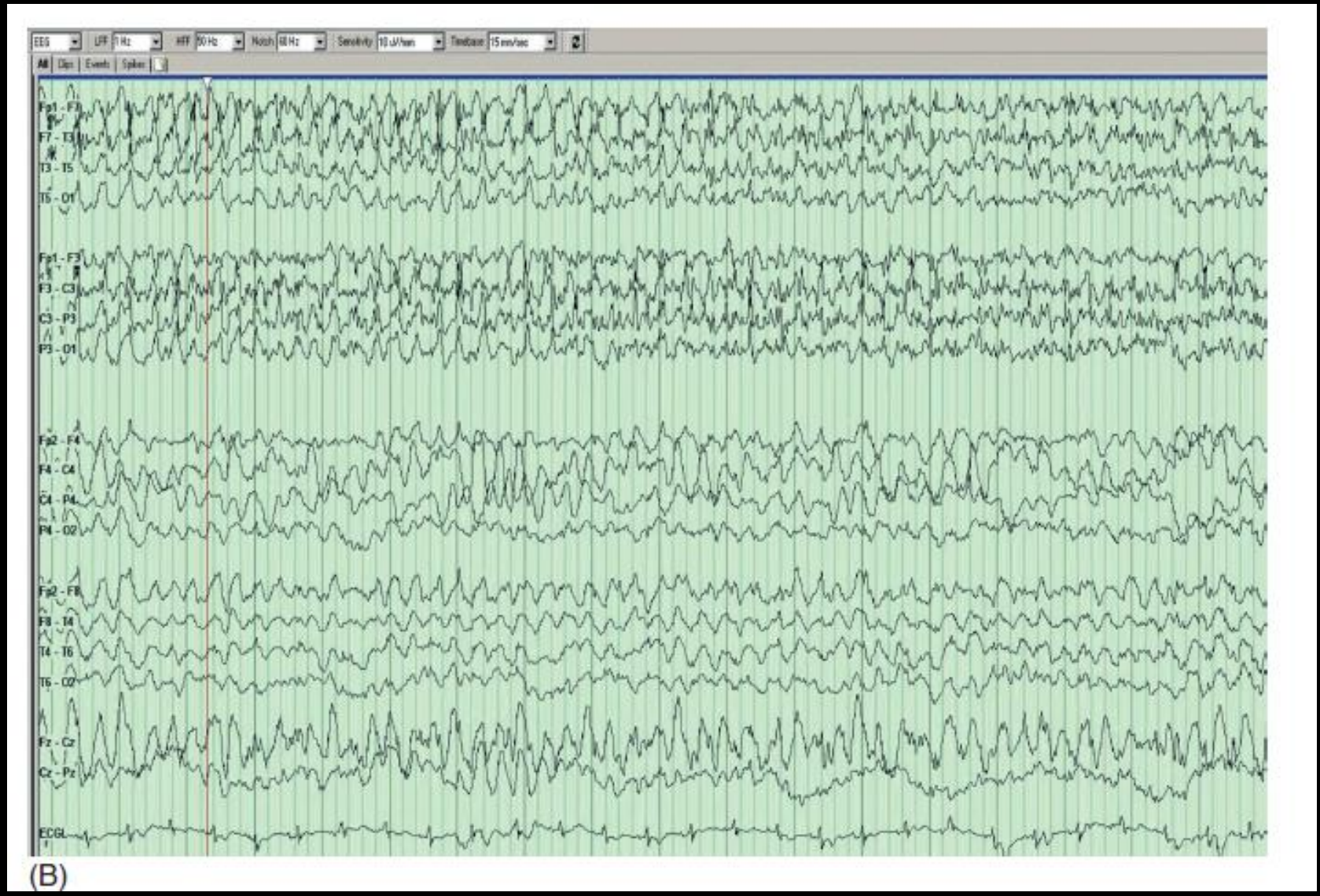
T4-T6
T6-O2
FZ-CZ
CZ-PZ
LOC
ROC
EKG

Focal NCSE (left)



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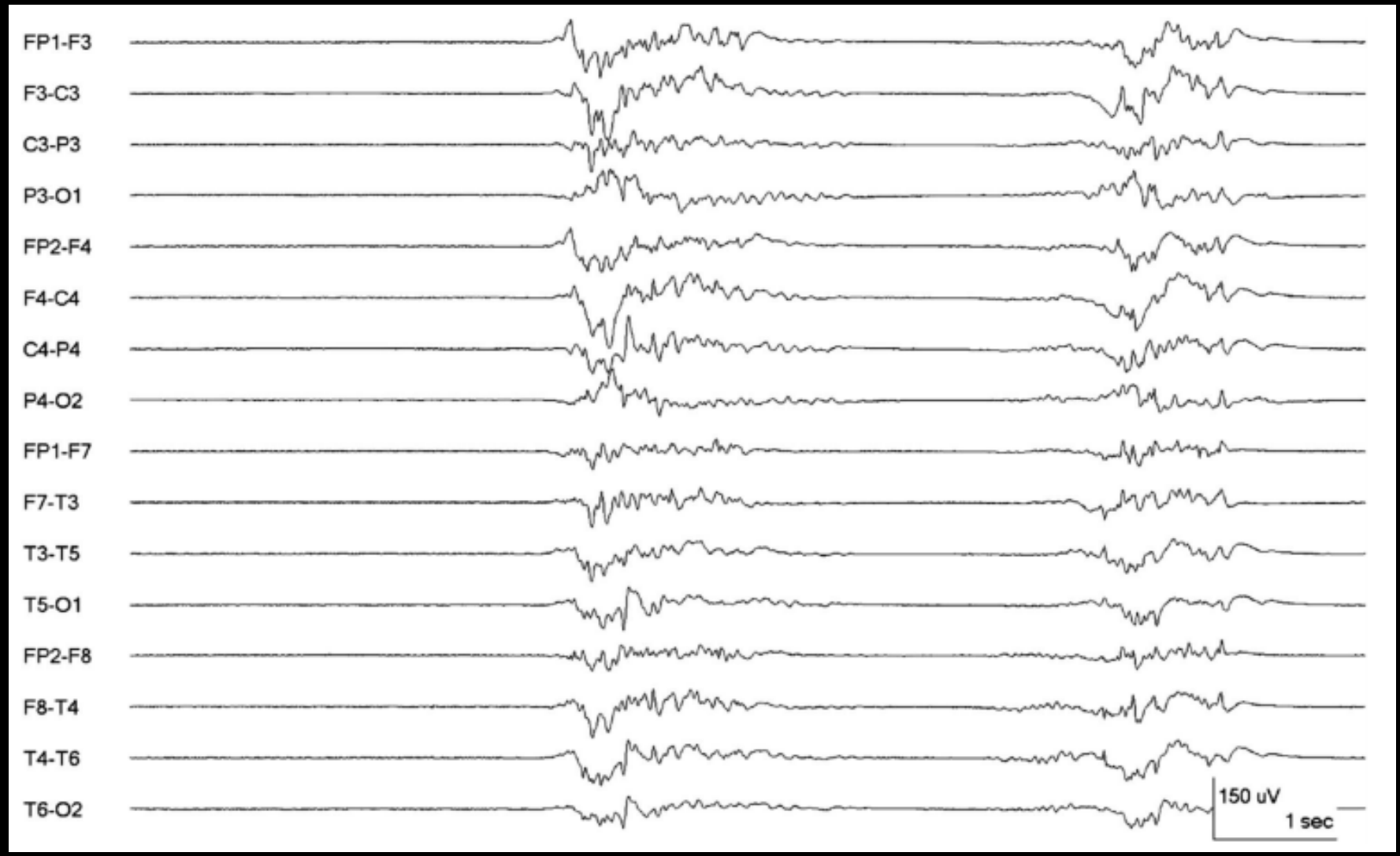
Postanoxic brain injury (encephalopathy)

- Low voltage patterns:
  - Suppression (<10 uV)
  - Attenuation (>10 uV but <50% of predominant background)
  - Low voltage (<20uV)
- Burst attenuation/suppression pattern w/o identical bursts:
  - Alternating pattern of heterogenous bursts and attenuation or suppression for at least 50% of the recording.

- Burst attenuation/suppression pattern w identical bursts:
  - Bursts appear identical in the initial 500 ms of each discharge
  - Abrupt tranision
  - More likely to occur in absence of sedation (carry poor prognosis).

- Other EEG pattern seen are : GPDs, GRDA+S, GSW (typical freq 0.5-2 Hz).
- Also, Bipds, less commonly LPDs.
- SIRPIDs (SIRPIDs are associated with poor outcome when occurring during hypothermia, but are more favorable when arising after rewarming).
- Sz and SE
- Alpha, theta and spindle coma.

B-S



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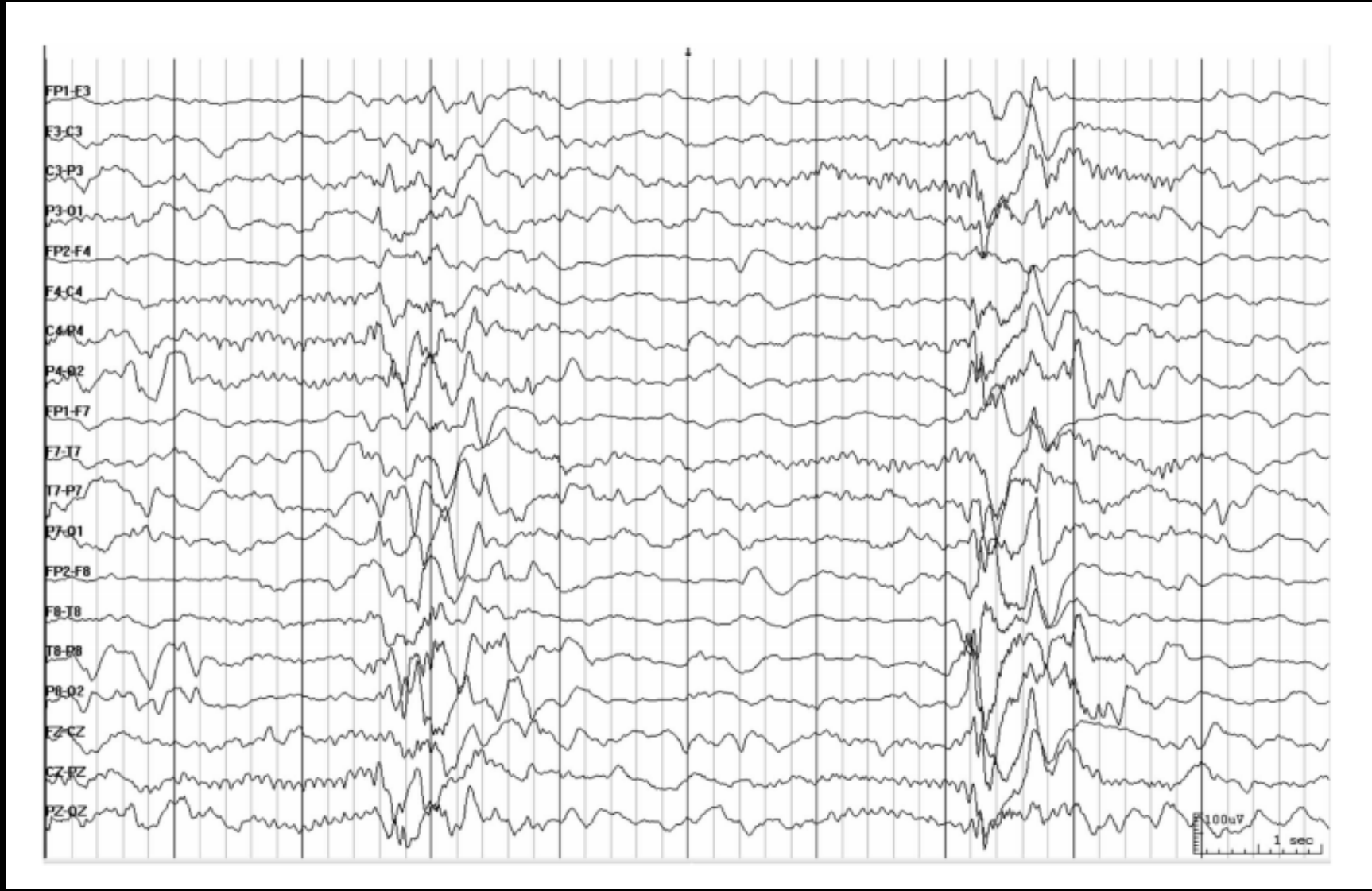
B-A



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ACNS Standardized Critical Care EEG Terminology

Table of major and minor changes between the 2012 and 2021 versions

Major changes

EEG background

- *"Variability"* and "*Stage II sleep transients (K-complexes and spindles)"* now combined under "*State changes"*.
- Cyclic Alternating Pattern of Encephalopathy (CAPE) *(new term: Section A7)*
- Identical bursts *(new term: Section A4d)*

Rhythmic and Periodic Patterns (RPPs: PDs, RDA and SW)

- Unilateral Independent (UI) *(new Main Term 1 option: Section C1d)*
- Frequency
  - For PDs and SW, typical frequencies >2.5 Hz can only be applied to RPPs <10 s duration ("very brief" by definition); if PDs or SW have a typical frequency >2.5 Hz and are ≥10 s these would qualify as electrographic seizures (criterion A) and should be referred to as such rather than as PDs or SW.
  - No RPP in this terminology can have a typical frequency of >4 Hz; if a pattern is >4 Hz and ≥0.5 s, it would always meet criteria for either BIRDs (if <10 s) or an electrographic seizure (if ≥10 s) (see definitions below). If <0.5 s, this would not qualify as any RPP, but might qualify as a polyspike.
- Evolution
  - Evolution of an RPP is now limited to patterns that are ≤4 Hz AND <10 s duration. Any >4-Hz RPP with evolution lasting <10 s would qualify as a definite BIRD (see Section E). Any RPP with evolution lasting ≥10 s meets criterion B of an electrographic seizure and should be coded as such.
- Extreme Delta Brush (EDB) *(new term: Section C3i)*
- Stimulus-Terminated *(new modifier)*

Electrographic and Electroclinical Seizure Activity

- Electrographic seizure (ESz) *(new term: Section D1)*

- Electrographic *status epilepticus* (ESE) *(new term: Section D2)*
- Electroclinical seizure (ECSz) *(new term: Section D3)*
- Electroclinical *status epilepticus* (ECSE) (*new term: Section D4)*
- *Possible* electroclinical status epilepticus *(new term: Section D4b)*

Brief Potentially Ictal Rhythmic Discharges (BIRDs) (new term: Section E)

Ictal-Interictal Continuum (IIC) (new term: Section F)

Minor Changes

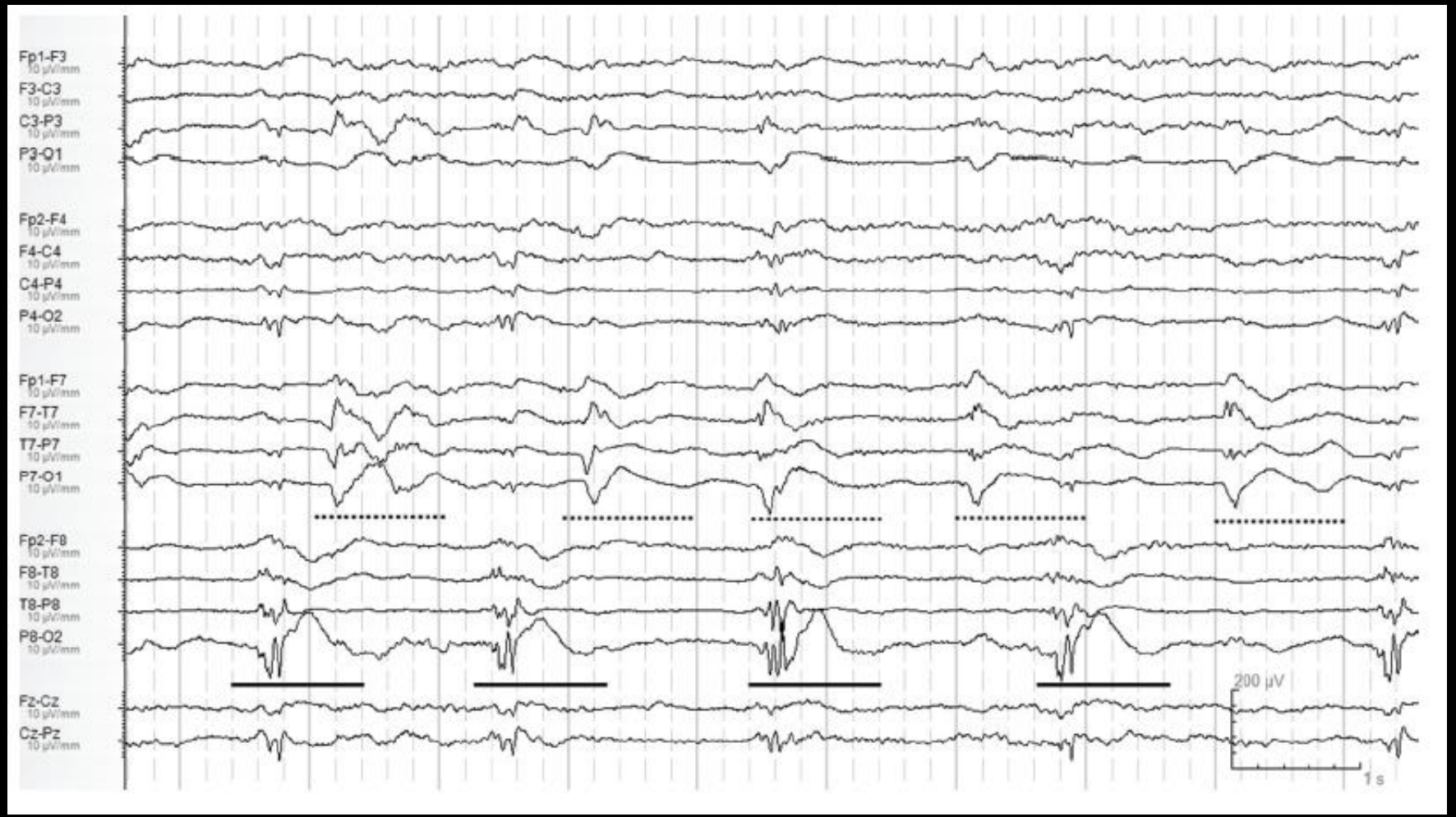
EEG background

- Continuity
  - Nearly continuous changed from ≤10% to 1-9% attenuation/suppression
  - Burst suppression changed from >50% attenuation/suppression to 50-99%
  - Suppression/attenuation changed from entirety to >99% of the record
- Highly Epileptiform Bursts
  - Previously: present if multiple epileptiform discharges are seen within the majority (>50%) of bursts and occur at an average of 1/s or faster OR if a rhythmic, potentially ictal-appearing pattern occurs at 1/s or faster within the majority (>50%) of bursts.
  - Updated to: present *if 2 or more* epileptiform discharges (spikes or sharp waves) are seen within the majority (>50%) of bursts and occur at an average of 1 Hz or faster *within a single burst (frequency is calculated as the inverse of the typical interpeak latency of consecutive epileptiform discharges within a single burst)* OR if a rhythmic, potentially ictal-appearing pattern occurs at 1/s or faster within the majority (>50%) of bursts.

Rhythmic and Periodic Patterns

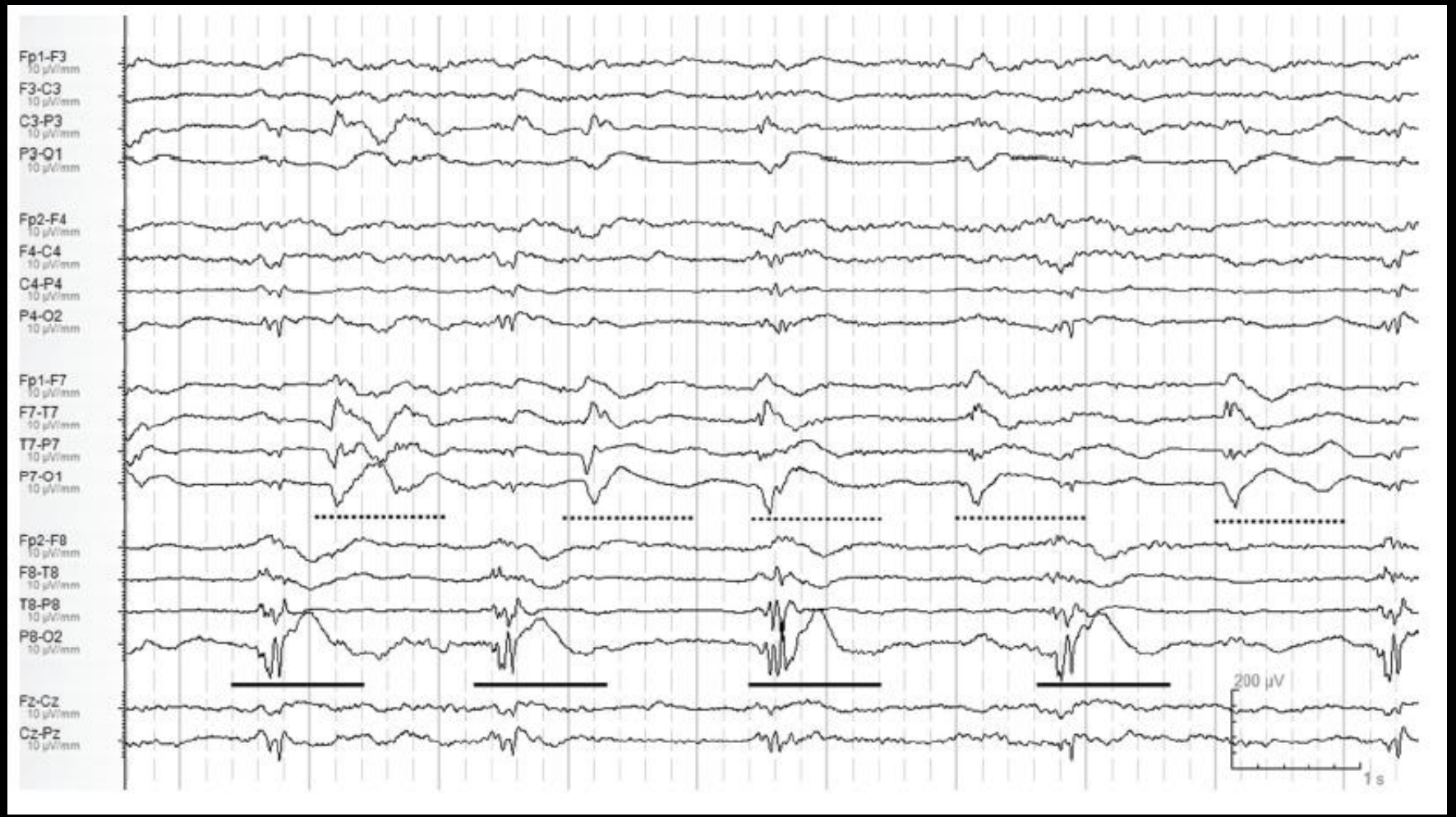
- Duration:
  - Intermediate duration changed from 1-4.9 mins to 1-9.9 mins (to match the definition of focal status epilepticus with impaired consciousness by the International League Against Epilepsy).[15]
  - Long duration accordingly changed from 5-59 mins to 10-59 mins
- Absolute voltage (amplitude)
  - Medium, changed from 50-199 μV to 50-149 μV
  - High accordingly changed from ≥200 μV to ≥150 μV
- Polarity changed from major modifier to minor modifier

What is the pattern?



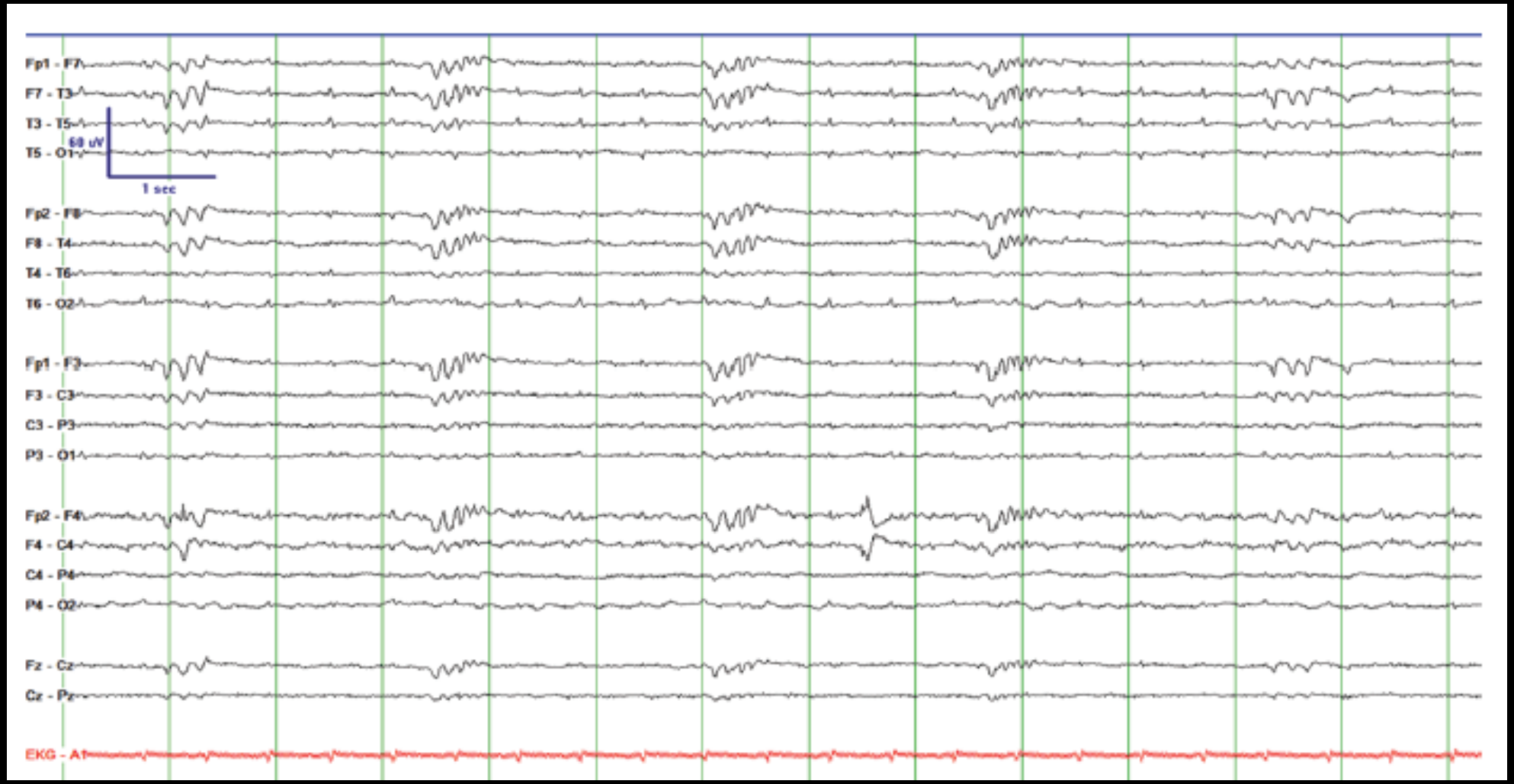
Handbook of ICU EEG Monitoring, edited by Suzette M. LaRoche, and Hiba Arif Haider, Springer Publishing Company, 2018.

BiPDs



Handbook of ICU EEG Monitoring, edited by Suzette M. LaRoche, and Hiba Arif Haider, Springer Publishing Company, 2018.

What is the pattern?



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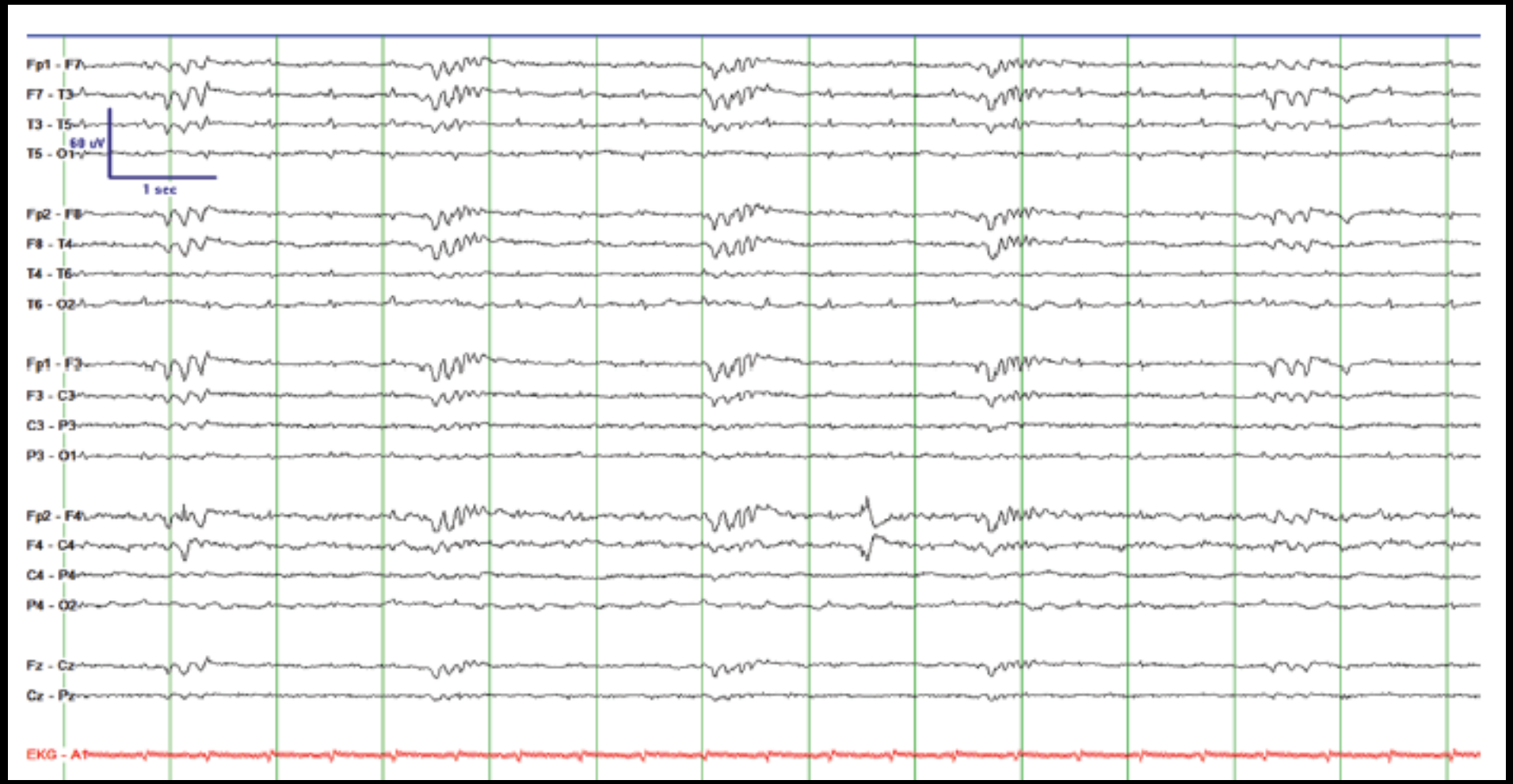
Ventilator artifact (water in the tube)



Schmitt, 2018

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Artifacts

- By definition artifacts on EEG are not due to a brain activity ! But sometimes, it is really hard to tell.
- ICU environment is one of the worst enemies of EEG machines, techs, and readers because of:
  - Many electrical devices, a lot of noise
  - Patient movements are common
  - Prolonged EEGs → skin breakdown
  - Lab draws, suctioning, cleaning …

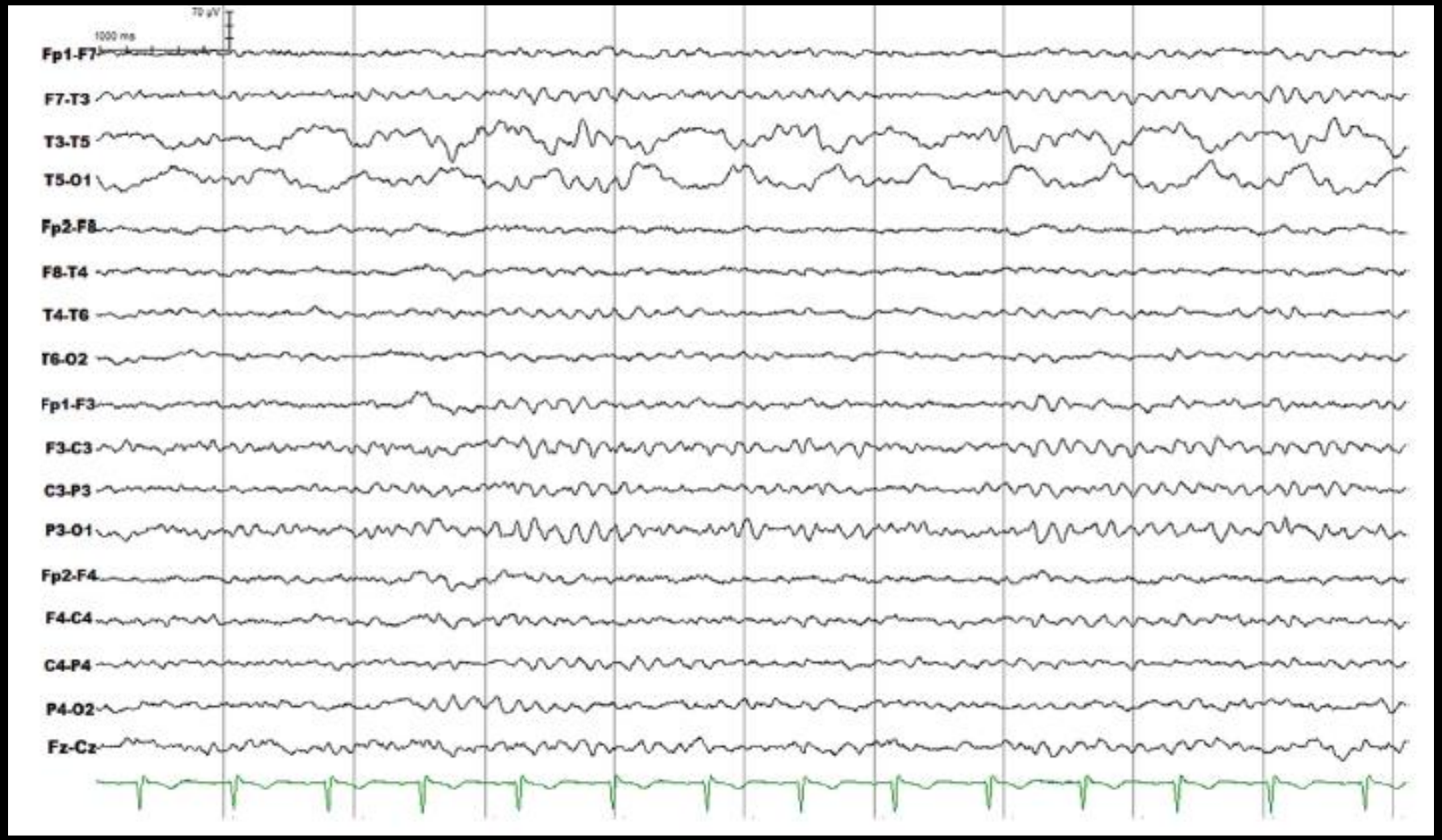
Schmitt, 2018
Meriläinen M, Kyngäs H, Ala-Kokko et al, 2010

Handbook of ICU EEG Monitoring, edited by Suzette M. LaRoche, and Hiba Arif Haider, Springer Publishing Company, 2018.

- Examples of physiologic artifacts:
  - Eye movements: more prominent frontal leads (blinks, flutter, lateral rectus muscle spikes)
  - EKG artifact, usually most prominent in A1, A2. short and wide necks.
  - Pacemaker artifacts
  - Pulse artifact: rhythmic, slow, 200-300 msec after QRS, it goes away if you moved EKG lead.
  - Ballistocardiographic artifact.
  - Of course, EMG artifact

- Non-physiologic artifacts:
  - AC current 60 Hz artifact
  - Electrode artifact
  - Instrumental artifact (moving input cable, static electricity)
  - Environmental (vents, bed percussions, ECMo, LVAD, …)

Pulse artifact:



Schmitt, 2018

Handbook of ICU EEG Monitoring, edited by Suzette M. LaRoche, and Hiba Arif Haider, Springer Publishing Company, 2018.

Summary:

- Periodic and rhythmic patterns are very common patterns seen on EEGs, particularly in critically ill patients.
- Recognizing these patterns as first liners and being able to identify the ones with high risk for seizures is crucial.
- Status epilepticus is a neurological emergency, and earlier treatment usually carries better outcome.

Thank you for listening !!

MUSC Health
Medical University of South Carolina

Questions?