

Virtual  
**EEG**  
course  
2022

18<sup>TH</sup> SEPTEMBER



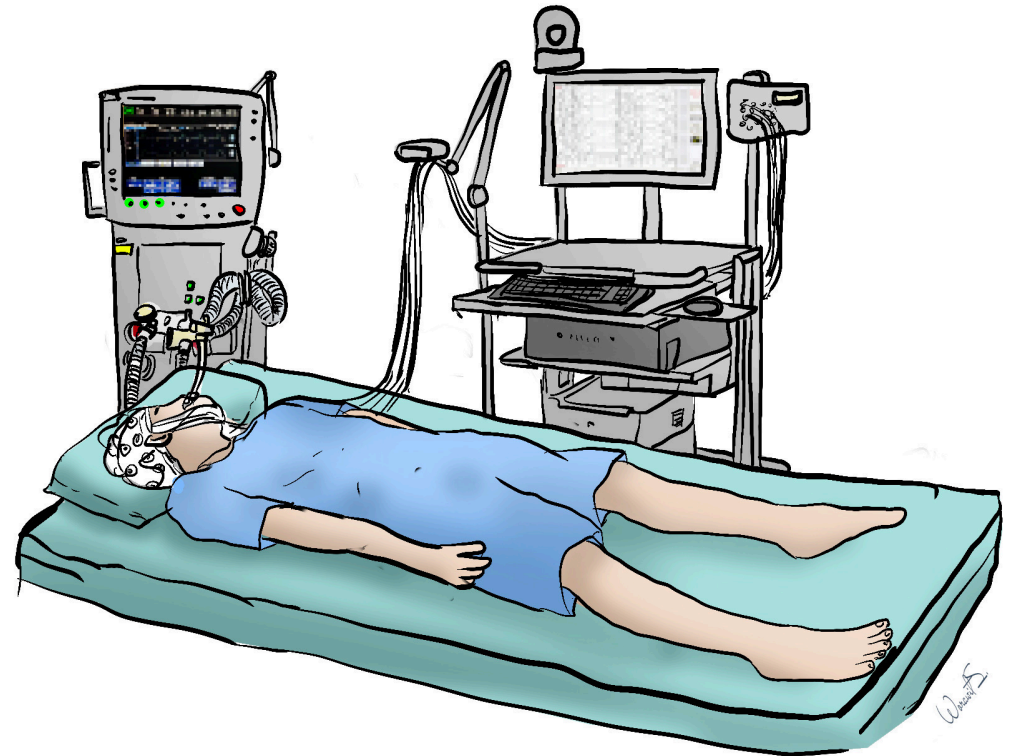
สมาคมโรคลมชักแห่งประเทศไทย

# EEG patterns in encephalopathy and coma

**Assistant Professor. Apisit Boongird**

**Division of Neurology**

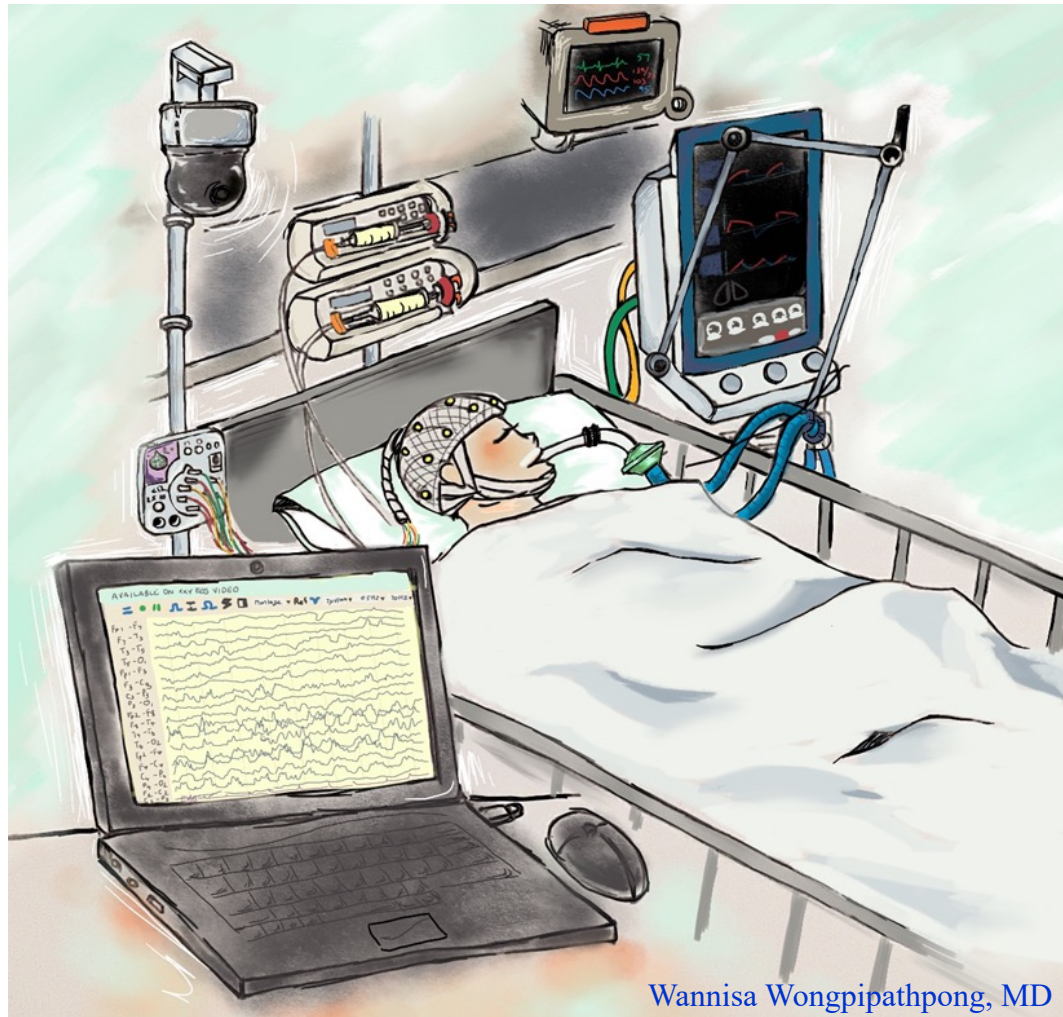
**Ramathibodi Hospital**



# Objectives

- EEG patterns in encephalopathy
- EEG patterns in coma
- Cases

# Consensus Statement on Critical Care Continuous EEG (CCEEG)



Wannisa Wongpipathpong, MD

## Recommendations for CCEEG

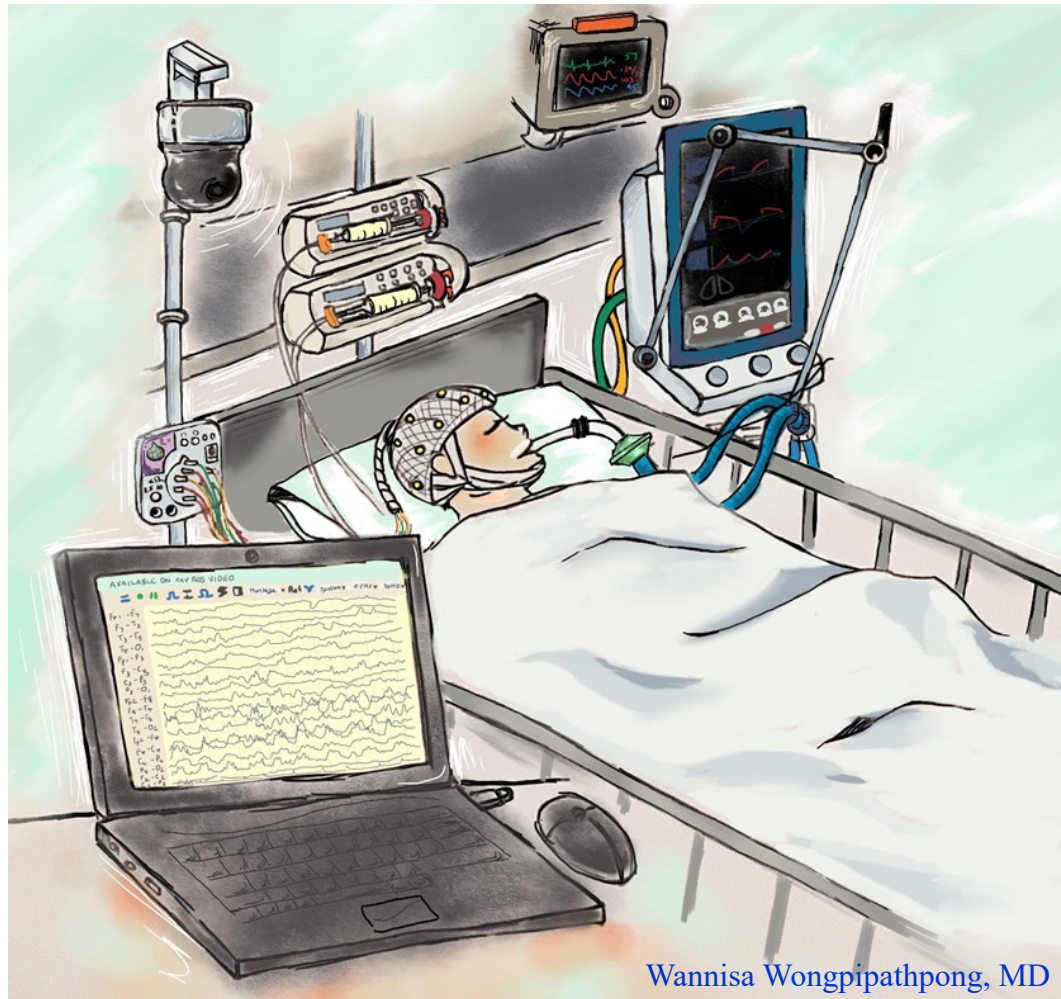
Diagnosis of nonconvulsive seizures

Diagnosis of nonconvulsive status epilepticus

Paroxysmal events

Assessment of the efficacy of therapy for seizures and status epilepticus

# Consensus Statement on Critical Care Continuous EEG (CCEEG)



Wannisa Wongpipathpong, MD

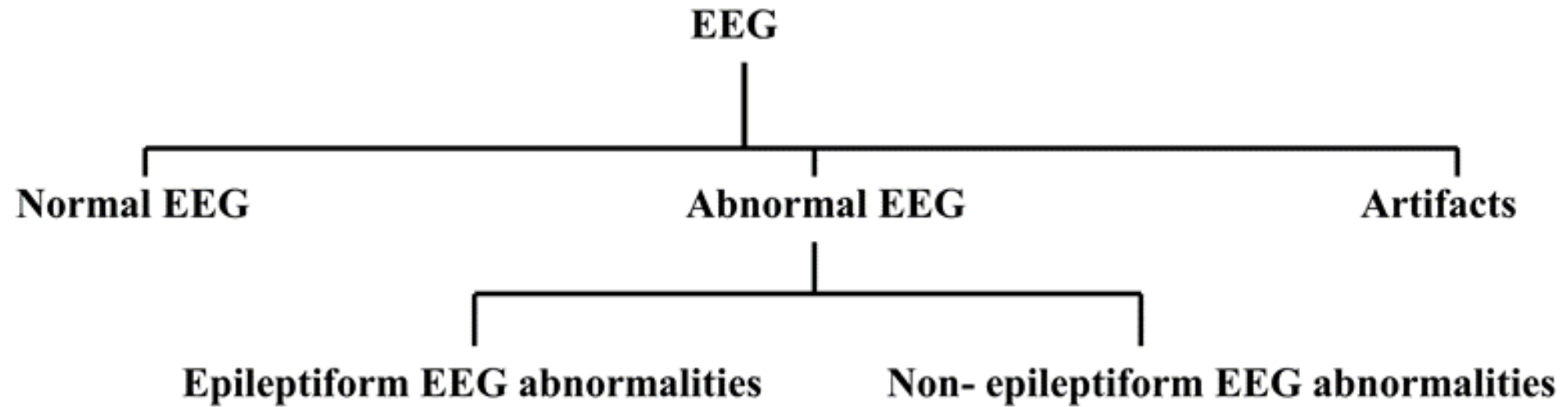
## Suggestions for CCEEG

Identification of ischemia in patients at high risk for cerebral ischemia

Assessment of level of consciousness in patients receiving intravenous sedation or pharmacologically induced coma

Prognostication in patients after cardiac arrest

# Reading the EEG



# Reading the EEG

- EEG background
- Reactivity
- Abnormal EEG patterns
  - epileptiform abnormality vs non- epileptiform EEG abnormality

# ACNS Standardized Critical Care EEG Terminology 2021

# ACNS Standardized Critical Care EEG Terminology 2021: Reference Chart

A. EEG Background									
Symmetry	Background EEG frequency	PDR	Continuity	Reactivity	State Changes	Cyclic Alternating Pattern of Encephalopathy (CAPE)	Voltage	AP Gradient	Breach effect
Symmetric	Beta	Present Specify frequency	Continuous: <1% periods of suppression (<10 μV) or attenuation (≥10 μV but <50% of background voltage)	Reactive	Present with normal stage N2 sleep transients	Present	High ≥150 μV	Present	Present
Mild asymmetry <50% Voltage OR 0.5-1 Hz Frequency	Alpha	Absent	Nearly continuous: 1-9% periods of suppression or attenuation	Unreactive	Present but with abnormal stage N2 sleep transients	Absent	Normal ≥20 to <150 μV	Absent	Absent
Marked asymmetry ≥50% Voltage OR >1 Hz Frequency	Theta	Unclear							
	Delta		Discontinuous: 10-49% periods of suppression or attenuation	Unclear	Absent	Unknown/unclear	Low 10 to <20 μV	Reverse	Unclear
			Burst-suppression or Burst-attenuation: 50-99% periods of suppression or attenuation	Unknown			Suppressed <10 μV		
			Suppression: >99% periods of suppression or attenuation						

Localization of Bursts (G/ L/ BI/ UI/ Mf)	If Burst-suppression or Burst-attenuation then specify if:
Highly Epileptiform Bursts (Present or Absent)	←
Identical Bursts (Present or Absent)	

## B. Sporadic Epileptiform Discharges

Prevalence
Abundant ≥1/10s
Frequent ≥1/min but <1/10s
Occasional ≥1/h but <1/min
Rare <1/h

## C. Rhythmic and Periodic Patterns (RPPs)

Main term 1	Main term 2
<b>G</b> <i>Generalized</i> - Optional: Specify frontally, occipitally, or midline predominant; or generalized, not otherwise specified.	<b>PD</b> <i>Periodic Discharges</i>
<b>L</b> <i>Lateralized</i> - Optional: Specify unilateral, bilateral asymmetric, or bilateral asynchronous - Optional: Specify lobe(s) most involved or hemispheric.	<b>RDA</b> <i>Rhythmic Delta Activity</i>
<b>BI</b> <i>Bilateral Independent</i> - Optional: Specify symmetric or asymmetric - Optional: Specify lobe(s) most involved or hemispheric.	<b>SW</b> <i>Spike and Wave</i> OR <i>Polyspike and Wave</i> OR <i>Sharp and Wave</i>
<b>UI</b> <i>Unilateral Independent</i> - Optional: Specify unilateral, bilateral asymmetric, or bilateral asynchronous for each pattern - Optional: Specify lobe(s) most involved	
<b>Mf</b> <i>Multifocal</i> - Optional: Specify symmetric or asymmetric - Optional: Specify lobe(s) most involved or hemispheric	

Major modifiers								Minor modifiers				
Prevalence	Duration	Frequency	Phases <sup>1</sup>	Sharpness <sup>2</sup>	Voltage (Absolute) <sup>3</sup>	Voltage (Relative) <sup>3</sup>	Stimulus Induced or Stimulus Terminated	Evolution <sup>4</sup>	Onset	Triphasic <sup>5</sup>	Lag	Polarity <sup>2</sup>
Continuous ≥90%	Very long ≥1 h	4 Hz	>3	Spiky <70 ms	High ≥150 μV	>2	SI Stimulus Induced	Evolving	Sudden ≤3 s	Yes	A-P Anterior-Posterior	Negative
		3.5 Hz					ST Stimulus Terminated					
Abundant 50-89%	Long 10-59 min	3 Hz	3	Sharp 70-200 ms	Medium 50-149 μV	≤2	Spontaneous only	Fluctuating	Gradual >3 s	No	P-A Posterior-Anterior	Positive
		2.5 Hz					Static					
Frequent 10-49%	Intermediate duration 1-9.9 min	2 Hz	1	Sharply contoured >200 ms	Low 20-49 μV		Unknown	Static			No	Unclear
		1.5 Hz										
Occasional 1-9%	Brief 10-59 s	1 Hz		Blunt >200 ms	Very low <20 μV							
		0.5 Hz										
Rare <1%	Very brief <10 s	<0.5 Hz										

Plus (+) Modifiers
No +
+F <i>Superimposed fast activity – applies to PD or RDA only</i>
EDB ( <i>Extreme Delta Brush</i> ): A specific subtype of +F
+R <i>Superimposed rhythmic activity – applies to PD only</i>
+S <i>Superimposed sharp waves or spikes, or sharply contoured – applies to RDA only</i>
+FR <i>If both subtypes apply – applies to PD only</i>
+FS <i>If both subtypes apply – applies to RDA only</i>

NOTE 1: Phases: Applies to PD and SW only, including the slow wave of the SW complex  
 NOTE 2: Sharpness and Polarity: Applies to the predominant phase of PD and the spike or sharp component of SW only  
 NOTE 3: Relative voltage: Applies to PD only  
 NOTE 4: Evolution: Refers to frequency, location or morphology  
 NOTE 5: Triphasic: Applies to PD or SW only

## D. Electrographic and Electroclinical Seizures

Electrographic Seizure (ESz)	Electroclinical Seizure (ECSz)
Either: A) Epileptiform discharges averaging >2.5 Hz for ≥10 s (>25 discharges in 10 s), OR B) Any pattern with definite evolution and lasting ≥10 s	Any EEG pattern with either: A) Definite clinical correlate time-locked to the pattern (of any duration), OR B) EEG <i>and</i> clinical improvement with a parenteral (typically IV) anti-seizure medication

Electrographic Status Epilepticus (ESE)	Electroclinical Status Epilepticus (ECSE)
An electrographic seizure for either: A) ≥10 continuous minutes, OR B) A total duration of ≥20% of any 60-minute period of recording.	An electroclinical seizure for either: A) ≥10 continuous minutes, OR B) A total duration of ≥20% of any 60-minute period of recording, OR C) ≥5 continuous minutes if the seizure is convulsive (i.e., with bilateral tonic-clonic motor activity). Possible ECSE: An RPP that qualifies for the IIC (below) that is present for ≥10 continuous minutes or for a total duration of ≥20% of any 60-minute period of recording, which shows EEG improvement with a parenteral anti-seizure medication <i>BUT</i> without clinical improvement.

E. Brief Potentially Ictal Rhythmic Discharges (BIRDs)	F. Ictal-Interictal Continuum (IIC)
Focal (including L, BI, UI or Mf) or generalized rhythmic activity >4 Hz (at least 5 waves at a regular rate) lasting ≥0.5 to <10 s, not consistent with a known normal pattern or benign variant, not part of burst-suppression or burst-attenuation, without definite clinical correlate, and that has at least one of A, B or C below: <b>Definite BIRDs</b> feature either: A. Evolution ("evolving BIRDs") OR B. Similar morphology and location as interictal epileptiform discharges or seizures in the same patient <b>Possible BIRDs</b> are C. Sharply contoured but without (a) or (b) above	1. Any PD or SW pattern that averages >1.0 Hz but <2.5 Hz over 10 s (>10 but ≤25 discharges in 10 s); OR 2. Any PD or SW pattern that averages ≥0.5 Hz and ≤1 Hz over 10 s (≥5 and ≤10 discharges in 10 s), and has a plus modifier or fluctuation; OR 3. Any lateralized RDA averaging >1 Hz for at least 10 s (at least 10 waves in 10 s) with a plus modifier or fluctuation; AND 4. Does not qualify as an ESz or ESE.



# **A. EEG background**

## A. EEG Background

A. EEG Background									
Symmetry	Background EEG frequency	PDR	Continuity	Reactivity	State Changes	Cyclic Alternating Pattern of Encephalopathy (CAPE)	Voltage	AP Gradient	Breach effect
<b>Symmetric</b>  <b>Mild asymmetry</b> <50% Voltage OR 0.5-1 Hz Frequency  <b>Marked asymmetry</b> ≥50% Voltage OR >1 Hz Frequency	<b>Beta</b>	<b>Present</b> Specify frequency	<b>Continuous:</b> <1% periods of <b>suppression</b> (<10 μV) or <b>attenuation</b> (≥10μV but <50% of background voltage)	<b>Reactive</b>	Present with normal stage N2 sleep transients	<b>Present</b>	<b>High</b> ≥150 μV	<b>Present</b>	<b>Present</b>
	<b>Alpha</b>	<b>Absent</b>		<b>Nearly continuous:</b> 1-9% periods of <b>suppression attenuation</b>	<b>Unreactive</b>	Present but with abnormal stage N2 sleep transients	<b>Absent</b>	<b>Normal</b> ≥20 to <150 μV	<b>Absent</b>
	<b>Theta</b>	<b>Unclear</b>	<b>SIRPIDs only</b>		Present but without stage N2 sleep transients	<b>Unknown/unclear</b>	<b>Low</b> 10 to <20 μV	<b>Reverse</b>	<b>Unclear</b>
	<b>Delta</b>		<b>Unclear</b>		<b>Unclear</b>	<b>Absent</b>		<b>Suppressed</b> <10 μV	
			<b>Discontinuous:</b> 10-49% periods of <b>suppression or attenuation</b>	<b>Unknown</b>					
			<b>Burst-suppression or Burst-attenuation:</b> 50-99% periods of <b>suppression or attenuation</b>						
			<b>Suppression:</b> >99% periods of <b>suppression or attenuation</b>						

<b>Localization of Bursts</b> (G/ L/ BI/ UI/ Mf)
<b>Highly Epileptiform Bursts</b> (Present or Absent)
<b>Identical Bursts</b> (Present or Absent)

If Burst-suppression or Burst-attenuation then specify if:

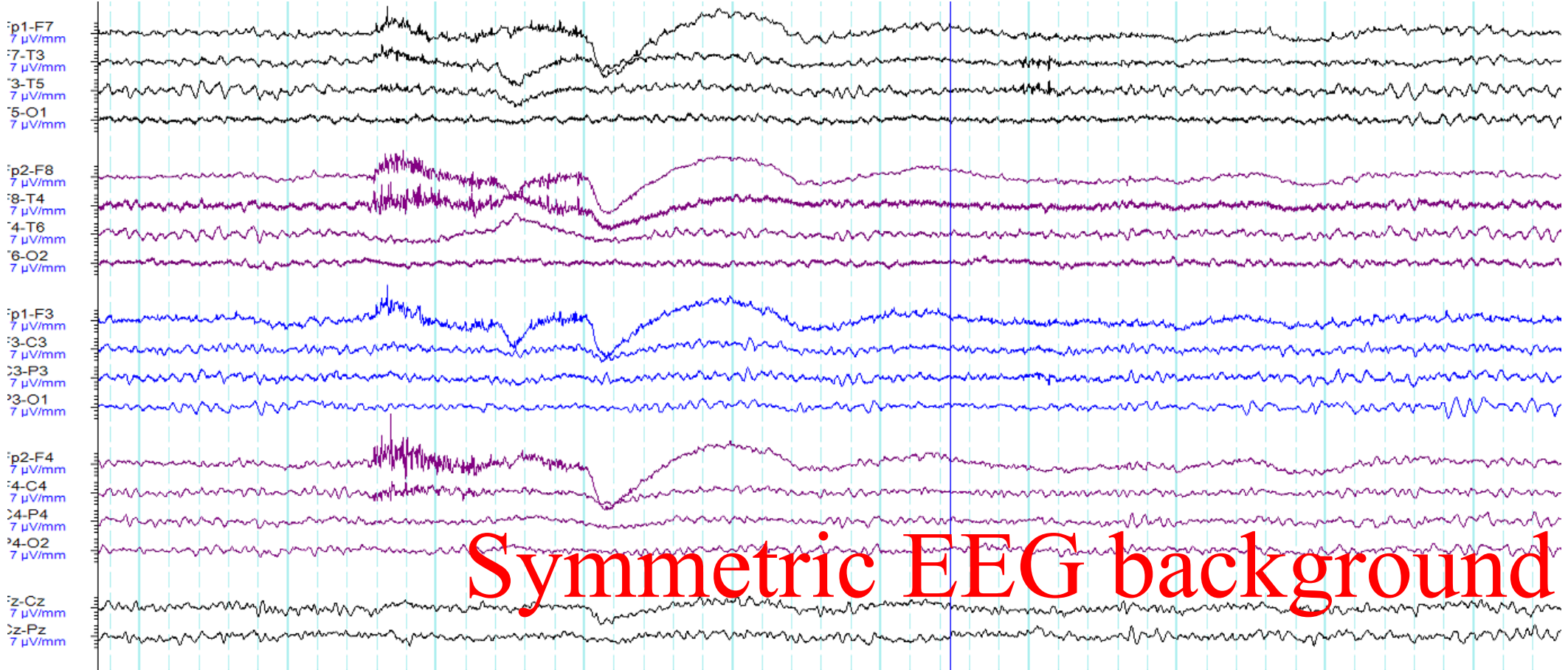
# 1. EEG background

a. Symmetric

b. Mild asymmetry (consistent asymmetry in voltage on an appropriate referential recording of  $< 50\%$  or consistent asymmetry in frequency of 0.5 to 1 Hz)

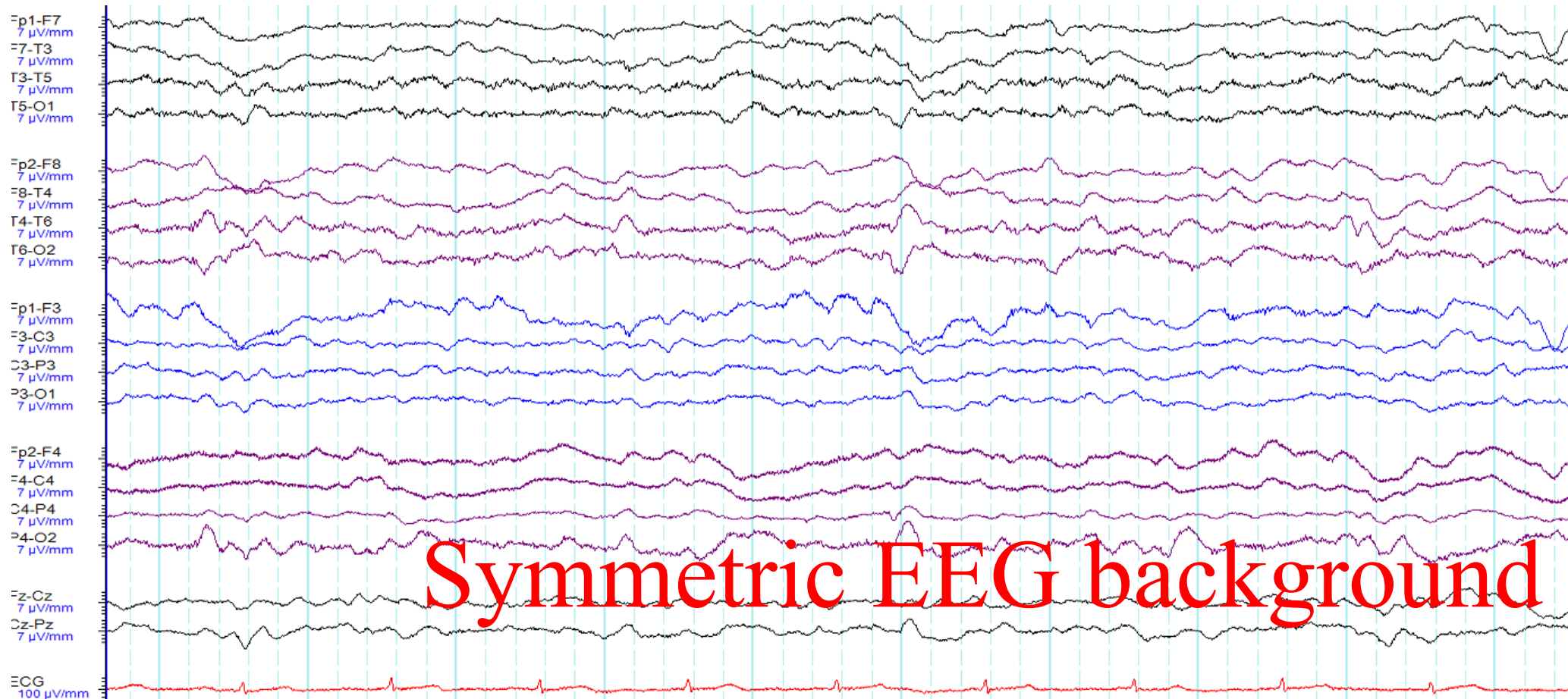
**c. Marked asymmetry (  $\geq 50\%$  voltage or  $>1$  Hz frequency asymmetry)**

# Normal awake

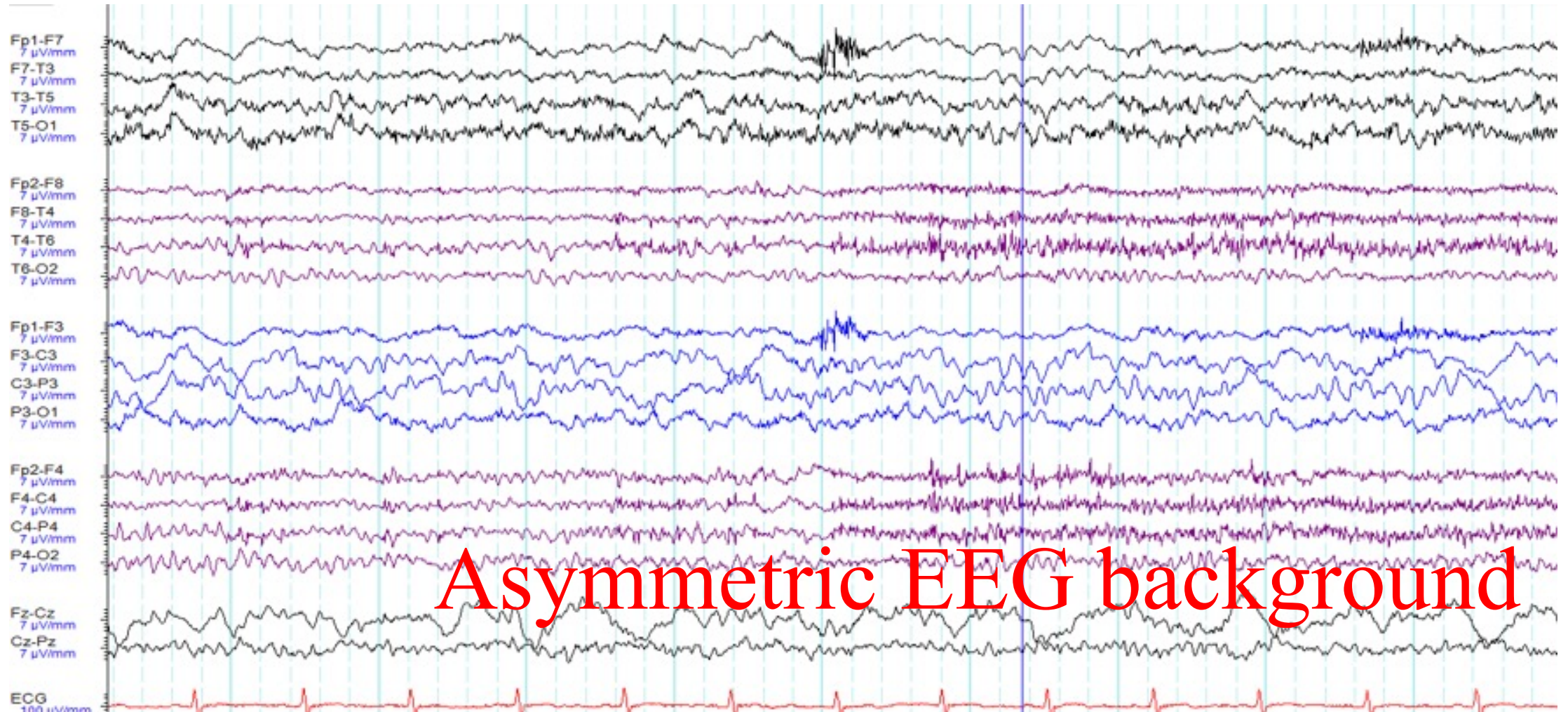


Symmetric EEG background

# Adult patient with altered mental status



# Adult patient with s/p craniectomy

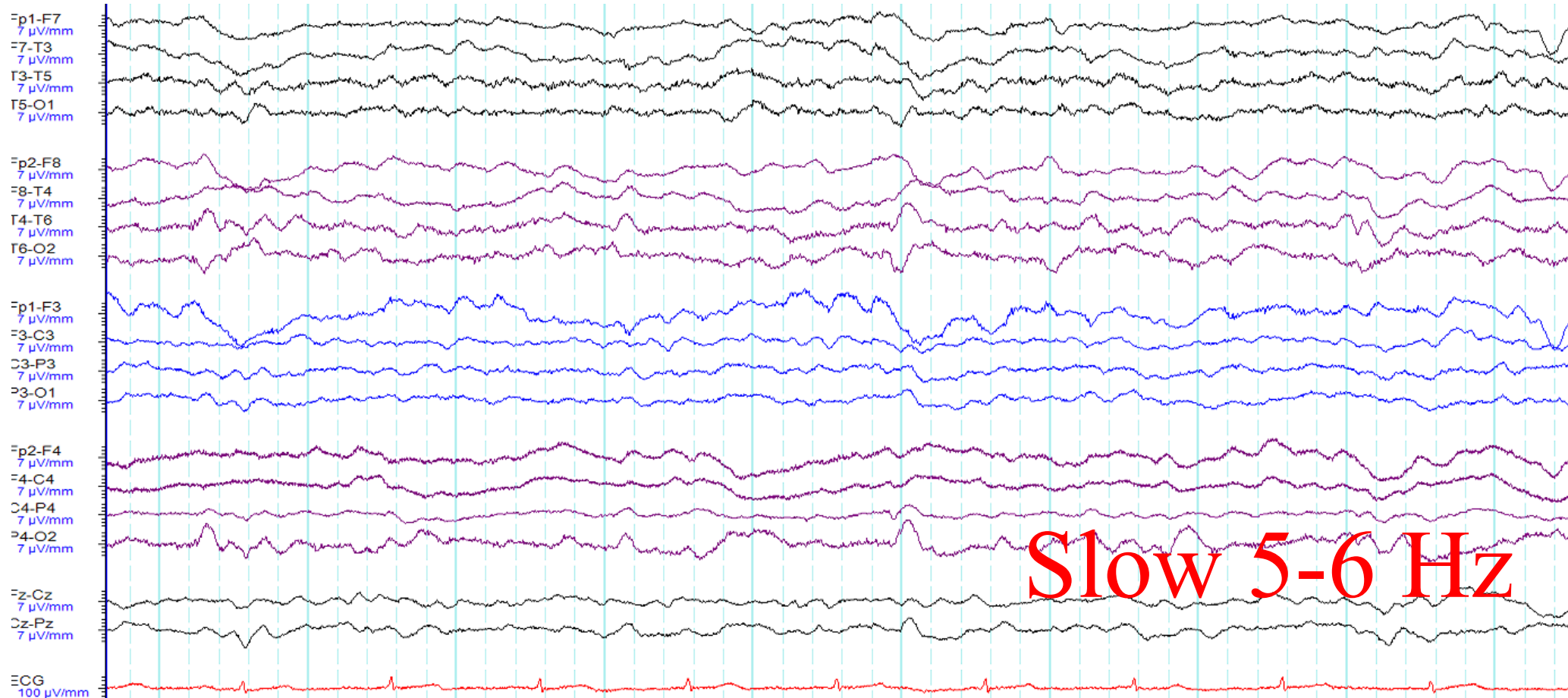


## **2. Predominant Background Frequency When Most Awake or After Stimulation**

- a. Beta ( >13 Hz)
- b. Alpha
- c. Theta
- d. Delta

Note: If two or three frequency bands are equally prominent, report each one.

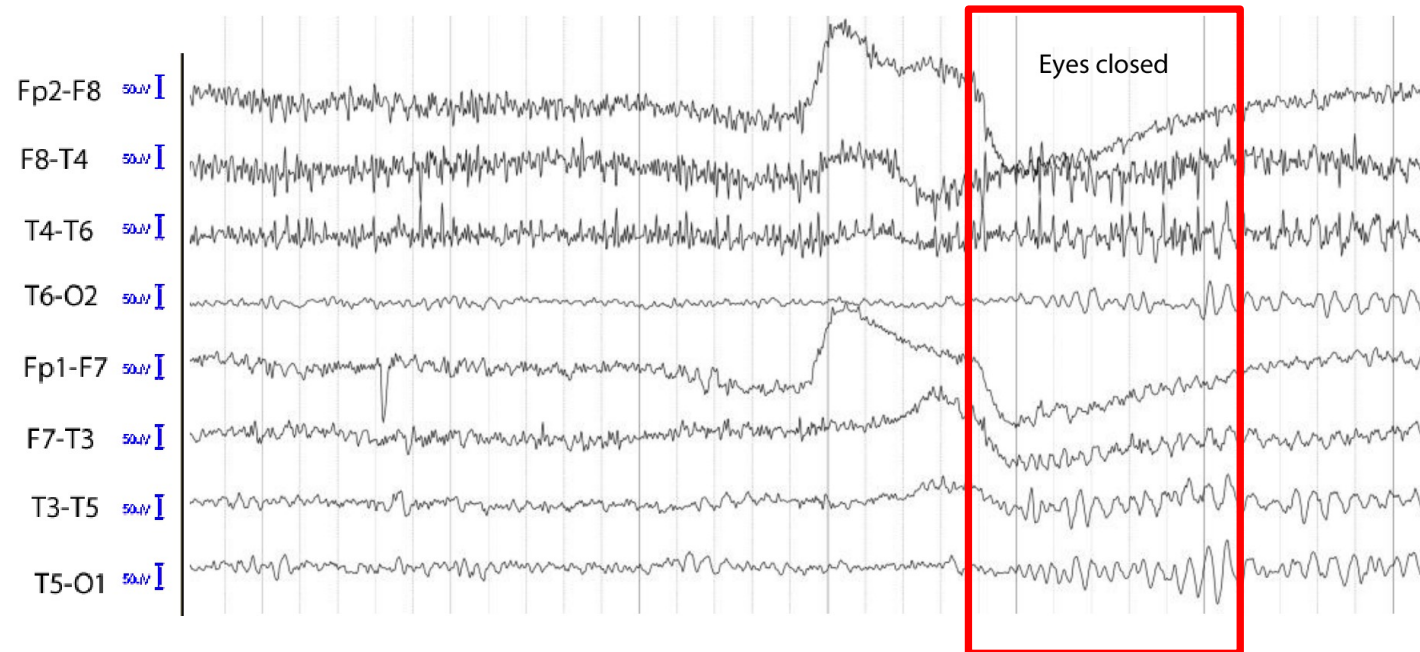
# A 60 yo with altered mental status

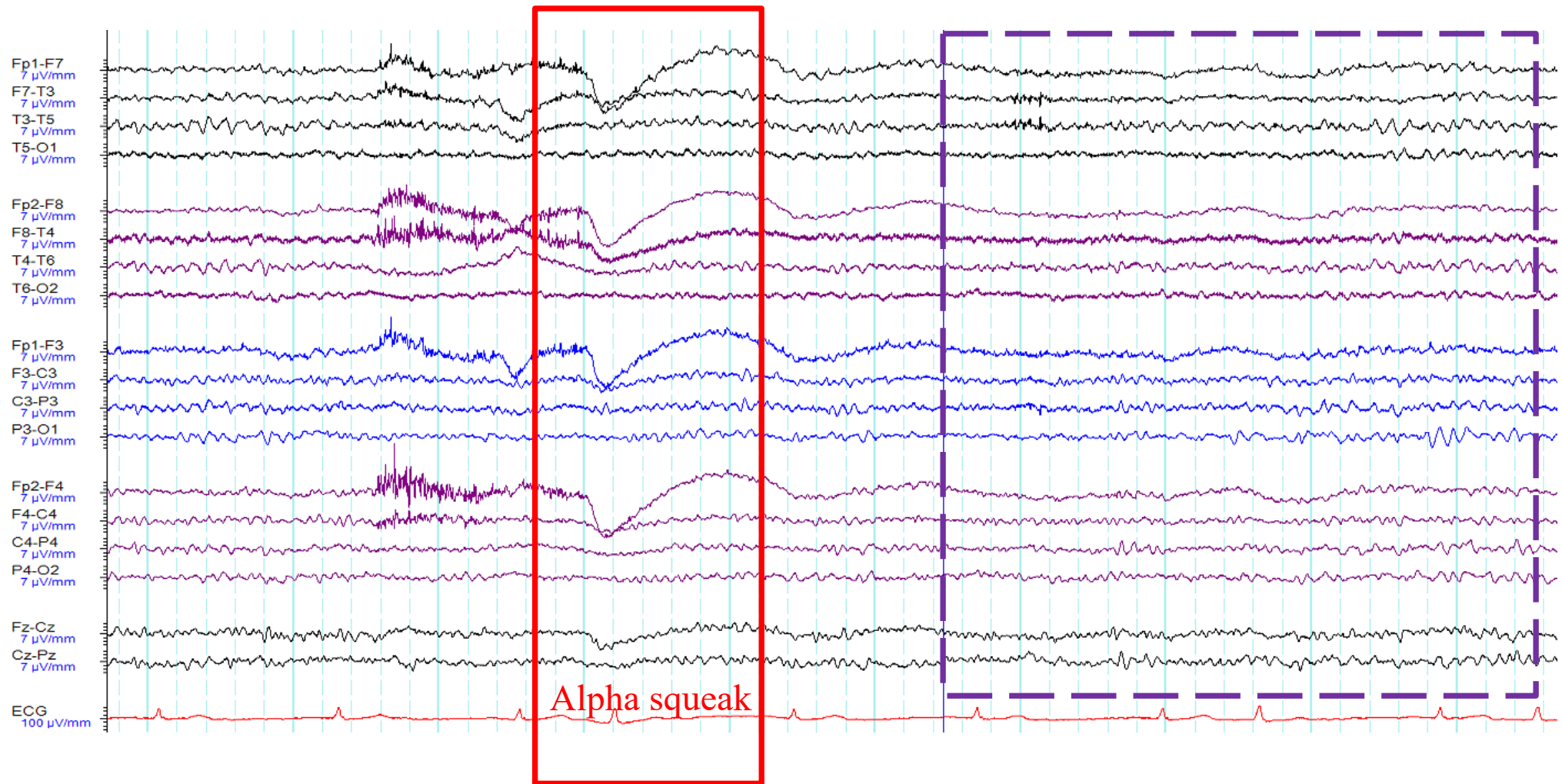




### 3. Posterior Dominant (“Alpha”) Rhythm

- Posterior Dominant (“Alpha”) Rhythm (must be demonstrated to attenuate with eye opening; wait  $> 1$  second after eye closure to determine frequency to avoid “alpha squeak”)

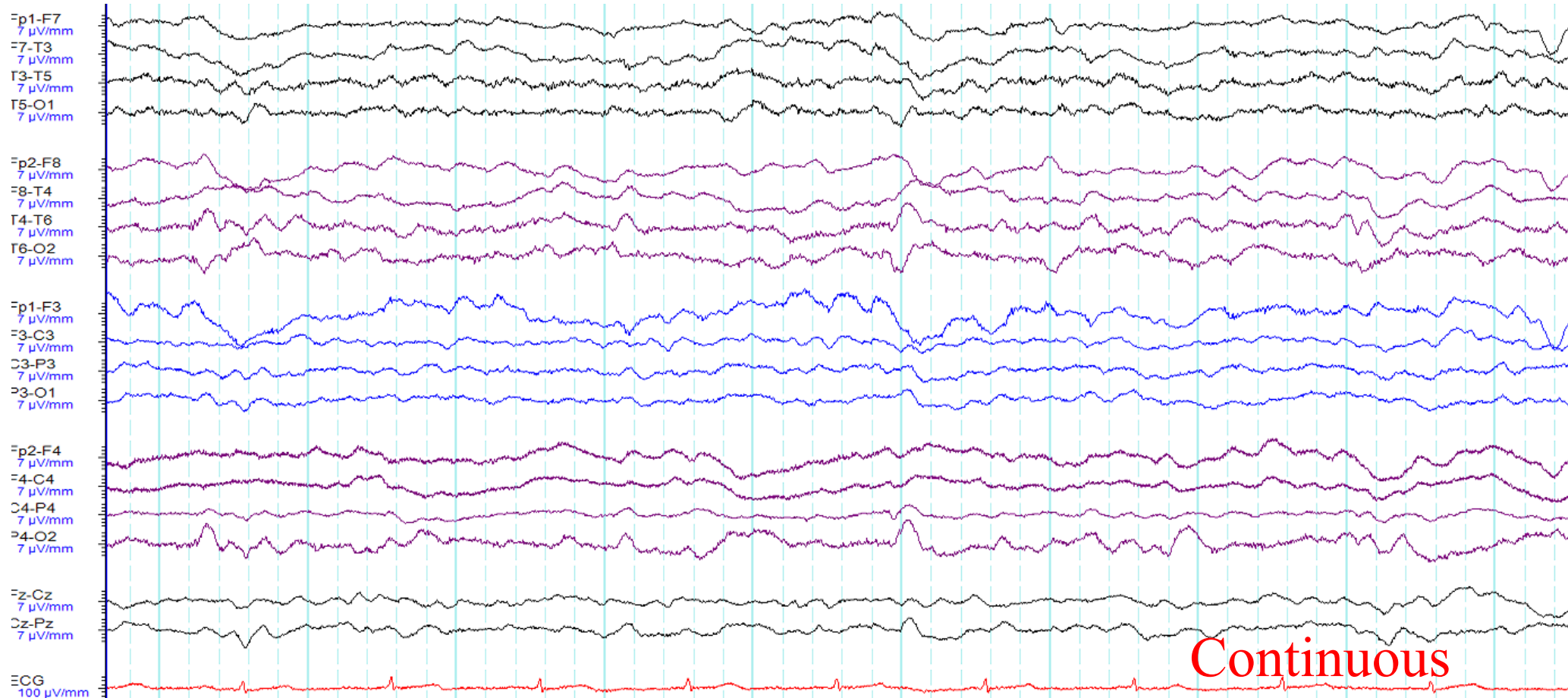


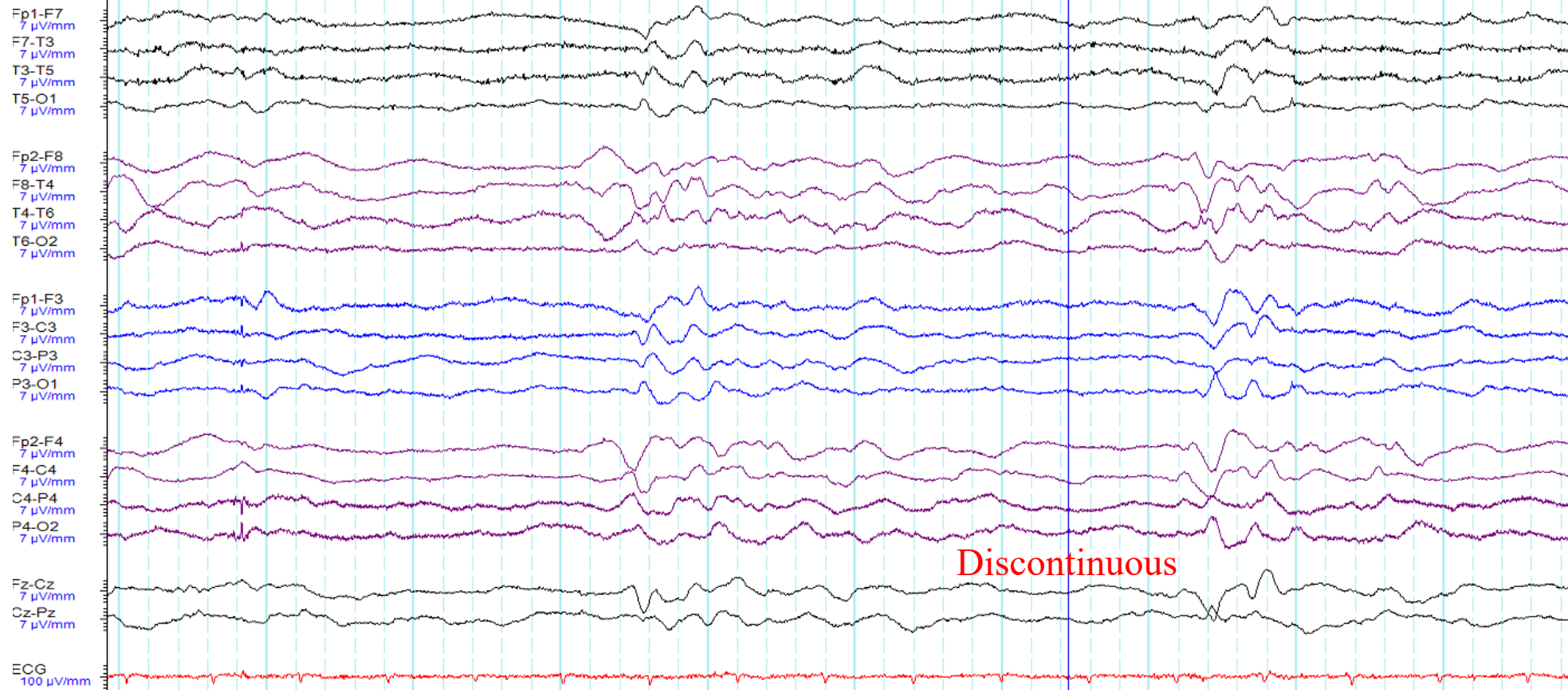


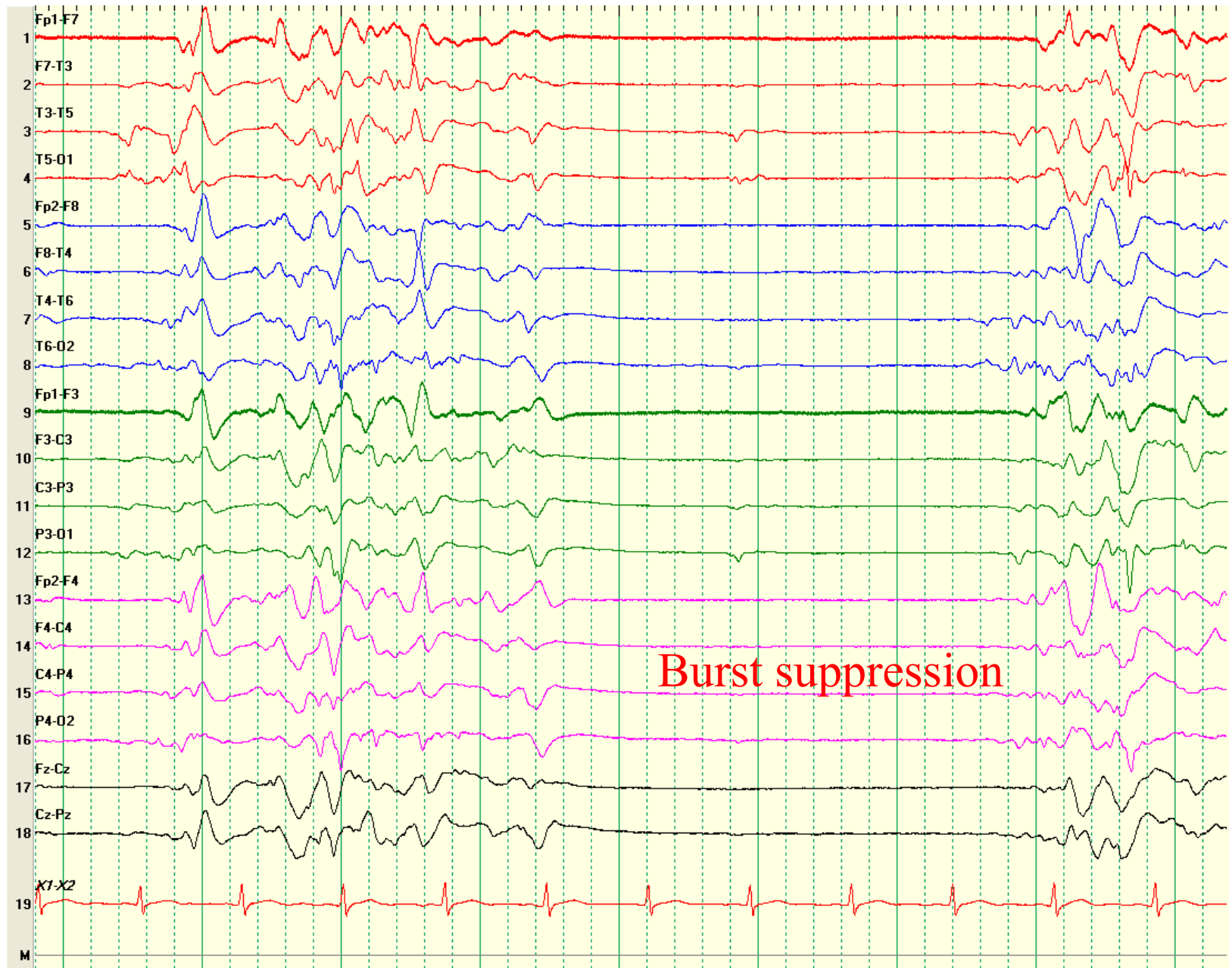
# 4. Continuity

- a. **Continuous**
- b. **Nearly Continuous:** continuous, but with occasional (1- 9% of the record) periods of attenuation or suppression lasting  $\geq 1$  second
  - Describe typical duration of attenuation/ suppression.
  - i. Attenuation: periods of lower voltage are  $\geq 10 \mu\text{V}$  but ,  $< 50\%$  of the higher voltage background
  - ii. Suppression: periods of lower voltage are  $< 10 \mu\text{V}$
- c. **Discontinuous:** A pattern of attenuation/suppression alternating with higher voltage activity, with 10% to 49% of the record consisting of attenuation or suppression
- d. **Burst attenuation/Burst suppression:** A pattern of attenuation/ suppression alternating with higher voltage activity, with 50% to 99% of the record consisting of attenuation
- e. **Suppression:**  $> 99\%$  of the record suppressed ( $<10 \mu\text{V}$ , as defined above)

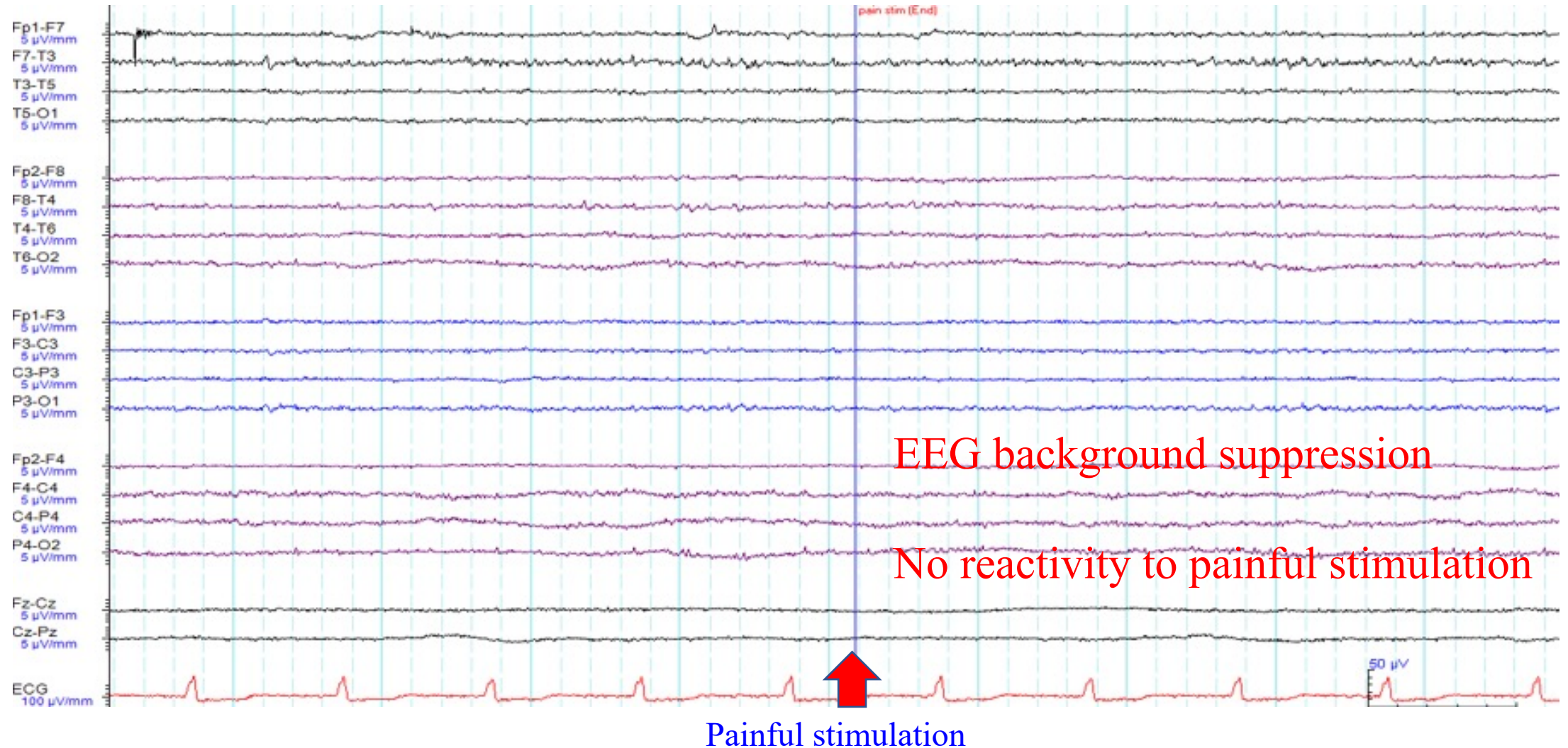
# Adult pt with altered mental status







# Adult with status postcardiac arrest



# 5. Reactivity

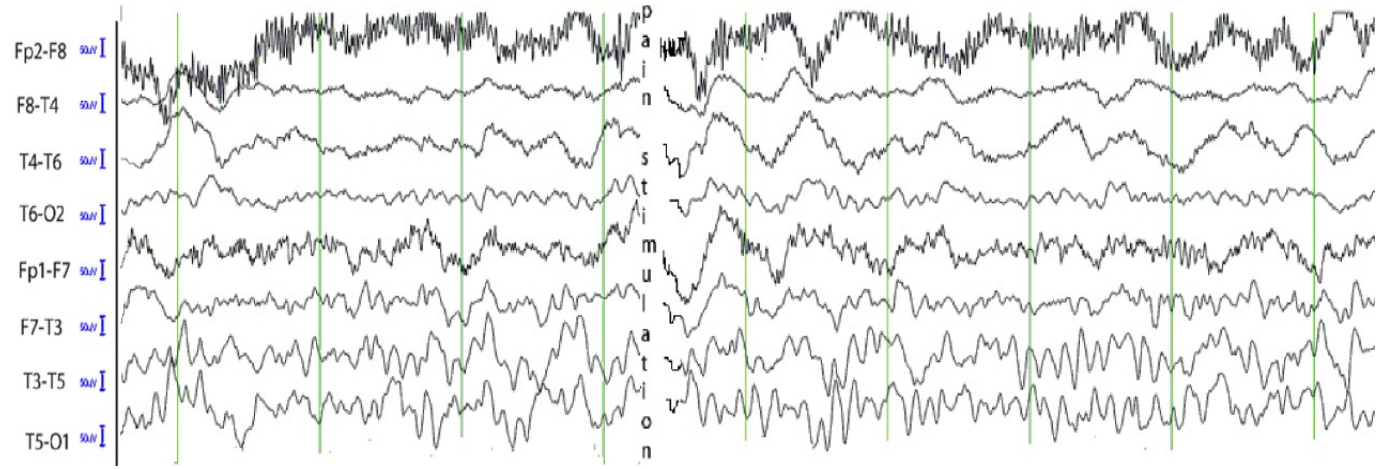
- Change in cerebral EEG activity to stimulation: This may include change in voltage or frequency, including attenuation of activity.

Categorize as the following:

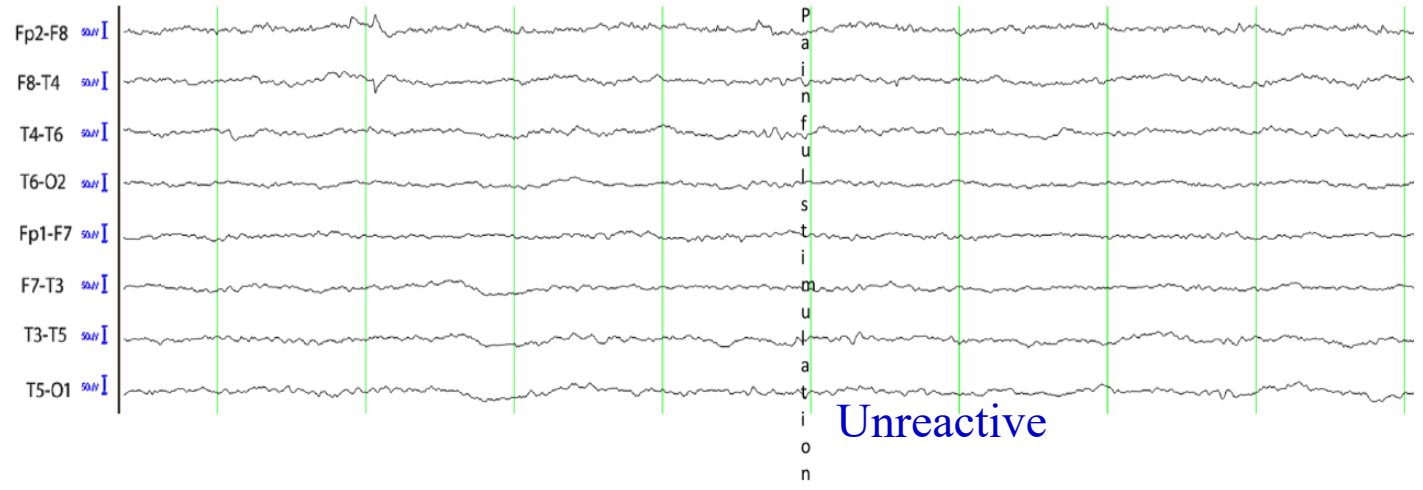
- a. Reactive
  - b. Unreactive
- Strength and/or nature of stimulus should be noted.
  - Appearance of muscle activity or eye blink artifacts does not qualify as reactive.



↓  
**Reactive**

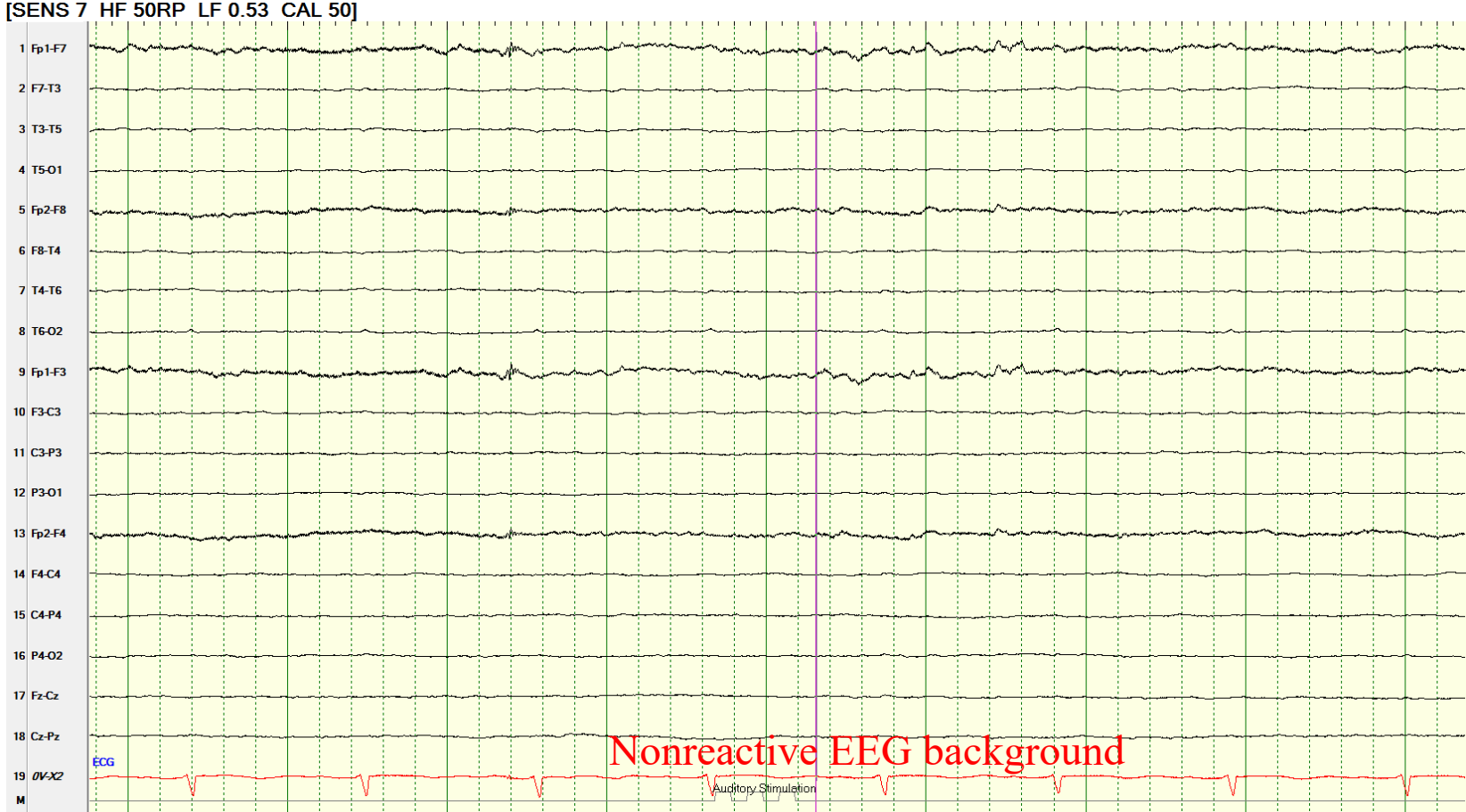


↓



**Unreactive**

# Adult with cardiac arrest



# 6. State Changes

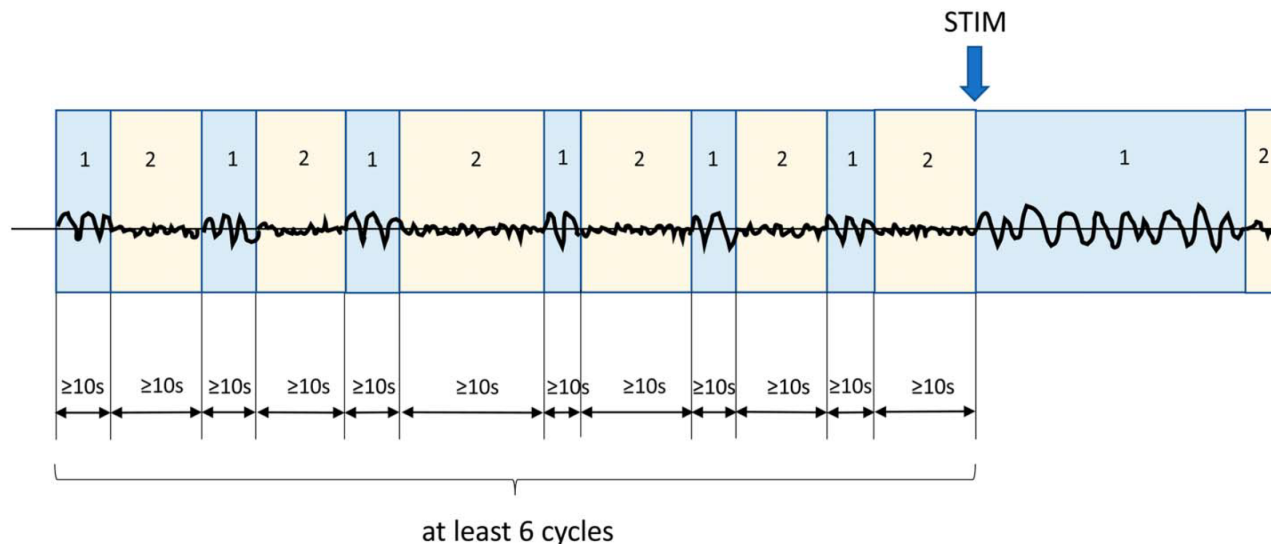
- Present if there are at least 2 sustained types of background EEG related to the level of alertness or stimulation; each must persist **at least 60 seconds** to qualify as a “state”.
- Stimulation should be able to transition the patient from the less alert to more alert/more stimulated state.
- State changes can also occur spontaneously.
- **The more alert/stimulated pattern is considered the primary reported “background” EEG pattern for the patient.**

# 6. State Changes

- a. Present with normal stage N2 sleep transients (K-complexes and spindles)
- b. Present but with abnormal stage N2 sleep transients
- c. Present but without stage N2 sleep transients
- d. Absent

## 7. Cyclic Alternating Pattern of Encephalopathy (CAPE)

- CAPE refers to changes in background patterns (which may include RPPs), each lasting **at least 10 seconds**, and spontaneously **alternating between the 2 patterns** in a regular manner for at least **six cycles** (but often lasts minutes to hours)



- Changes in EEG background between pattern 1 and pattern 2, where:
1. Each pattern lasts at least 10 seconds,
  2. Spontaneously alternates between the two patterns in a regular manner,
  3. For at least 6 cycles.

Cyclic Alternating Pattern of Encephalopathy (CAPE).

## **7. Cyclic Alternating Pattern of Encephalopathy (CAPE)**

- Present
- Absent
- Unknown/unclear.

# Cyclic Alternating Pattern of Encephalopathy (CAPE)

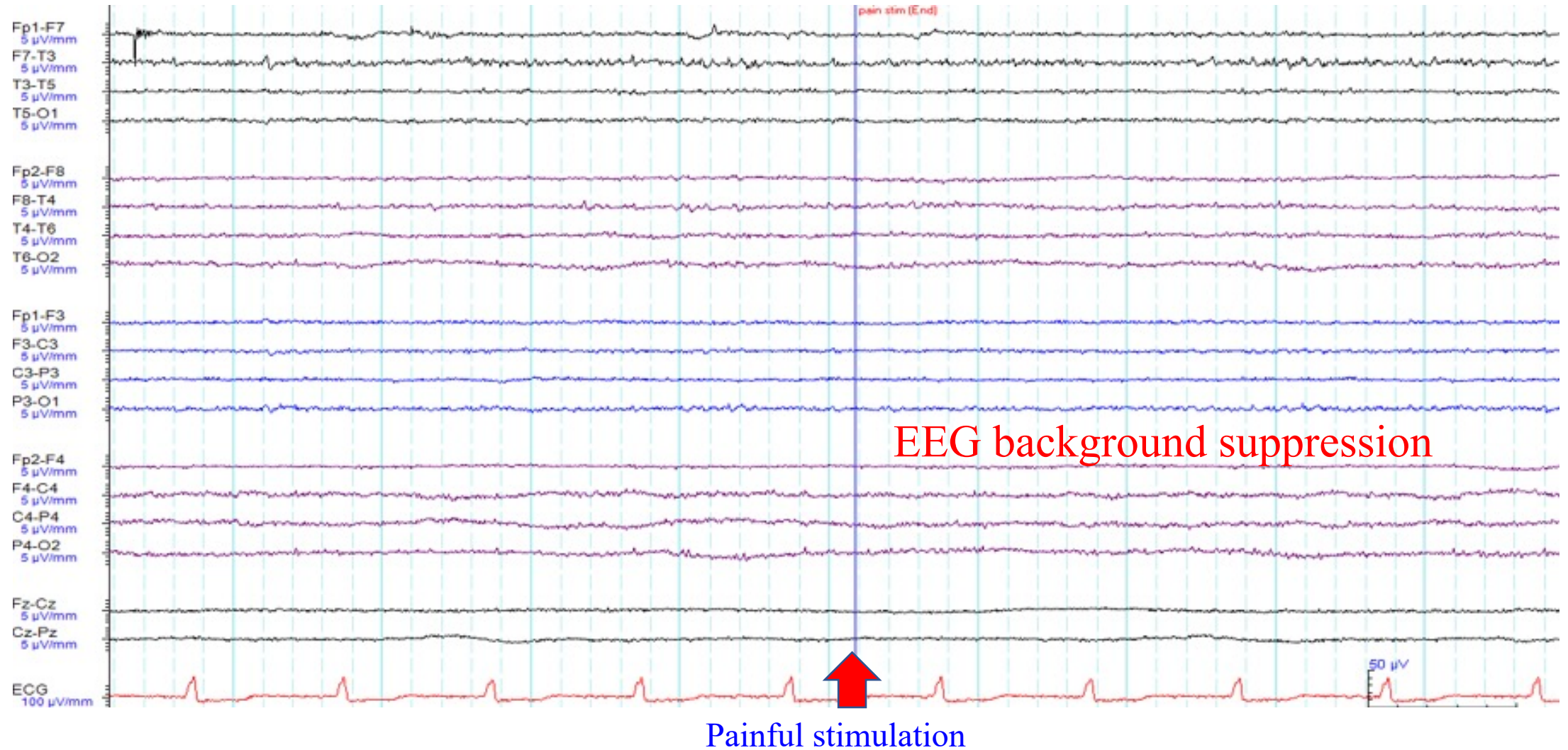
- EEG Cyclic Alternating Pattern(**ECAP**) is the periodic presence of a high-voltage slow waves alternating with low voltage irregular faster activity. This term was first described in comatose patients in 1944.
- **CAPE**
  - Seen in stuporous or comatose state
  - Seen in patients with all sorts of encephalopathy or sedation
  - Associated with good prognosis

# 8. Voltage

- a. **High:** most or all activity  $\geq 150 \mu\text{V}$  in longitudinal bipolar with standard 10-20 electrodes (measured from peak to trough)
  
- b. **Normal**
  
- c. **Low:** most or all activity ,  $< 20 \mu\text{V}$  in longitudinal bipolar with standard 10-20 electrodes (measured from peak to trough), but not qualifying as suppressed
  
- d. **Suppressed:** all activity ,  $< 10 \mu\text{V}$



# Adult with status postcardiac arrest



# 9. Anterior-Posterior (AP) Gradient

An AP gradient is present if, at any point in the epoch, there is a clear and persistent (at least 1 continuous minute) anterior to posterior gradient of voltages and frequencies such that lower voltage, faster frequencies are seen in anterior derivations, and higher voltage, slower frequencies are seen in posterior derivations. A reverse AP gradient is defined identically but with a posterior to anterior gradient of voltages and frequencies.

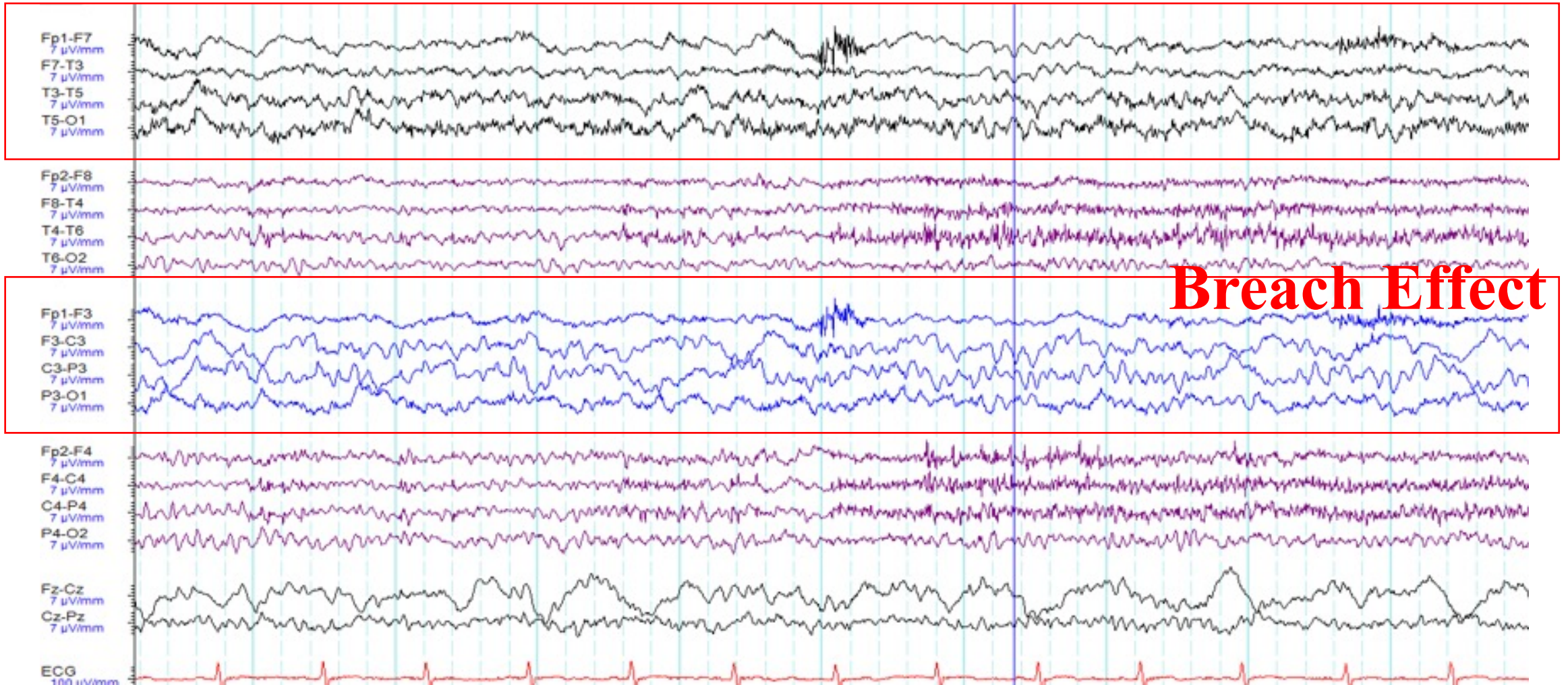
- a. Present.
- b. Absent.
- c. Present, but reversed

# 10. Breach Effect

EEG activity over or nearby a skull defect and consists of activity of higher amplitude and increased sharpness, primarily of faster frequencies, compared with the rest of the brain, especially compared with the homologous region on the opposite side of the head.

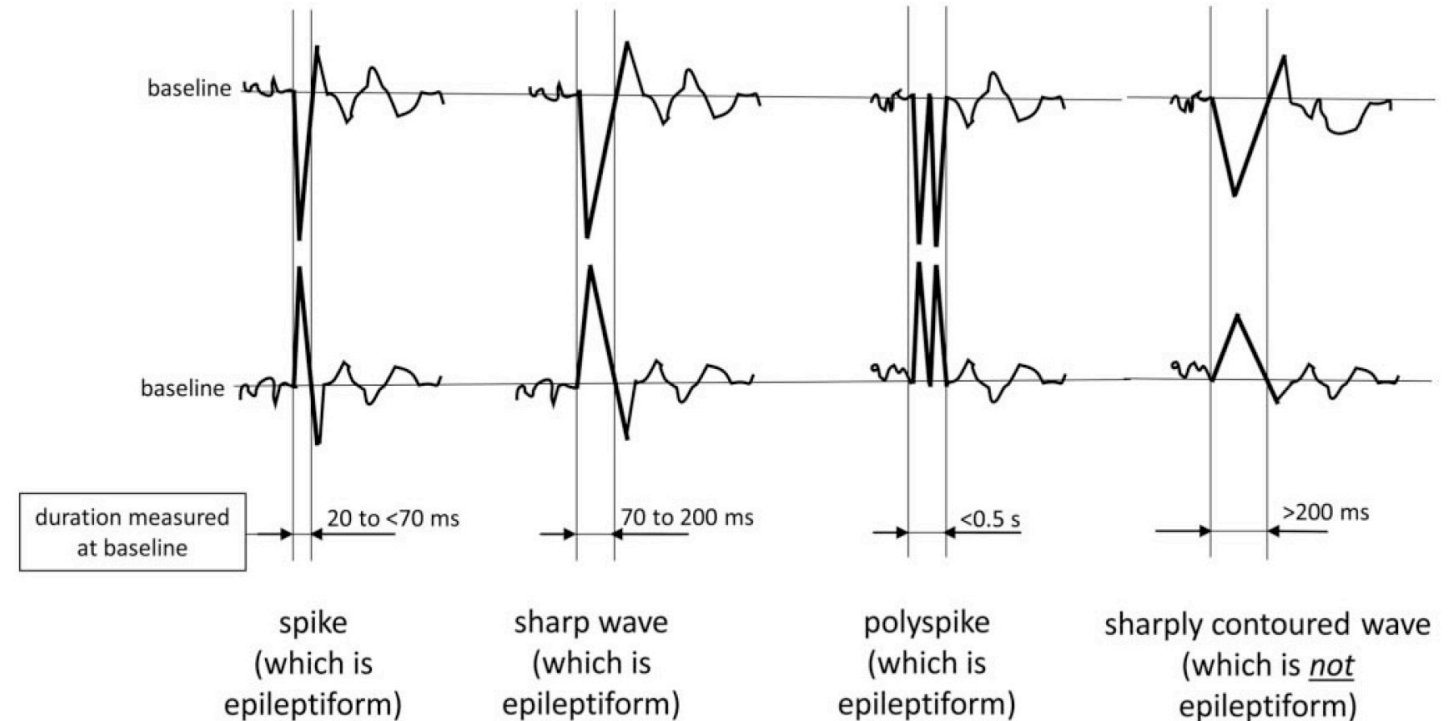
- a. Present (provide location)
- b. Absent.
- c. Unclear.

# Adult pt with s/p left craniectomy



## **B. Sporadic epileptiform discharges**

- A “**spike**” is defined as “a transient, clearly distinguished from background activity, with pointed peak at a conventional time scale and duration from 20 to < 70 ms,” with duration measured at the EEG baseline.
- A “**sharp wave**” is defined identically, but with a duration of 70 to 200 ms.
- A “**polyspike**” refers to 2 or more spikes occurring in a row with no interdischarge interval and lasting < 0.5 seconds.



# Sporadic epileptiform discharges

<b>B. Sporadic Epileptiform Discharges</b>
<b>Prevalence</b>
<b>Abundant</b> $\geq 1/10s$
<b>Frequent</b> $\geq 1/min$ but $< 1/10s$
<b>Occasional</b> $\geq 1/h$ but $< 1/min$
<b>Rare</b> $< 1/h$

## **C. Rhythmic and periodic patterns (RPPs)**



# C. Rhythmic and periodic patterns (RPPs)

- **Main term 1**

localization of the pattern

- **Main term 2**

the type of pattern

C. Rhythmic and Periodic Patterns (RPPs)	
Main term 1	Main term 2
<p><b>G</b> <i>Generalized</i> - Optional: Specify frontally, occipitally, or midline predominant; or generalized, not otherwise specified.</p>	<p><b>PD</b> <i>Periodic Discharges</i></p>
<p><b>L</b> <i>Lateralized</i> - Optional: Specify unilateral, bilateral asymmetric, or bilateral asynchronous - Optional: Specify lobe(s) most involved or hemispheric</p>	<p><b>RDA</b> <i>Rhythmic Delta Activity</i></p>
<p><b>BI</b> <i>Bilateral Independent</i> - Optional: Specify symmetric or asymmetric - Optional: Specify lobe(s) most involved or hemispheric</p>	<p><b>SW</b> <i>Spike and Wave</i> OR <i>Polyspike and Wave</i> OR <i>Sharp and Wave</i></p>
<p><b>UI</b> <i>Unilateral Independent</i> - Optional: Specify unilateral, bilateral asymmetric, or bilateral asynchronous for each pattern - Optional: Specify lobe(s) most involved</p>	
<p><b>Mf</b> <i>Multifocal</i> - Optional: Specify symmetric or asymmetric - Optional: Specify lobe(s) most involved or hemispheric</p>	

Major modifiers									Minor modifiers			
Prevalence	Duration	Frequency	Phases <sup>1</sup>	Sharpness <sup>2</sup>	Voltage (Absolute)	Voltage (Relative) <sup>3</sup>	Stimulus Induced or Stimulus Terminated	Evolution <sup>4</sup>	Onset	Triphasic <sup>5</sup>	Lag	Polarity <sup>2</sup>
Continuous ≥90%	Very long ≥1 h	4 Hz	>3	Spiky <70 ms	High ≥150 μV	>2	SI <i>Stimulus Induced</i>	Evolving	Sudden ≤3 s	Yes	A-P <i>Anterior-Posterior</i>	Negative
		3.5 Hz	3									
Abundant 50-89%	Long 10-59 min	3 Hz	2	Sharp 70-200 ms	Medium 50-149 μV	≤2	ST <i>Stimulus Terminated</i>	Fluctuating	Gradual >3 s	No	P-A <i>Posterior-Anterior</i>	Positive
		2.5 Hz										
Frequent 10-49%	Intermediate duration 1-9.9 min	2 Hz	1	Sharply contoured >200 ms	Low 20-49 μV		Spontaneous only	Static			No	Unclear
		1.5 Hz										
Occasional 1-9%	Brief 10-59 s	1 Hz		Blunt >200 ms	Very low <20 μV							
		0.5 Hz										
Rare <1%	Very brief <10 s	<0.5 Hz					Unknown					

Plus (+) Modifiers
<b>No +</b>
<b>+F</b> <i>Superimposed fast activity – applies to PD or RDA only</i>
<b>EDB (Extreme Delta Brush): A specific subtype of +F</b>
<b>+R</b> <i>Superimposed rhythmic activity – applies to PD only</i>
<b>+S</b> <i>Superimposed sharp waves or spikes, or sharply contoured – applies to RDA only</i>
<b>+FR</b> <i>If both subtypes apply – applies to PD only</i>
<b>+FS</b> <i>If both subtypes apply – applies to RDA only</i>

NOTE 1: Phases: Applies to PD and SW only, including the slow wave of the SW complex

NOTE 2: Sharpness and Polarity: Applies to the predominant phase of PD and the spike or sharp component of SW only

NOTE 3: Relative voltage: Applies to PD only

NOTE 4: Evolution: Refers to frequency, location or morphology

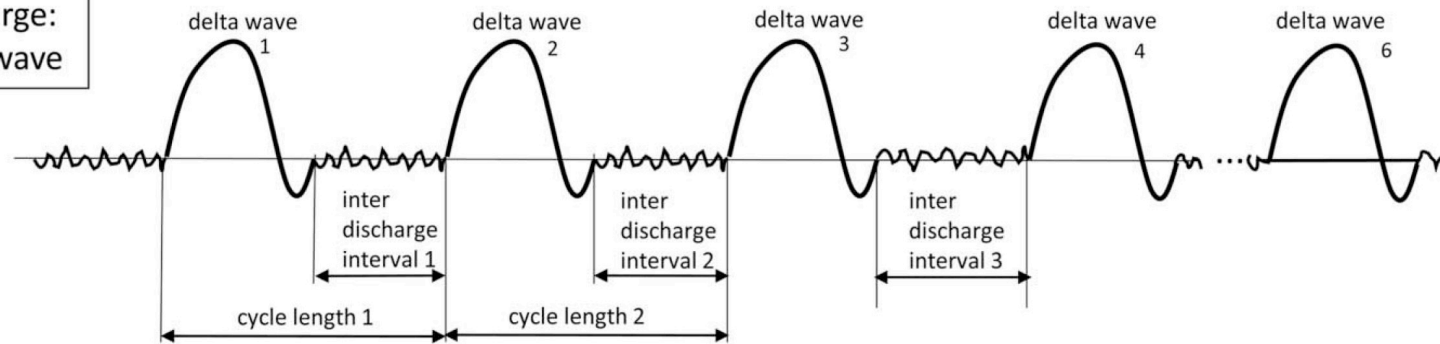
NOTE 5: Triphasic: Applies to PD or SW only

## a. Periodic Discharges (PDs)

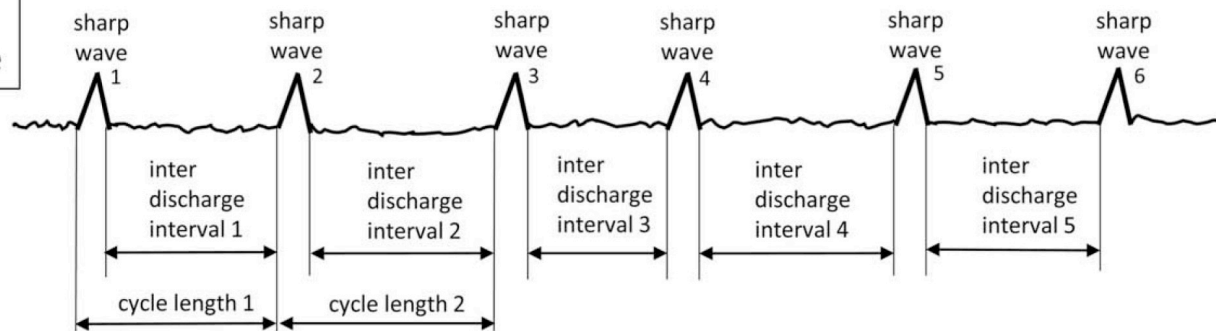
- **Periodic:** Repetition of a waveform with relatively uniform morphology and duration with a clearly discernible interdischarge interval between consecutive waveforms and recurrence of the waveform at nearly regular intervals.
- **Discharges:** Waveforms lasting  $< 0.5$  seconds, regardless of number of phases, or waveforms  $\geq 0.5$  seconds with no more than 3 phases.

*NOTE: A pattern can qualify as rhythmic or periodic as long as it continues for at least 6 cycles (e.g. 1/s for 6 s, or 3/s for 2 s).*

Discharge:  
delta wave



Discharge:  
sharp wave



## Periodic Discharges (PDs).

1. Repetition of a waveform with relatively uniform morphology and duration,
2. with a clearly discernable interdischarge interval between consecutive waveforms, and
3. recurrence of the waveform at nearly regular intervals: having a cycle length (i.e., period) varying by  $< 50\%$  from one cycle to the next in the majority ( $>50\%$ ) of cycle pairs.

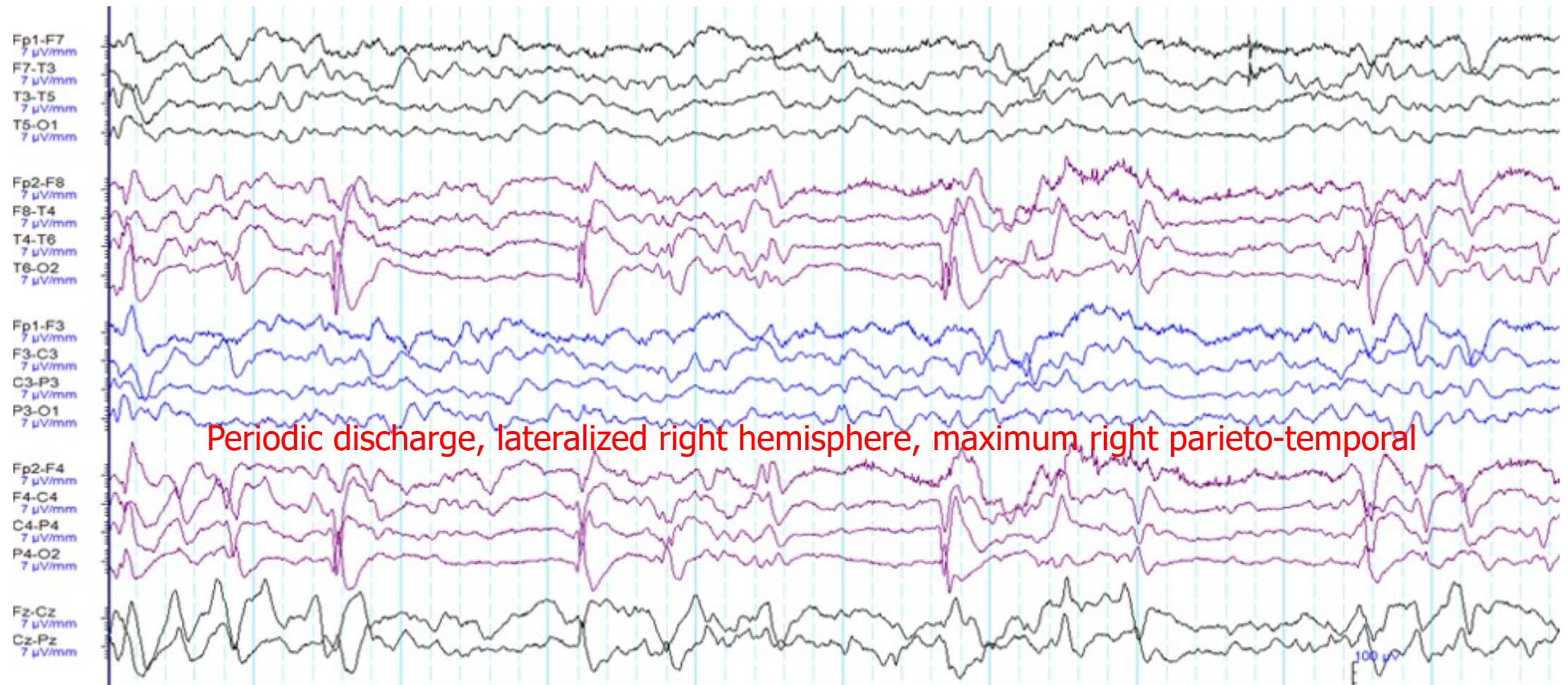
A pattern can qualify as rhythmic or periodic if and only if it continues for at least 6 cycles (e.g. 1 Hz for 6 seconds, or 3 Hz for 2 seconds).

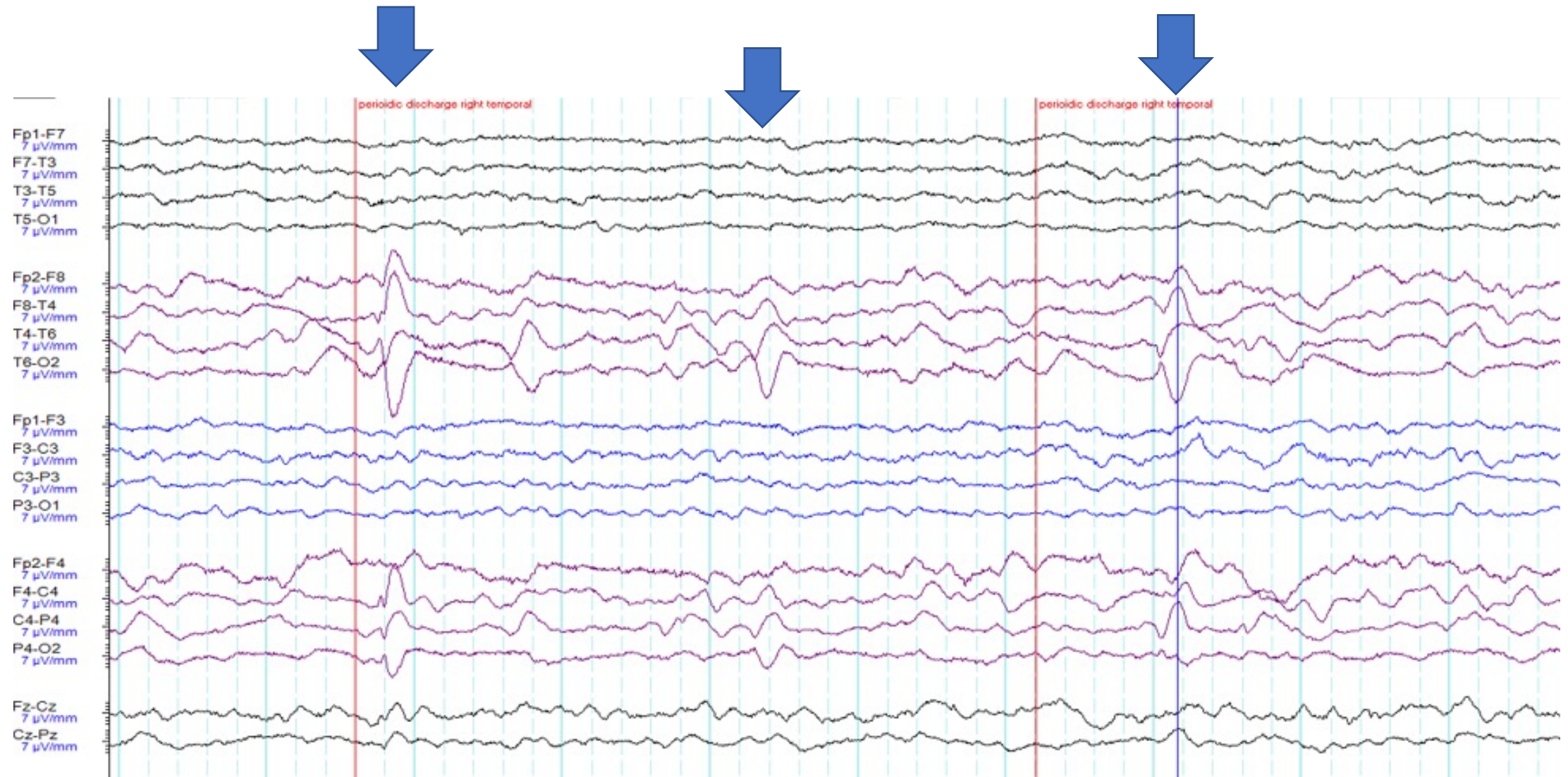
# Lateralized periodic discharges (LPD)

- LPD are frequently associated with acute, structural lesions involving the cortex.
  - Ischemic stroke
  - Herpes encephalitis

# Generalized periodic discharges (GPD)

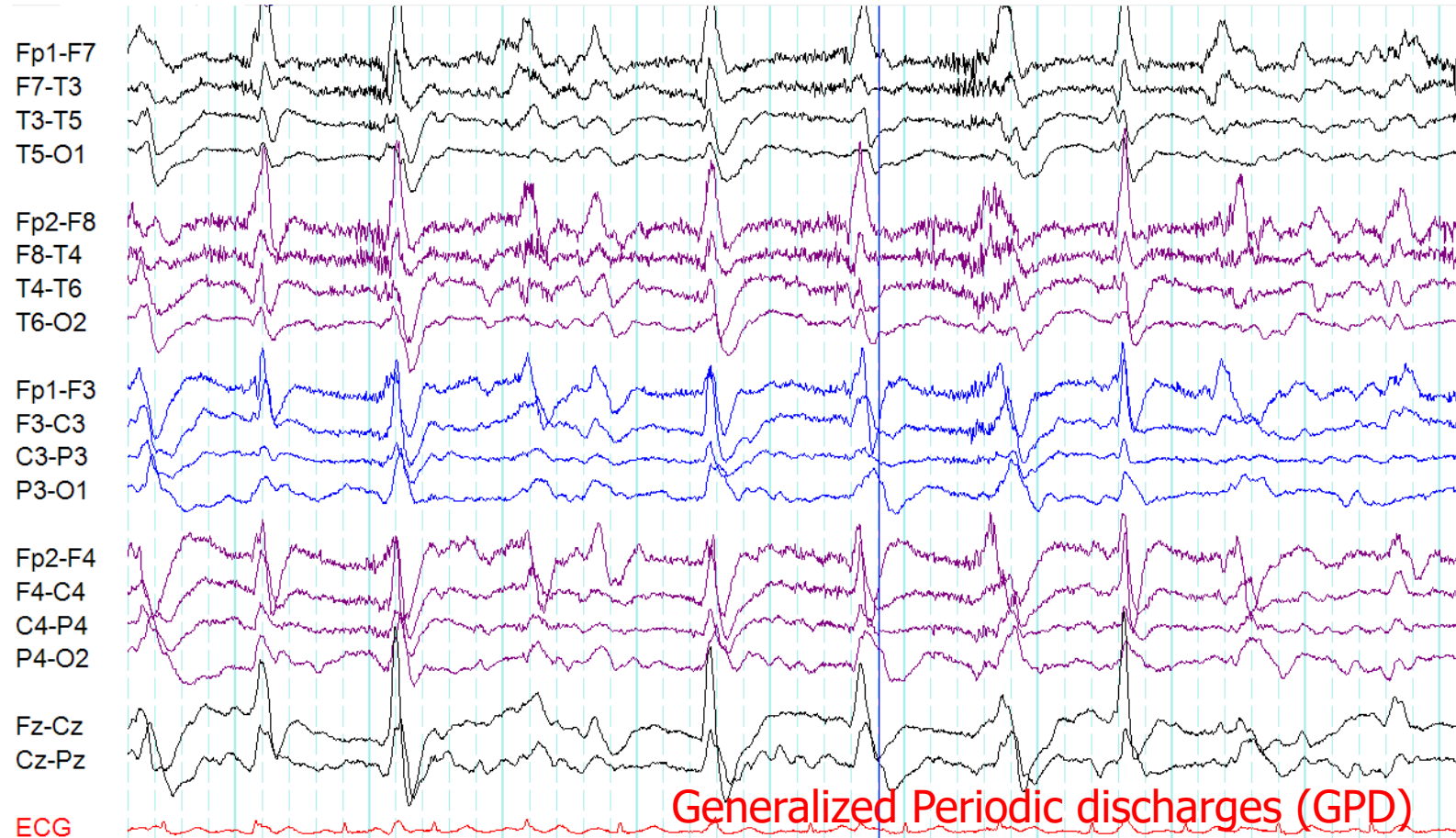
Category	
Neurovascular	HIE, stroke
Infectious	Sepsis, herpes encephalitis
Systemic illness	Hepatic encephalopathy, uremia, hypoglycemia
Neurodegenerative	CJD, Alzheimer
Toxicity	Withdrawal from barbiturate, BDZ Baclofen Lithium







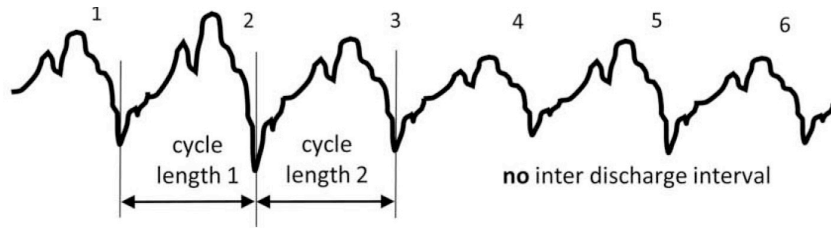
# Adult with postcardiac arrest



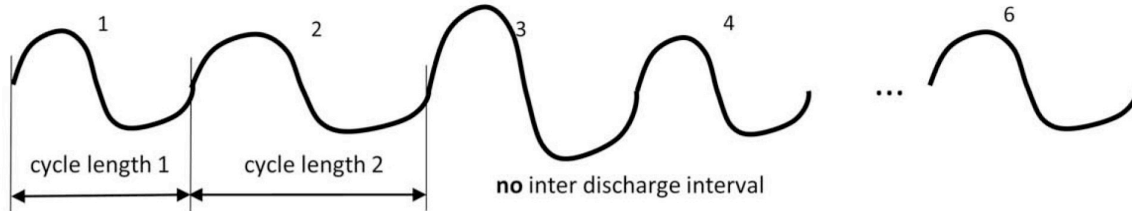
## b. Rhythmic Delta Activity (RDA)

- **Rhythmic:** Repetition of a waveform with relatively uniform morphology and duration and without an interval between consecutive waveforms
- The duration of one cycle (i.e., the period) of the rhythmic pattern should vary by,  $< 50\%$  from the duration of the subsequent cycle for most ( $> 50\%$ ) cycle pairs to qualify as rhythmic.

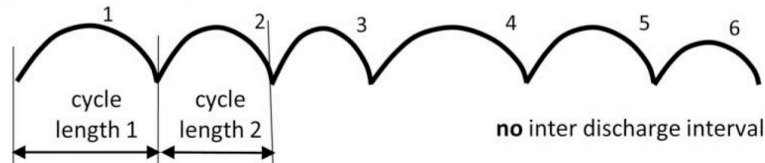
complex  
delta wave



sinusoidal  
delta wave



arciform  
delta wave



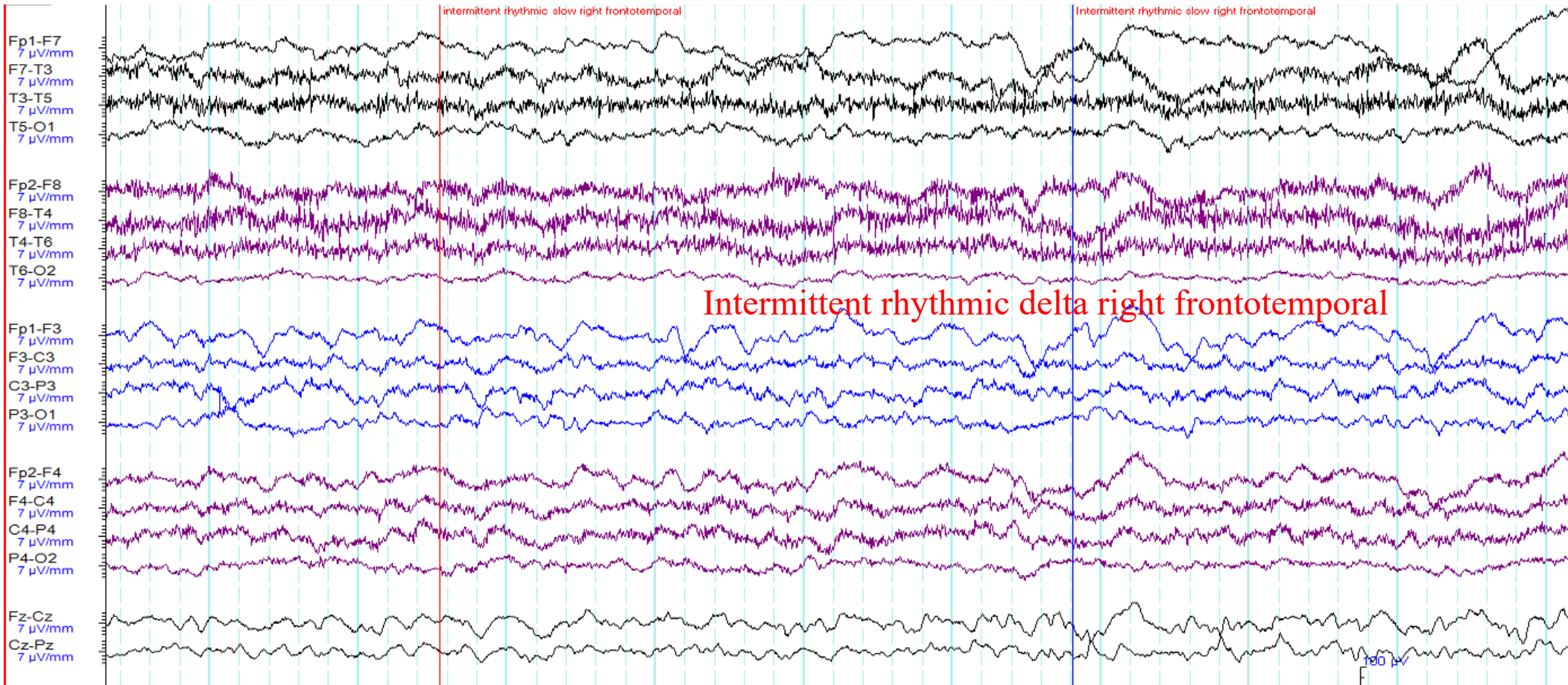
**NOT**  
RHYTHMIC

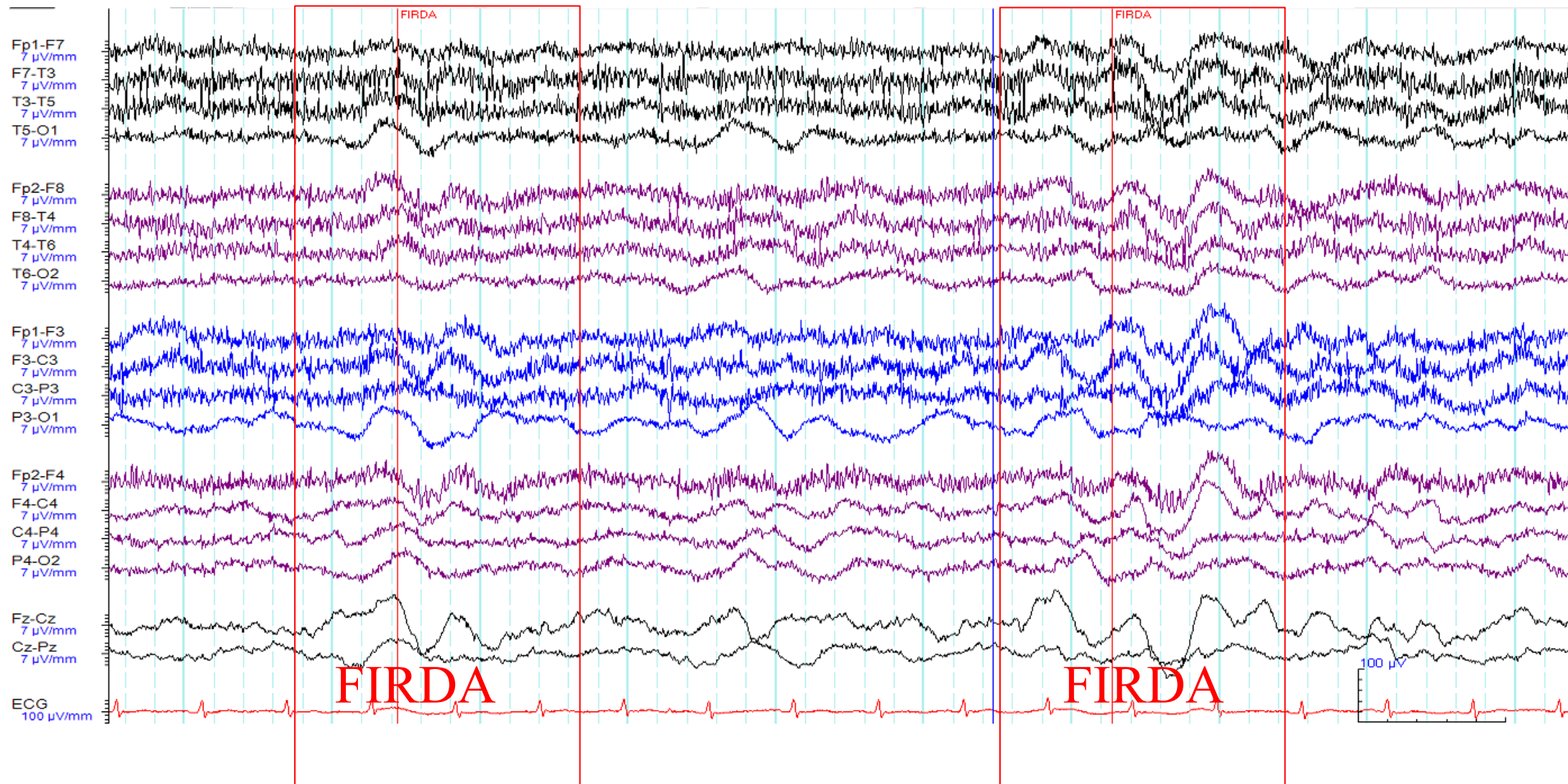


### Rhythmic Delta Activity (RDA).

1. Repetition of a waveform with relatively uniform morphology and duration and
2. without an interval between consecutive waveforms.
3. The duration of one cycle (i.e., the period) of the rhythmic pattern should vary by, <50% from the duration of the subsequent cycle for the majority (>50%) of cycle pairs to qualify as rhythmic.

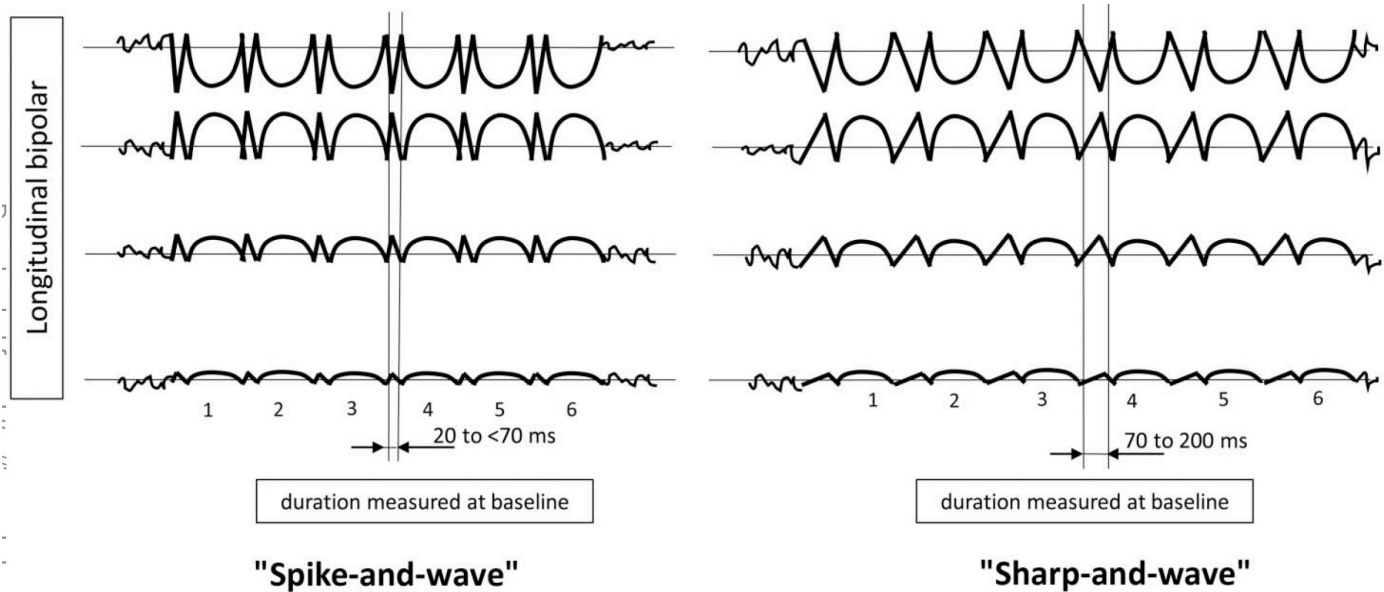
A pattern can qualify as rhythmic or periodic if and only if it continues for at least 6 cycles (e.g. 1 Hz for 6 seconds, or 3 Hz for 2 seconds).





## c. Spike-and-wave or Sharp-and-wave (SW)

- Spike, polyspike, or sharp wave consistently followed by a slow wave in a regularly repeating and alternating pattern (spike-wave-spike-wave-spike-wave), with a consistent relationship between the spike (or polyspike or sharp wave) component and the slow wave for at least six consecutive cycles and with no interval between one spike-wave complex and the next.



“Spike-and-wave” or “Sharp and-wave” (SW). Spike-and-wave or Sharp-and-wave (SW): Polyspike, spike, or sharp wave consistently followed by a slow wave in a regularly repeating and alternating pattern (spike-wave-spike wave-spike-wave), with a consistent relationship between the spike (or polyspike or sharp wave) component and the slow wave for at least 6 cycles; and with no interval between one spike-wave complex and the next (if there is an interval, this would qualify as PDs, where each discharge is a spike-and-wave).

# D. Electrographic and electroclinical seizures



## D. Electrographic and Electroclinical Seizures

### Electrographic Seizure (ESz)

*Either:*

- A) Epileptiform discharges averaging  $>2.5$  Hz for  $\geq 10$  s ( $>25$  discharges in 10 s), OR
- B) Any pattern with definite evolution and lasting  $\geq 10$  s

### Electroclinical Seizure (ECSz)

*Any EEG pattern with either:*

- A) Definite clinical correlate time-locked to the pattern (of any duration), OR
- B) EEG *and* clinical improvement with a parenteral (typically IV) anti-seizure medication

### Electrographic Status Epilepticus (ESE)

*An electrographic seizure for either:*

- A)  $\geq 10$  continuous minutes, OR
- B) A total duration of  $\geq 20\%$  of any 60-minute period of recording.

### Electroclinical Status Epilepticus (ECSE)

*An electroclinical seizure for either*

- A)  $\geq 10$  continuous minutes, OR
- B) A total duration of  $\geq 20\%$  of any 60-minute period of recording, OR
- C)  $\geq 5$  continuous minutes if the seizure is convulsive (i.e., with bilateral tonic-clonic motor activity).

*Possible ECSE:* An RPP that qualifies for the IIC (below) that is present for  $\geq 10$  continuous minutes or for a total duration of  $\geq 20\%$  of any 60-minute period of recording, which shows EEG improvement with a parenteral anti-seizure medication **BUT** without clinical improvement.

# Salzburg EEG consensus criteria for non-convulsive status epilepticus

## Patients without known epileptic encephalopathy

- EDs  $> 2.5$  Hz, or
- EDs  $\leq 2.5$  Hz or rhythmic delta/theta activity ( $> 0.5$ Hz) AND one of the following:
  - EEG and clinical improvement after IV AED\*, or
  - Subtle clinical ictal phenomena, or
  - Typical spatiotemporal evolution\*\*

## Patients with known epileptic encephalopathy

- Increase in prominence or frequency when compared to baseline with observable change in clinical state
- Improvement of clinical and EEG\* features with IV AEDs

\* If EEG improvement without clinical improvement, or if fluctuation without definite evolution, this should be considered possible NCSE.

\*\* Increment onset(increase in voltage and change in frequency), or evolution in pattern(change in frequency  $> 1$ Hz or change in location), or decrementing termination(voltage and frequency).

EDs: epileptiform discharges(spikes, polyspikes, sharp-waves, sharp-and-wave complexes)

IV AED: intravenous antiepileptic drugs

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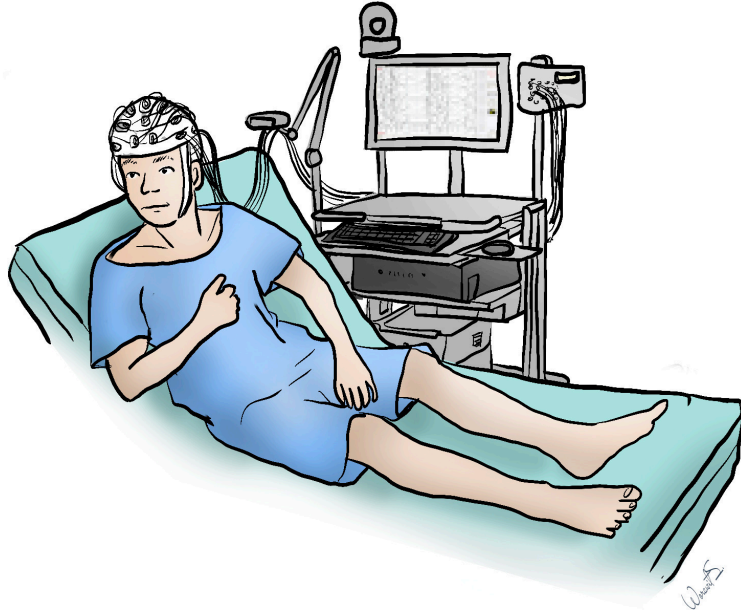


# **EEG patterns in encephalopathy**

**Assistant Professor. Apisit Boongird**

**Division of Neurology**

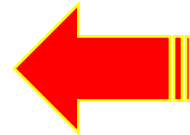
**Ramathibodi Hospital**



# EEG patterns in encephalopathy

**Clinical:** encephalopathy

**Electro-clinical correlations**



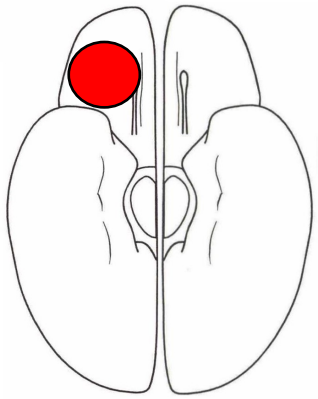
**EEG:** Degree of cerebral dysfunction

Seizure detection

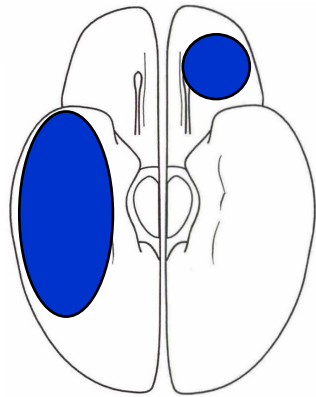
Clues for etiology of encephalopathy

# EEG

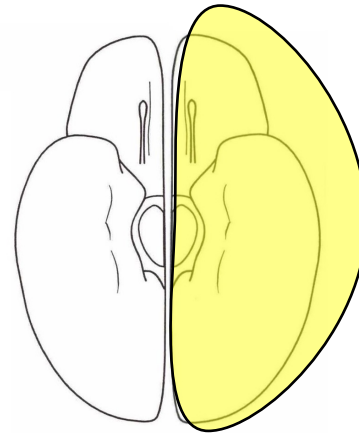
- Degree of cerebral dysfunction
- Areas of cerebral dysfunction



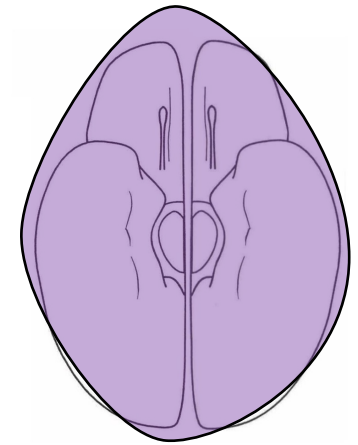
Focal



Multi-focal



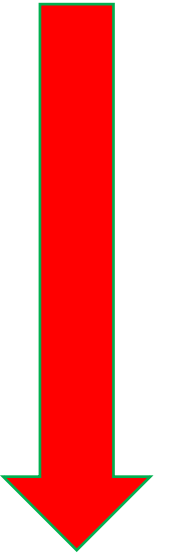
Lateralized



Diffuse

# EEG in encephalopathic patients

- Usually good correlation between EEG and depth of encephalopathy
  - Loss of PDR and slowing
  - Loss of EEG variability and reactivity
  - Loss of continuity, attenuation then suppression

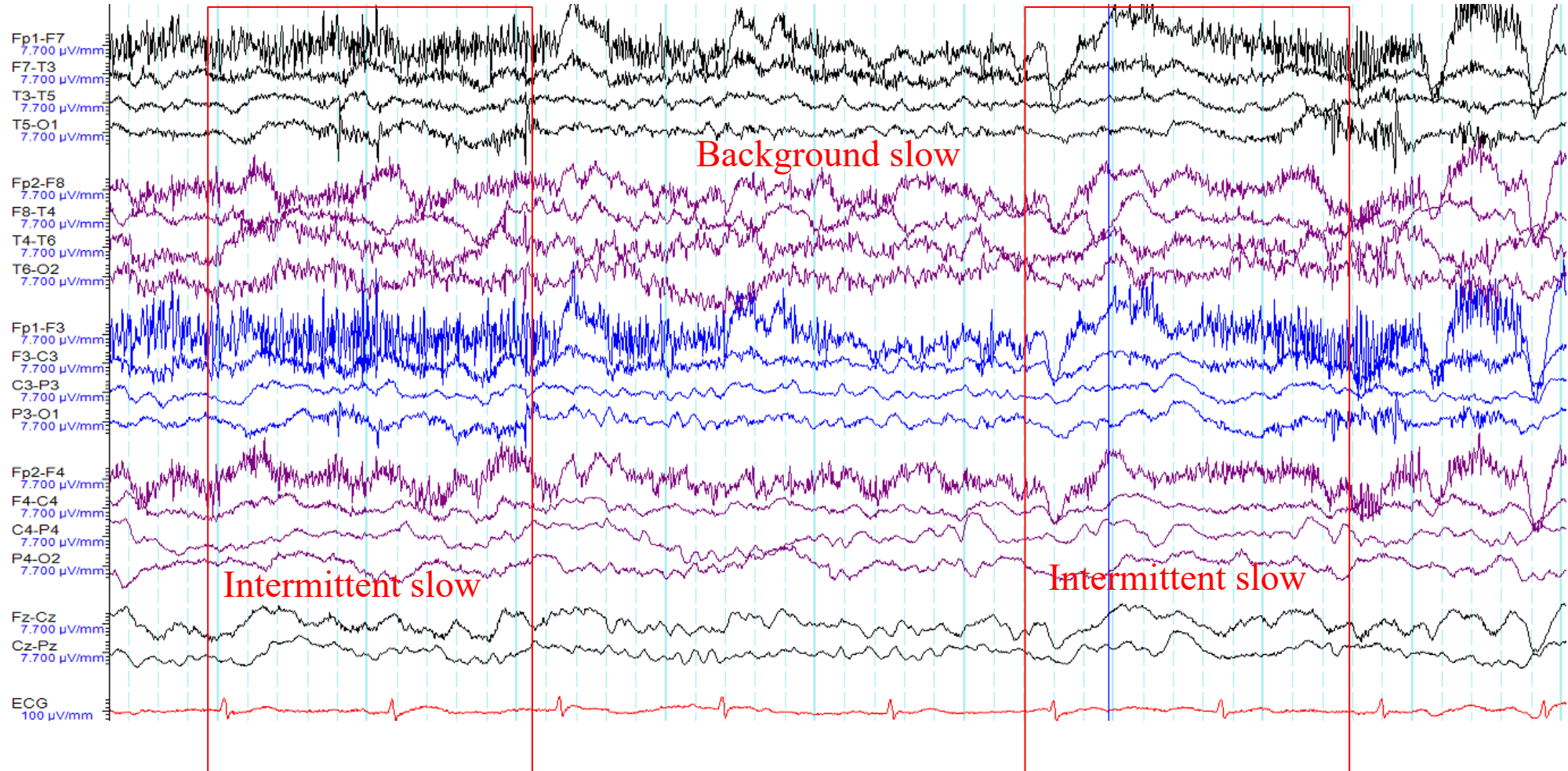


**worse**

# EEG patterns in encephalopathy

- Slow waves
  - Focal
  - Generalized

# Adult with altered mental status

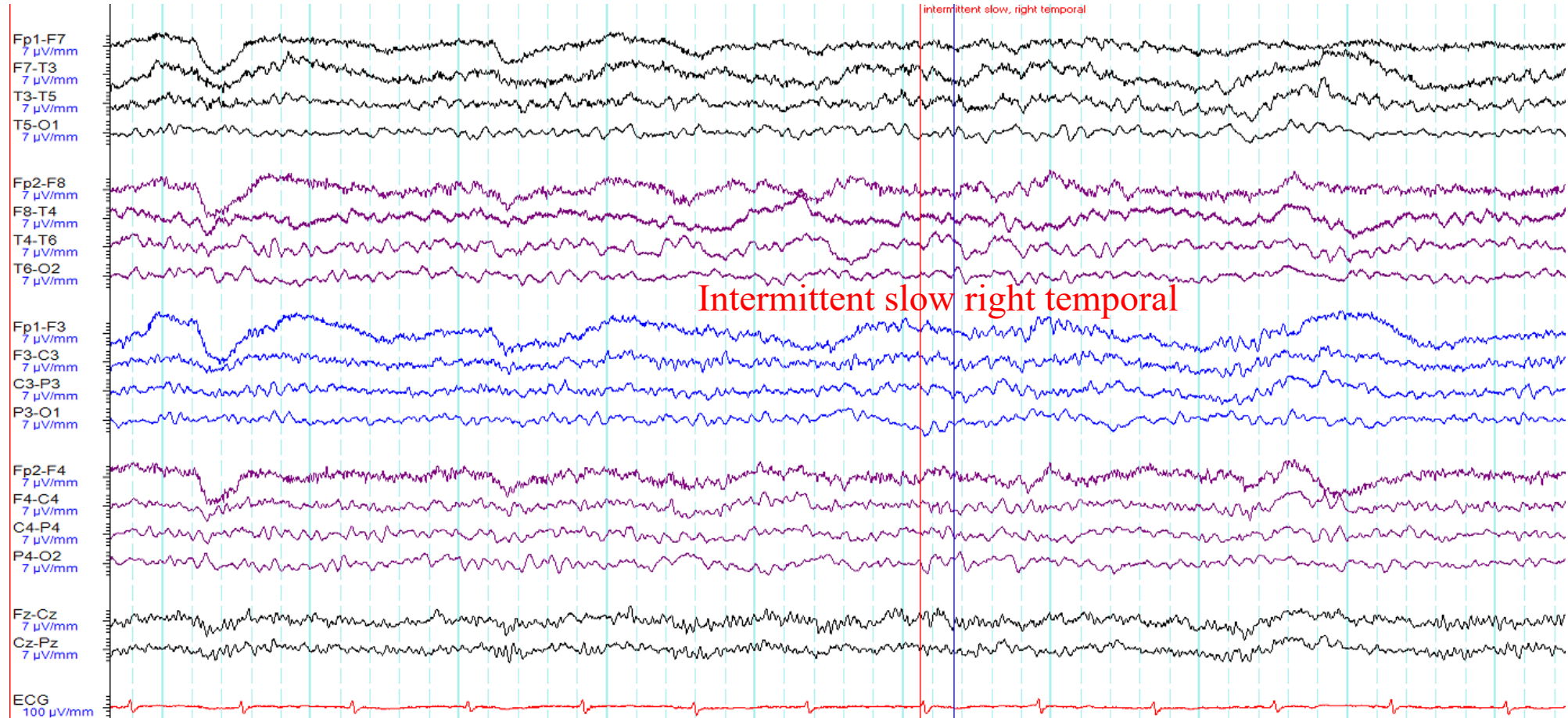




# Focal slowing

- Focal cerebral dysfunction

# Adult with behavioral changes



# Polymorphic delta activity (PDA)

- Characteristic:  $< 4$  Hz, no sustained rhythmicity, changing morphology and voltage
- Clinical significance: structural lesion or subcortical dysfunction

# Generalized slowing

- Bilateral cerebral dysfunction

# **Generalized asynchronous slow activity/ diffuse slowing**

- Mild encephalopathy 7-8 Hz
- Moderately severe diffuse encephalopathy (4-7Hz)
- Severe (0 - < 4 Hz)

# Rhythmic and periodic patterns in encephalopathy

- GRDA
- GPDs
- Triphasic waves

# Generalized rhythmic delta activity (GRDA)

- Characteristics: repetitive, generalized, monomorphic, rhythmic delta frequency
- Frontally predominant GRDA(FIRDA)
  - toxic metabolic encephalopathy
  - process that involves deep subcortical or cortical structural lesions
  - elevated ICP
- Occipitally predominant GRDA (ORIDA)
  - absence epilepsy

# Generalized periodic discharges(GPDs)

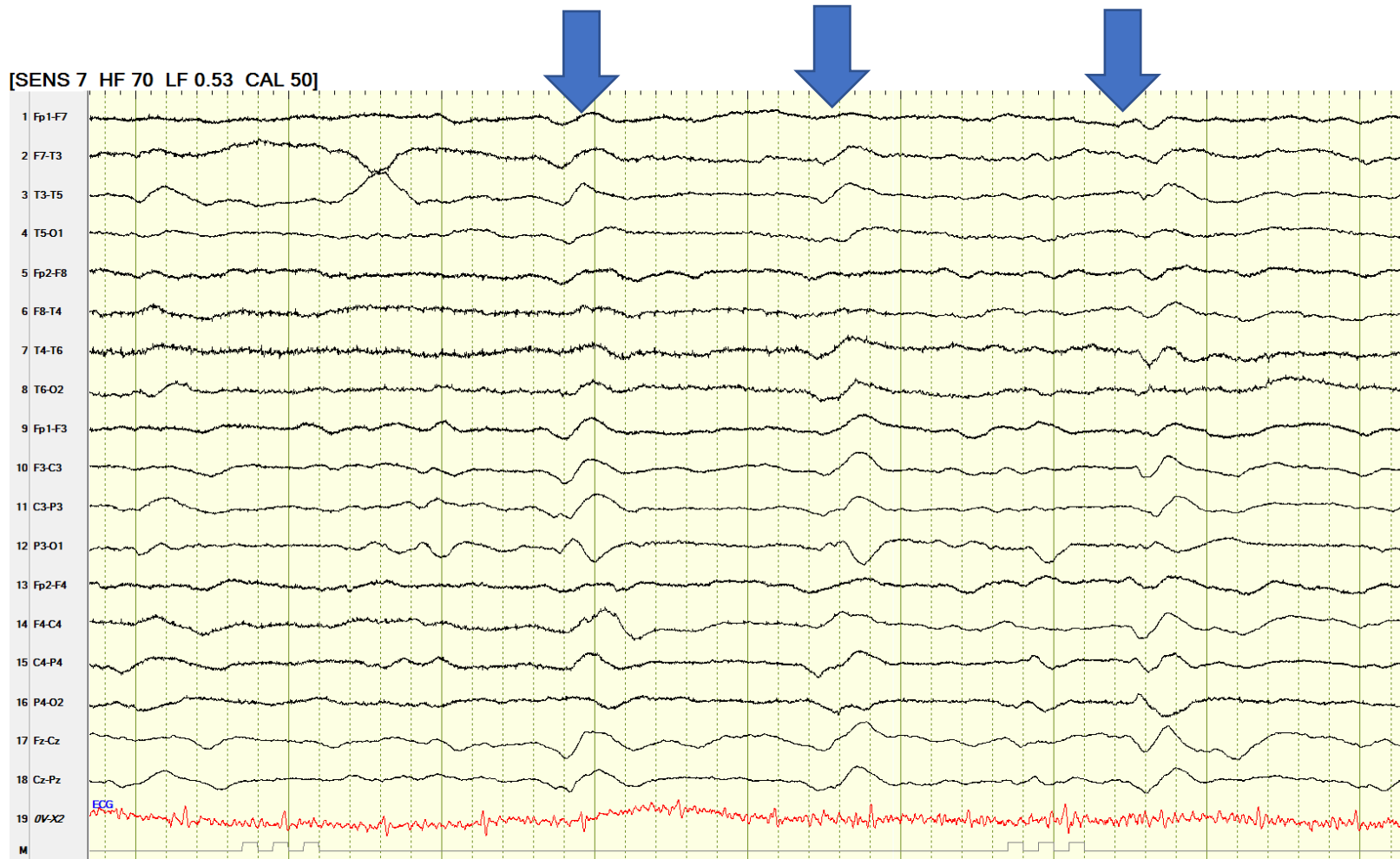




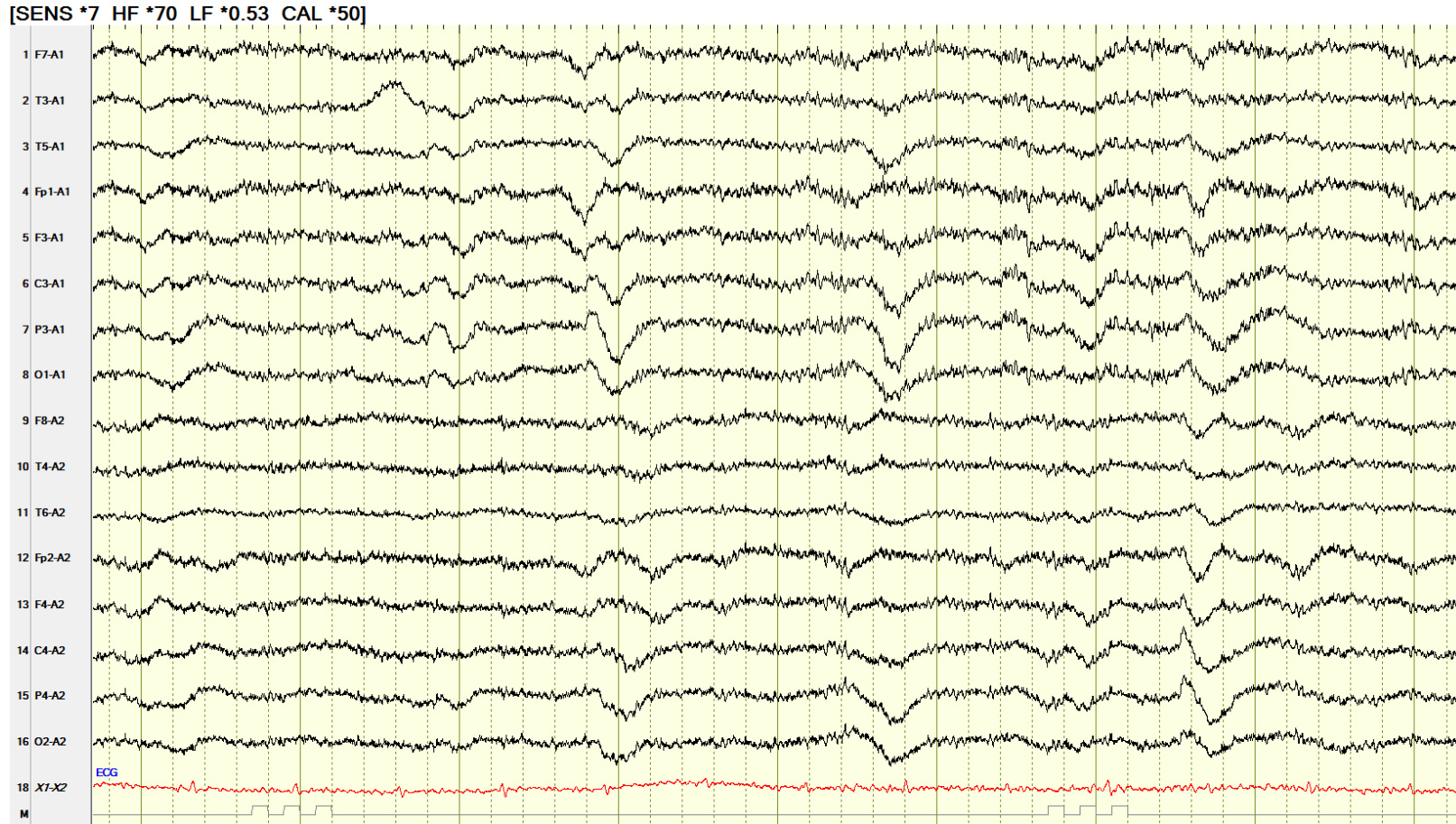
# Triphasic waves

- Triphasic waves (TW) are blunt, delta (2 to 3 Hz) waves which consist of a high-voltage positive wave preceded and followed by lower amplitude negative waves.
- TW are often present symmetrically and synchronously and are often generalized, though they can have a frontal predominance.
- The major positive component often has a fronto-occipital phase lag, which is best appreciated in an anterior-posterior bipolar montage.
- Clinical significance: metabolic encephalopathies  
neurodegenerative disorders

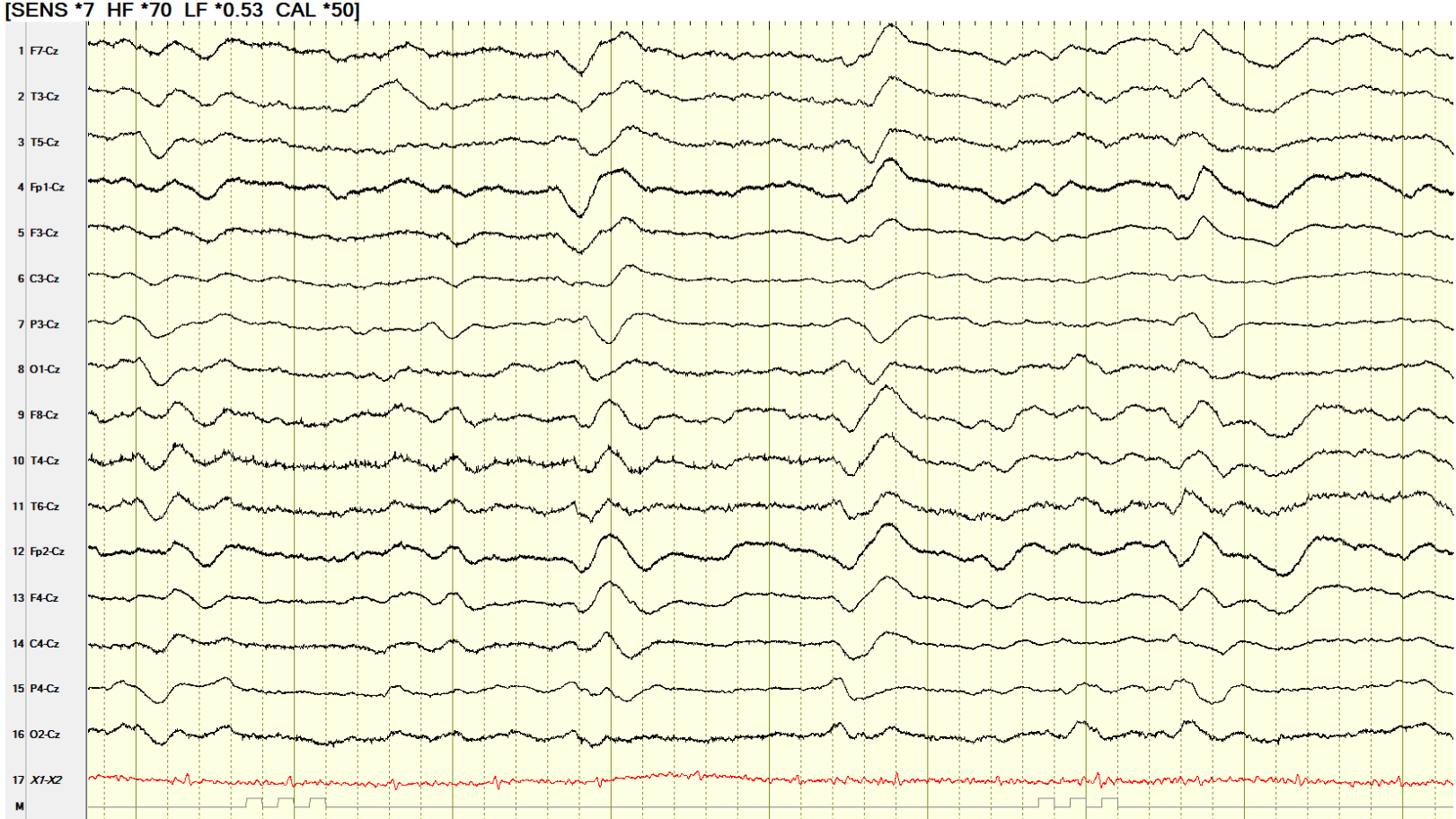
# Case A: Adult with hepatic failure



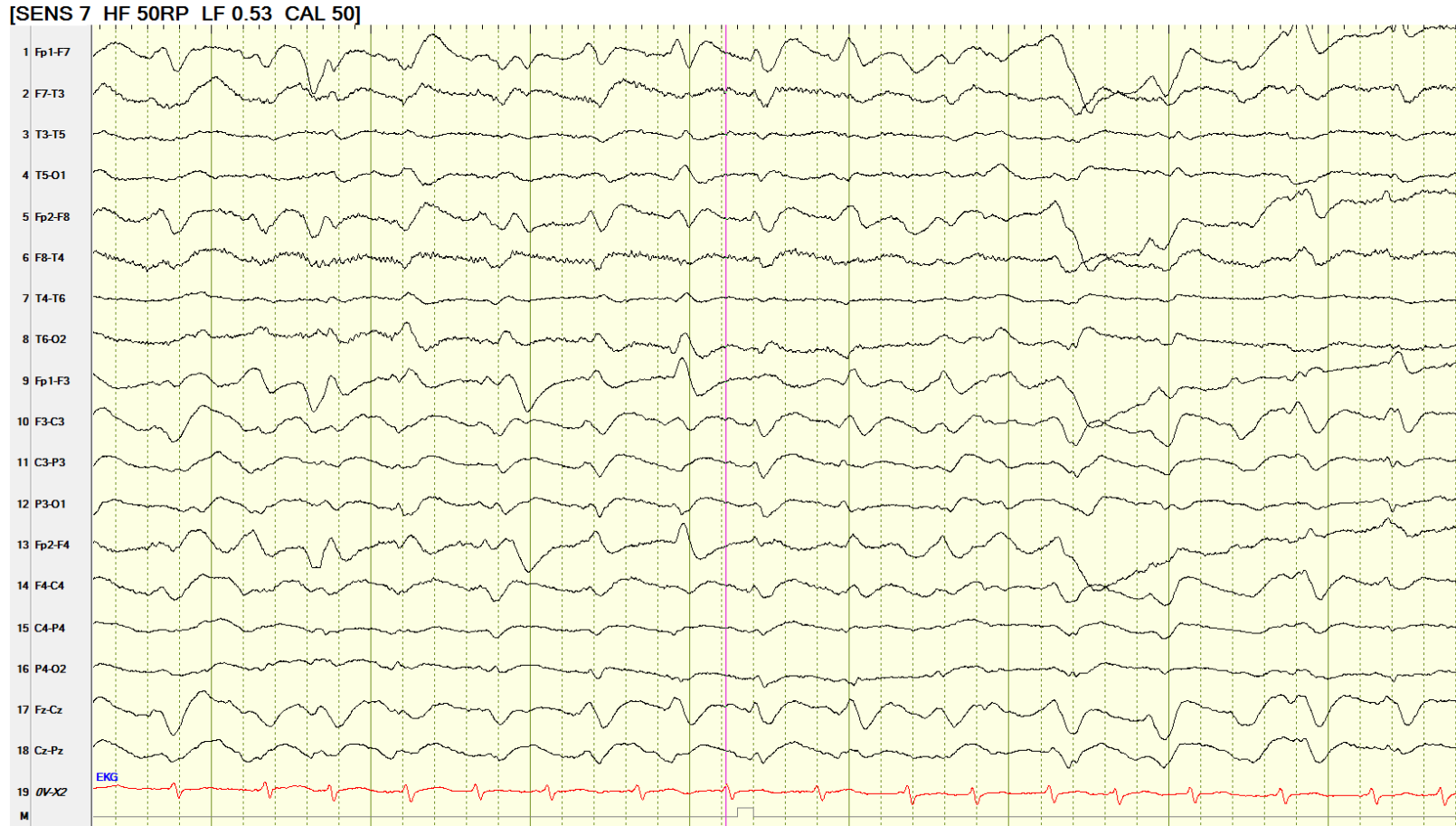
# A reference



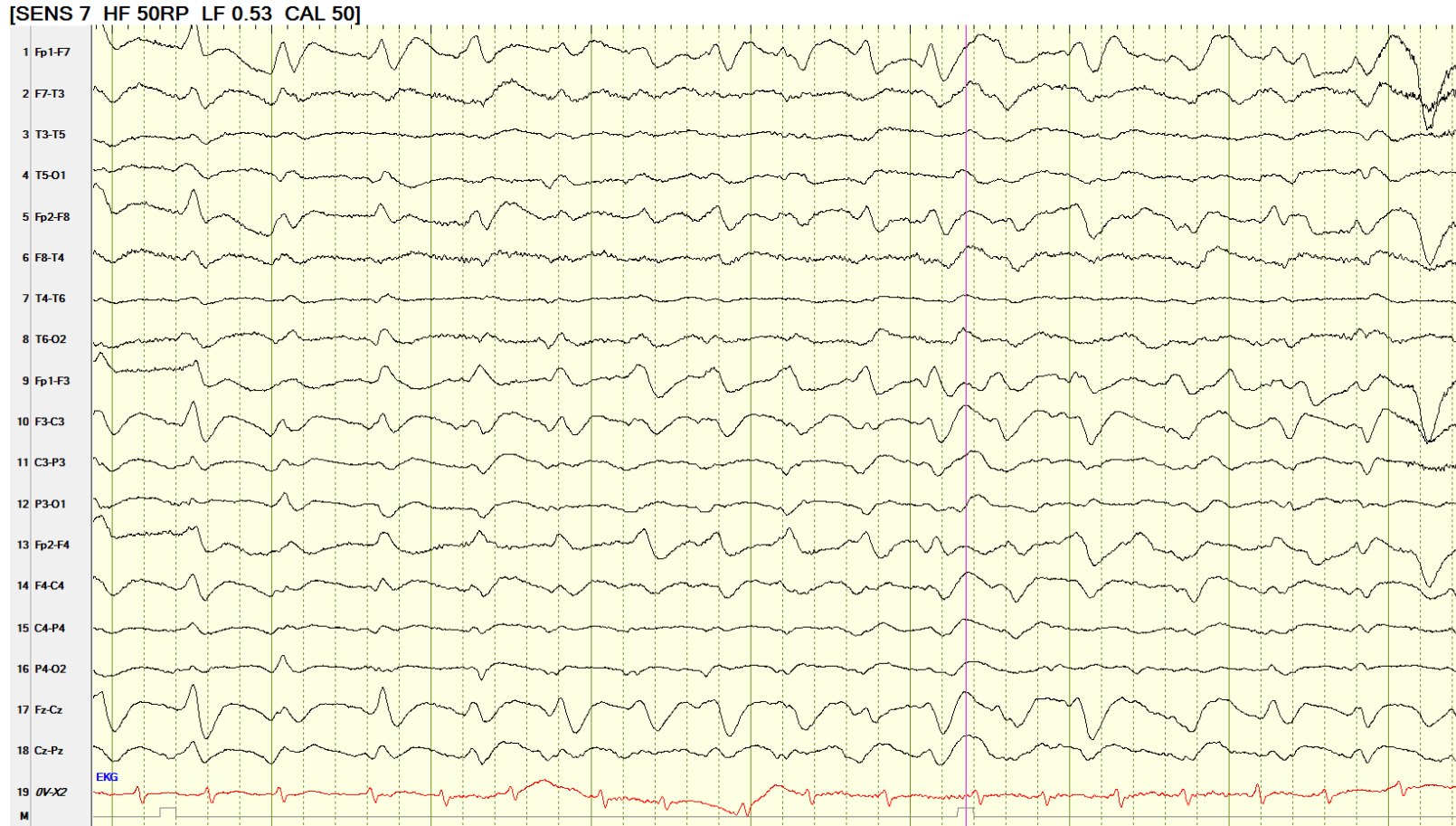
# Cz reference



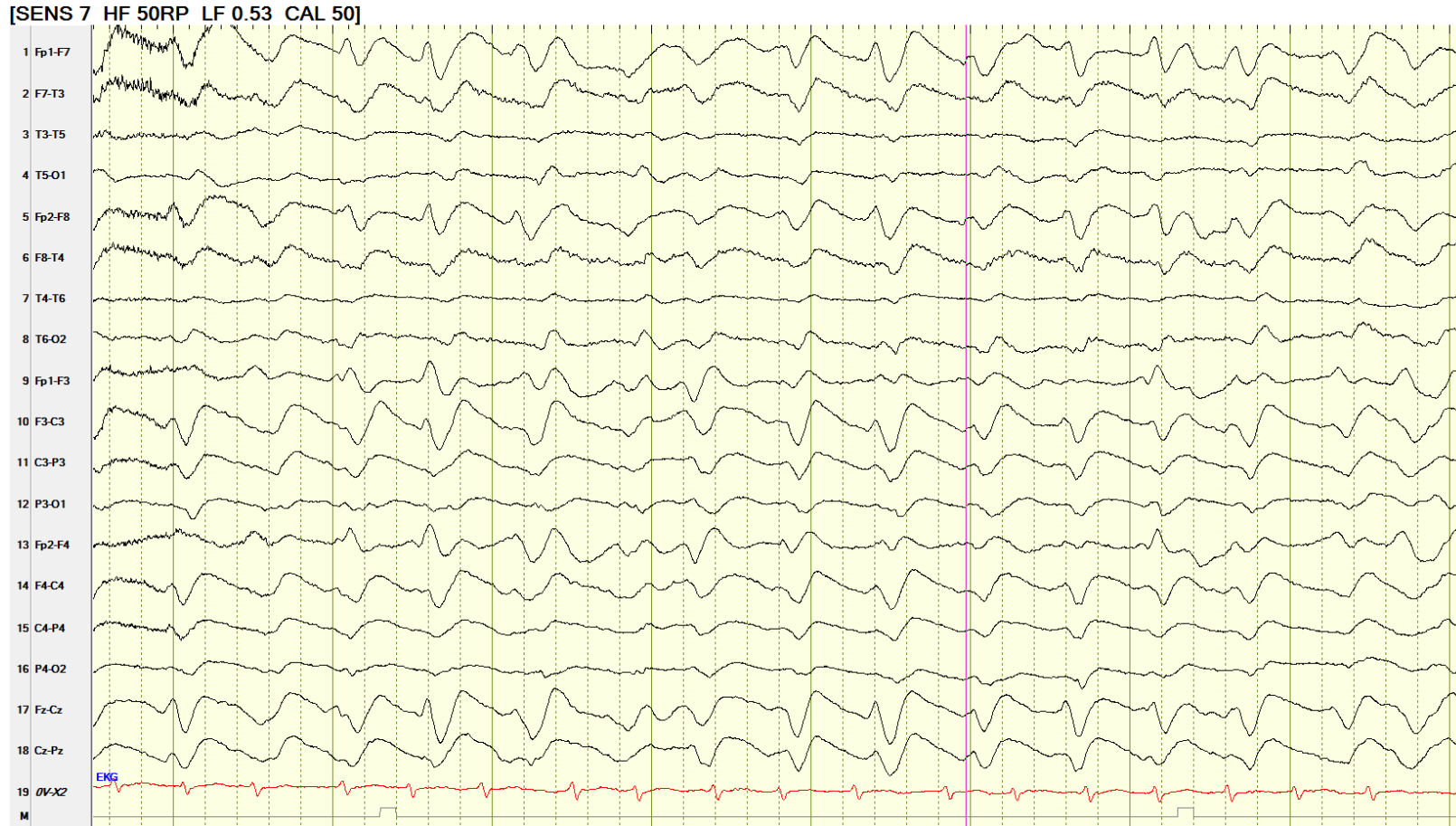
# Case B: Adult with PMH of decompensated liver cirrhosis



# Triphasic waves (GPDs with triphasic morphology)



# Triphasic waves (GPDs with triphasic morphology)



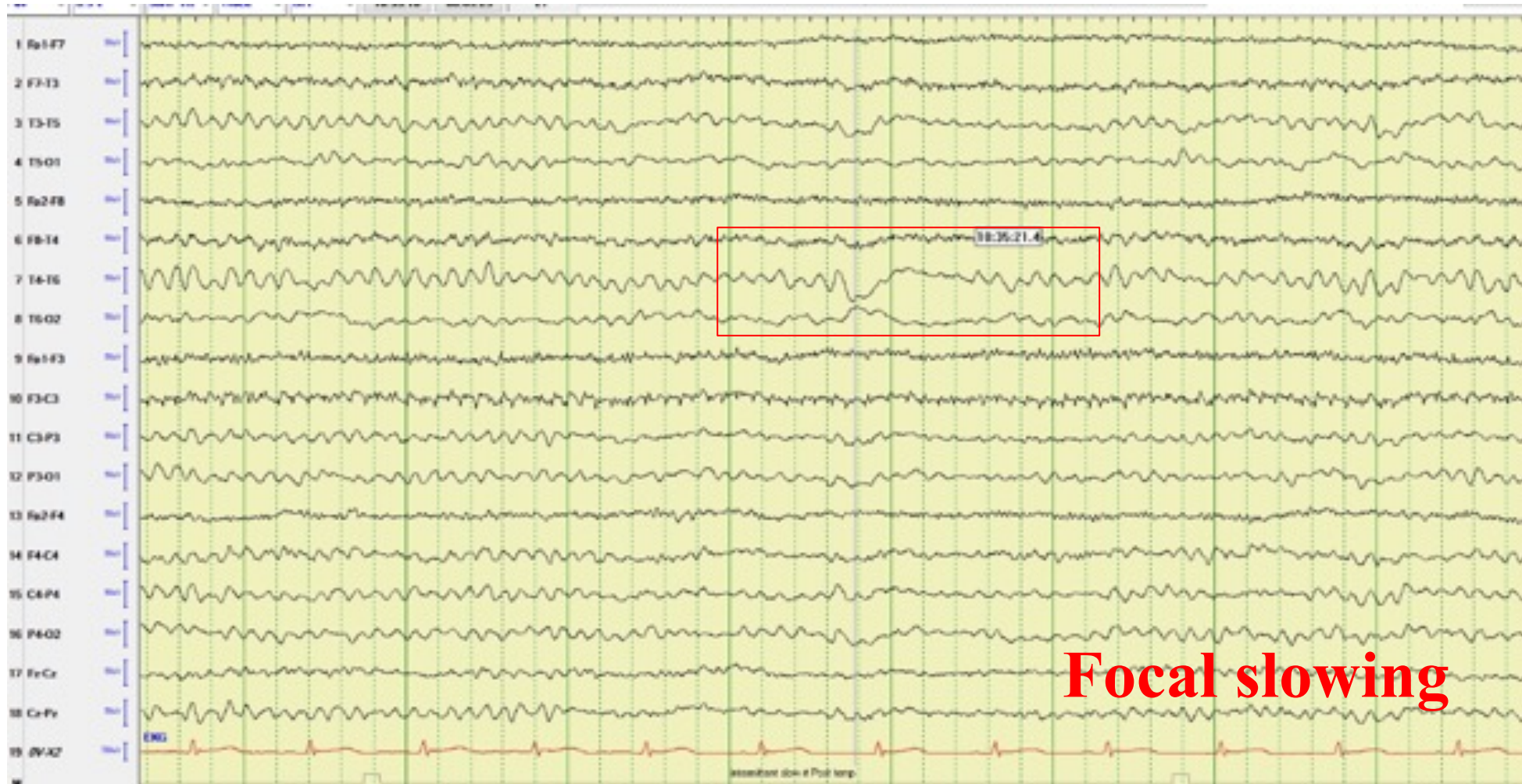
# Specific and suggestive EEG patterns



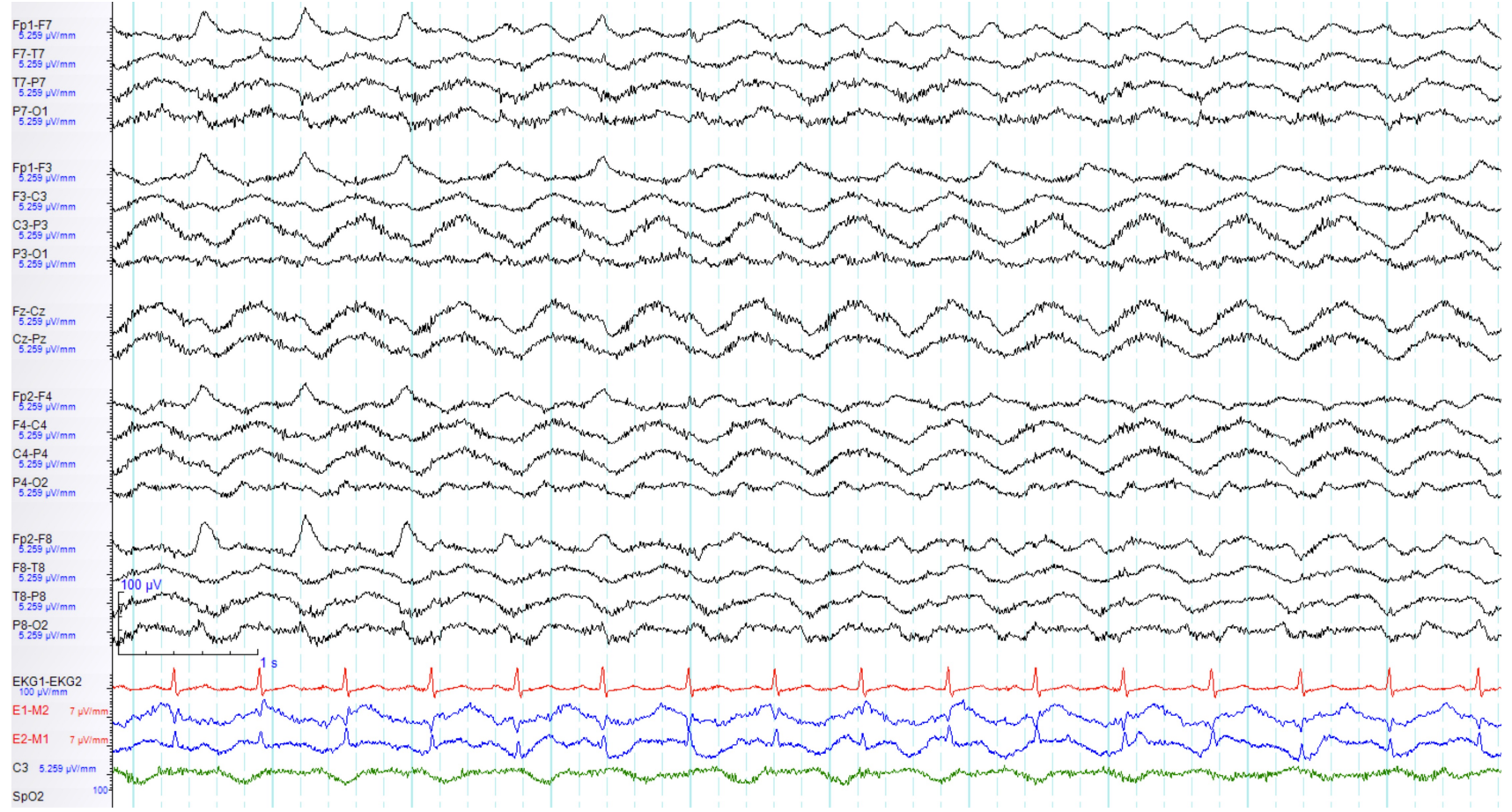
# Anti-NMDAR encephalopathy

- EEG findings
  - slow waves
  - extreme delta brush, a finding associated with a more prolonged illness
  - extreme spindles

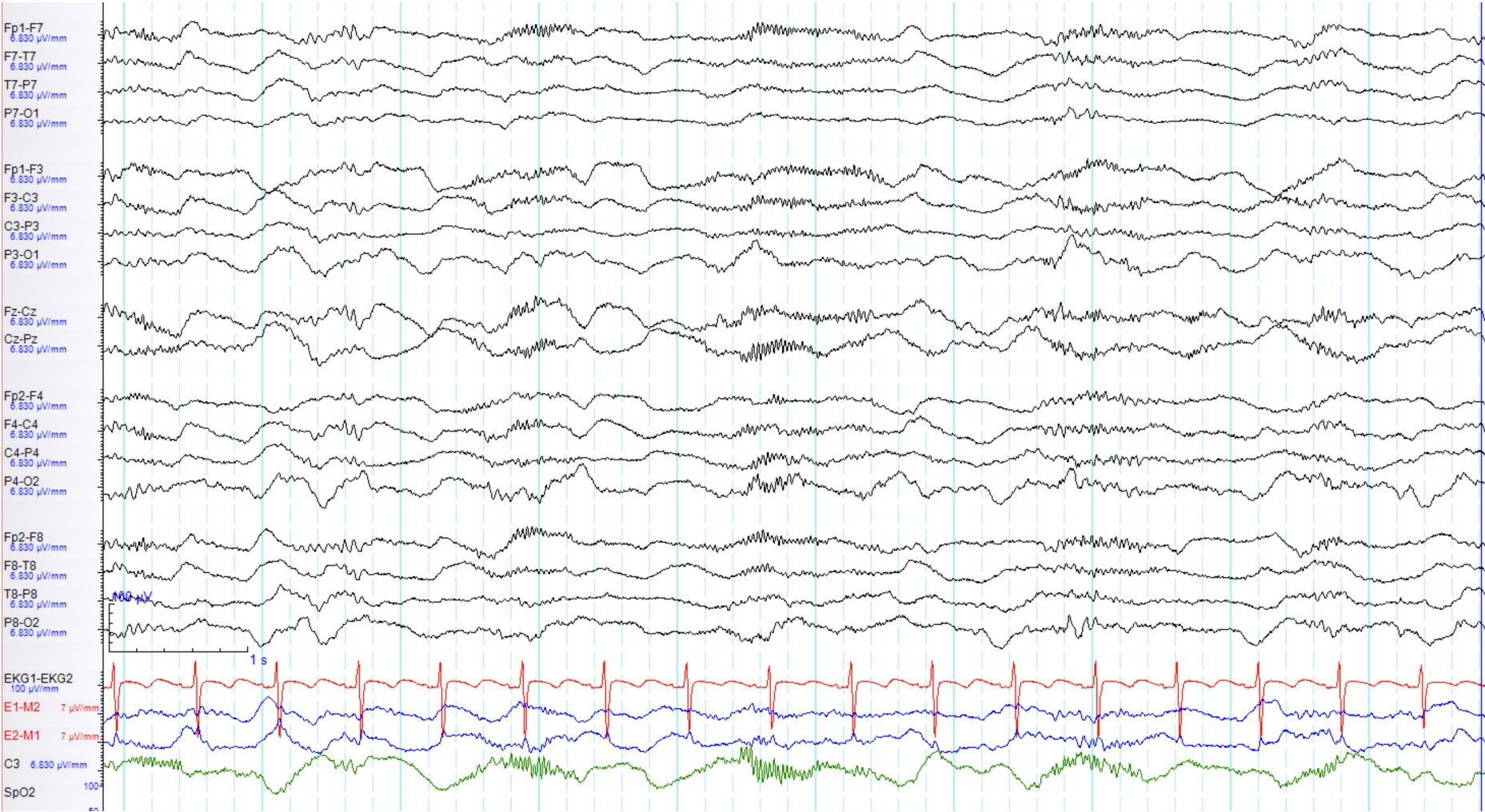
# Adult with NMDA receptor encephalitis



# Extreme delta brush



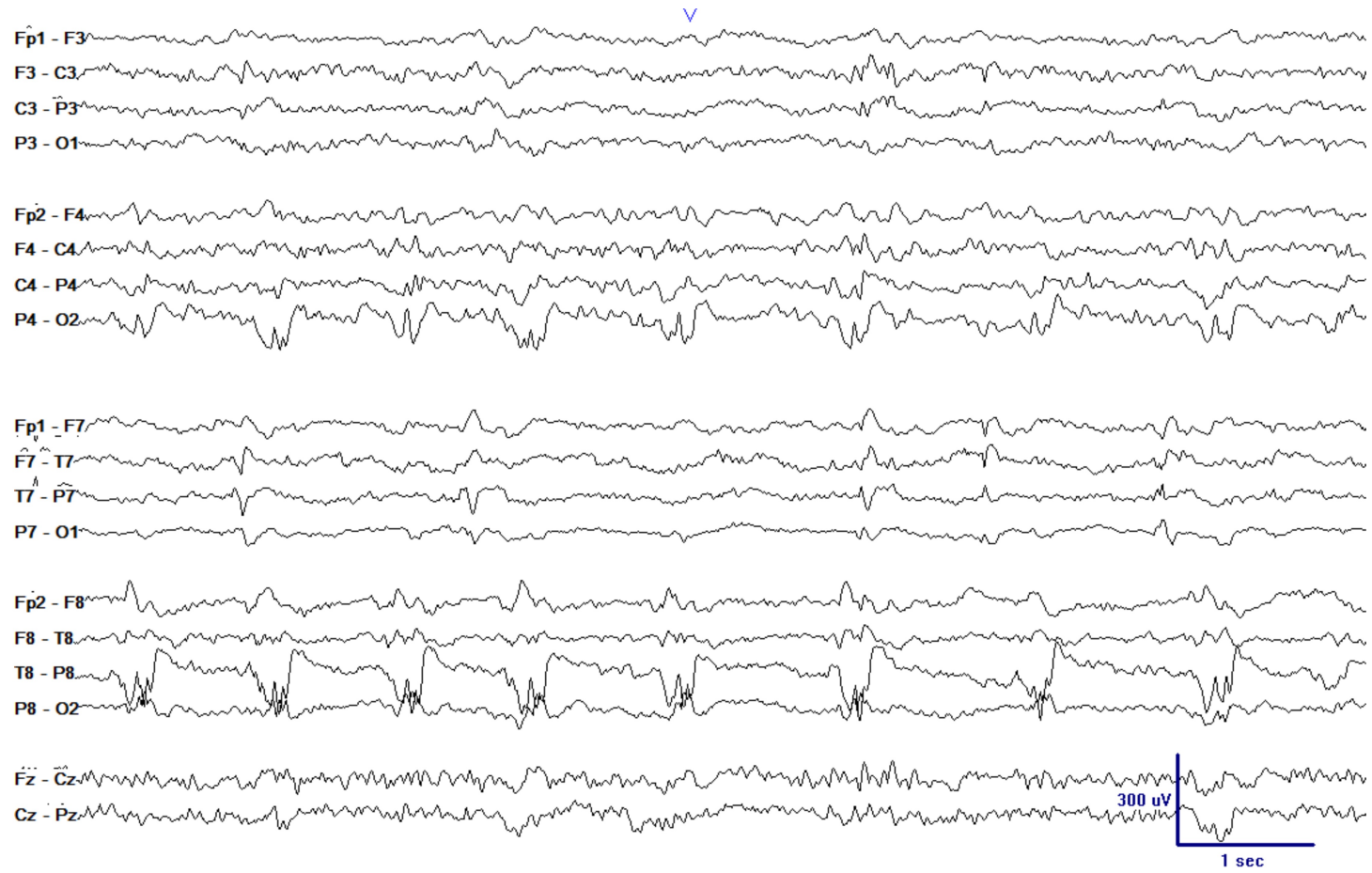
# Extreme spindles



# PRES

- Posterior LPDs and BIPDs

# Posterior BIPDS in PRES



# Sedation

- Delta/alpha and Delta/beta pattern
  - sedation
  - drug intoxication (benzodiazepines, barbiturates)

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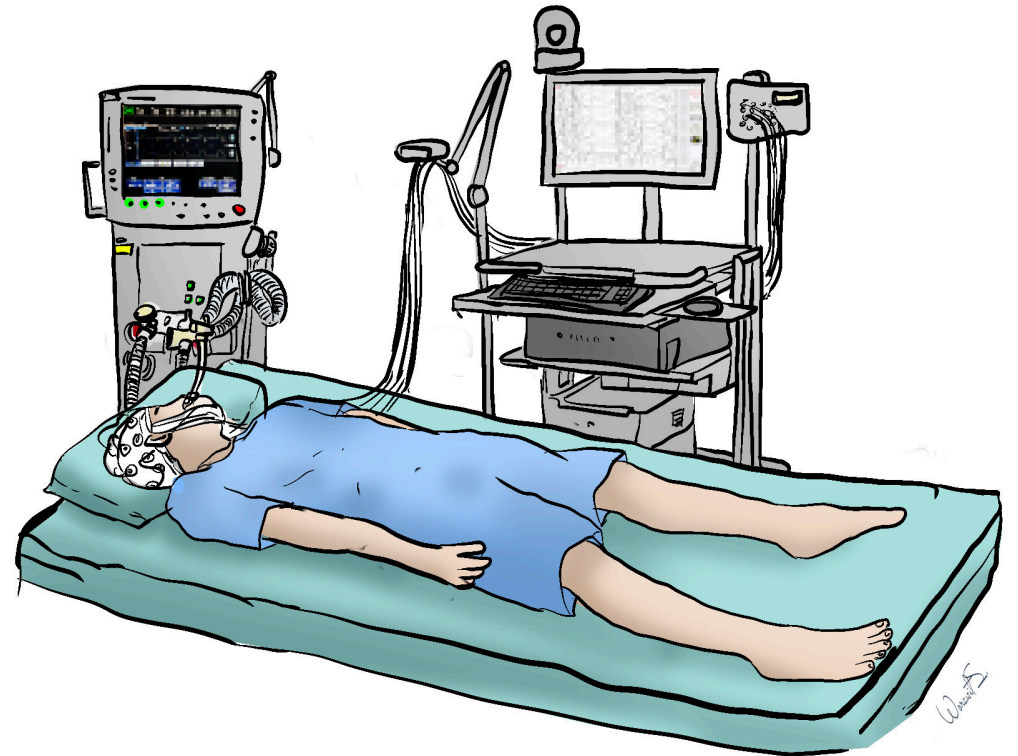
สมาคมโรคลมชักแห่งประเทศไทย

# EEG patterns in coma

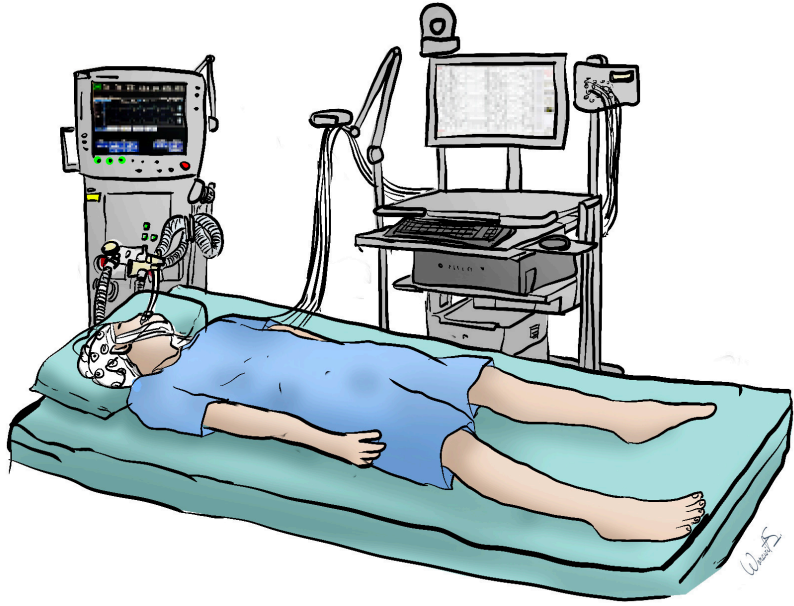
**Assistant Professor. Apisit Boongird**

**Division of Neurology**

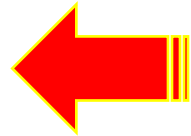
**Ramathibodi Hospital**







**Electro-clinical correlations**



# EEG patterns in coma

**Clinical:** coma

**EEG:** Degree of cerebral dysfunction

Seizure detection

Clues for etiology of coma

Prediction of prognosis

# Electroencephalographic assessment of coma

- Orderly progression of coma through various EEG patterns does not always occur.
- Many EEG patterns are suggestive of the degree of impairment rather than being specific for a cause of the coma.

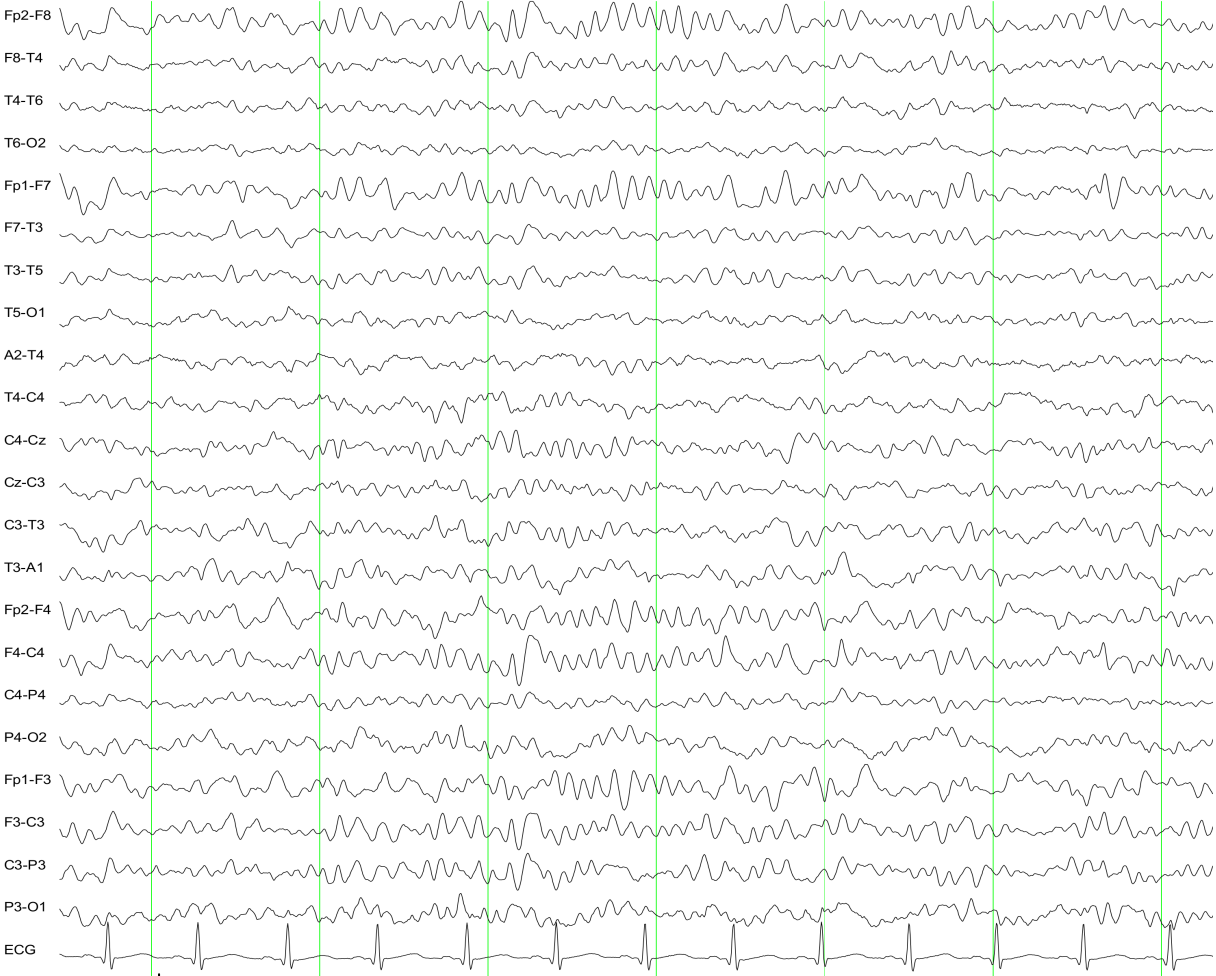
# Classification System for Coma

Grade	EEG findings
I	regular alpha, some theta
II	predominant theta
III	widespread delta (reactive or non-reactive), or spindle coma
IV	burst-suppression pattern; alpha coma pattern, theta coma pattern or delta (< 20uV)
V	flat (< 2uV)

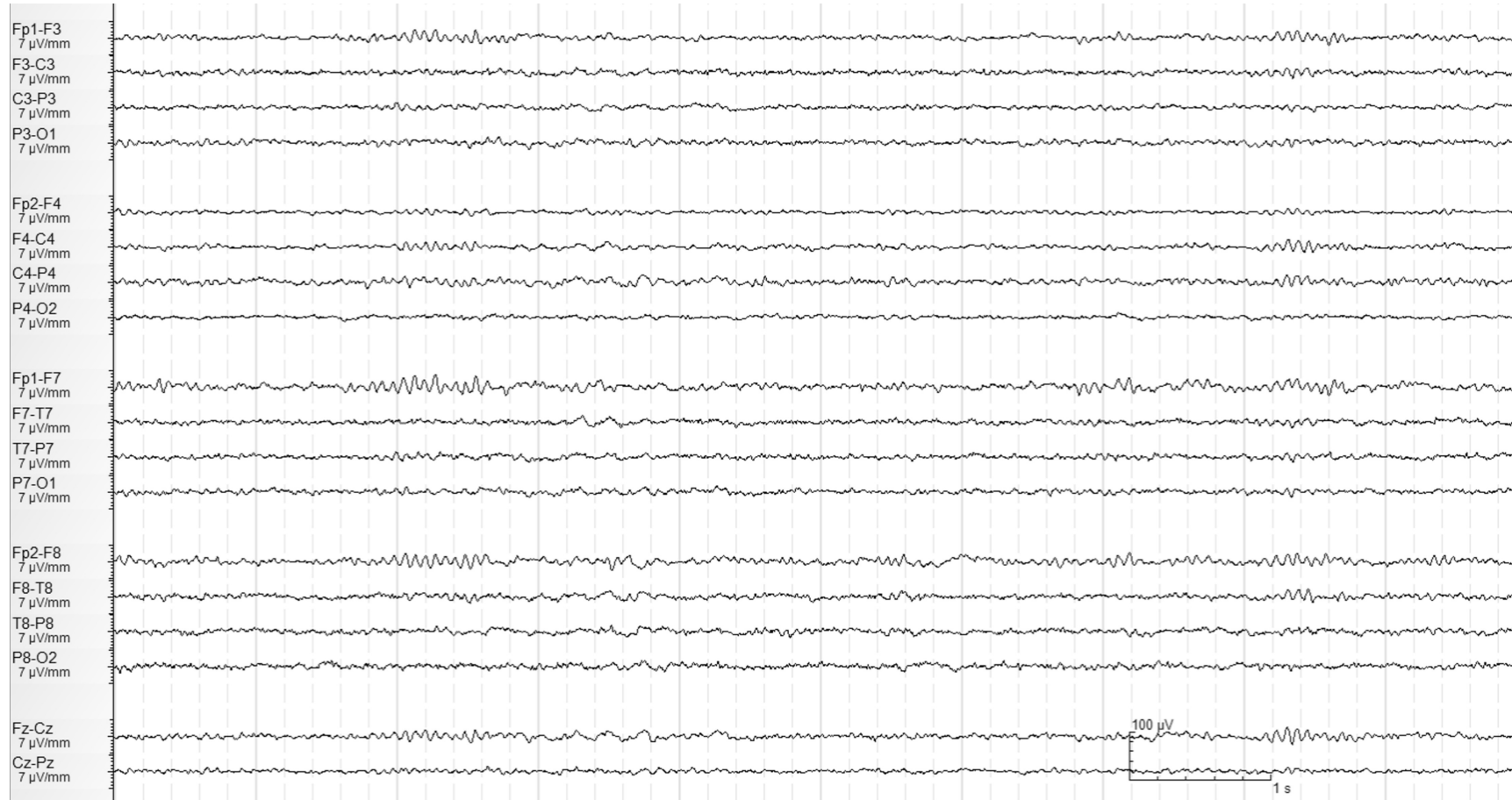
# Rhythmic coma patterns

- Continuous, unreactive monomorphic rhythmic activity, usually diffuse or frontal-predominant
  - Alpha
  - Beta
  - Sleep spindle-like activity
  - Theta
  - Delta
- Unfavorable outcome if the etiology of coma is irreversible

# Alpha coma



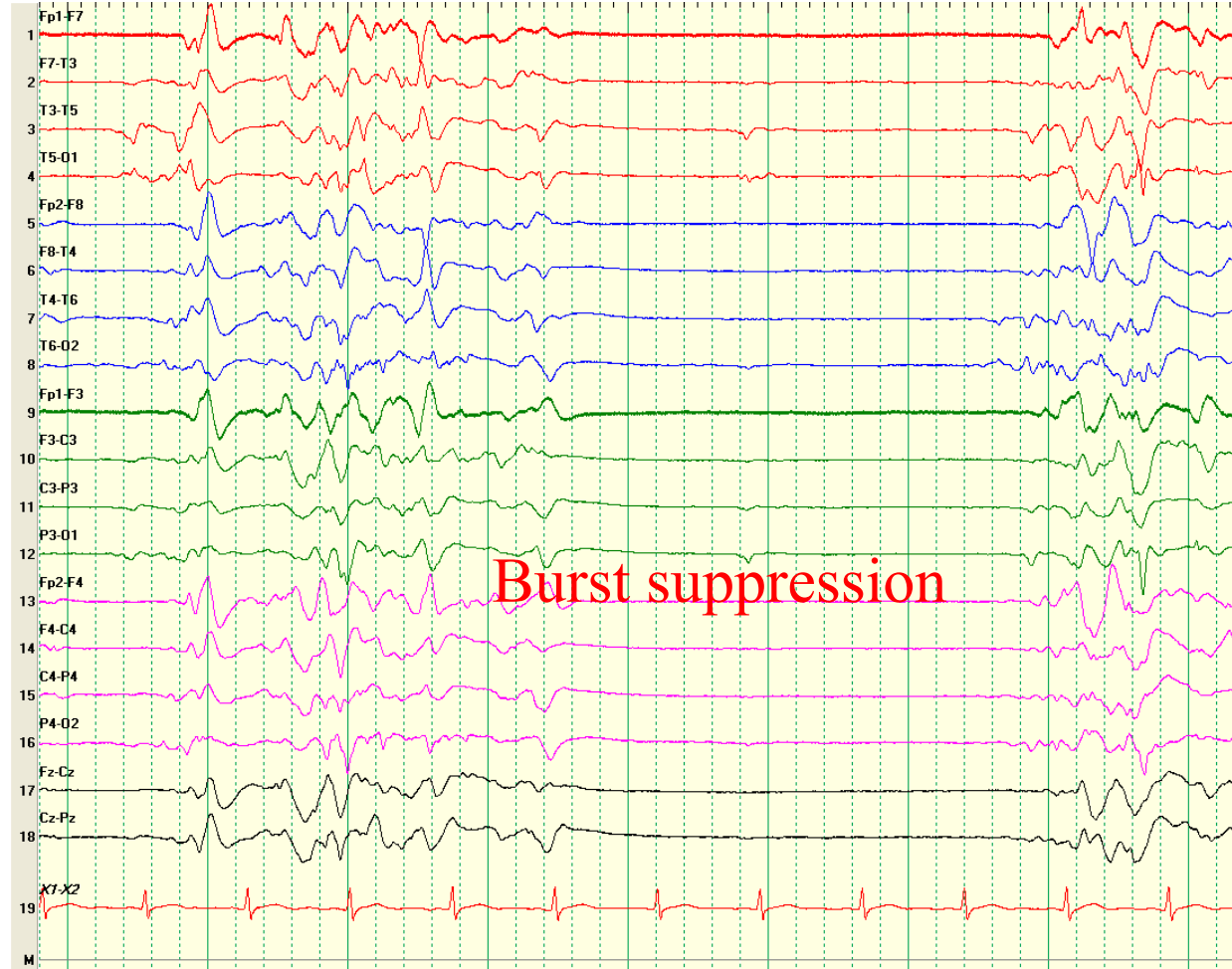
# Spindle coma



# Burst suppression

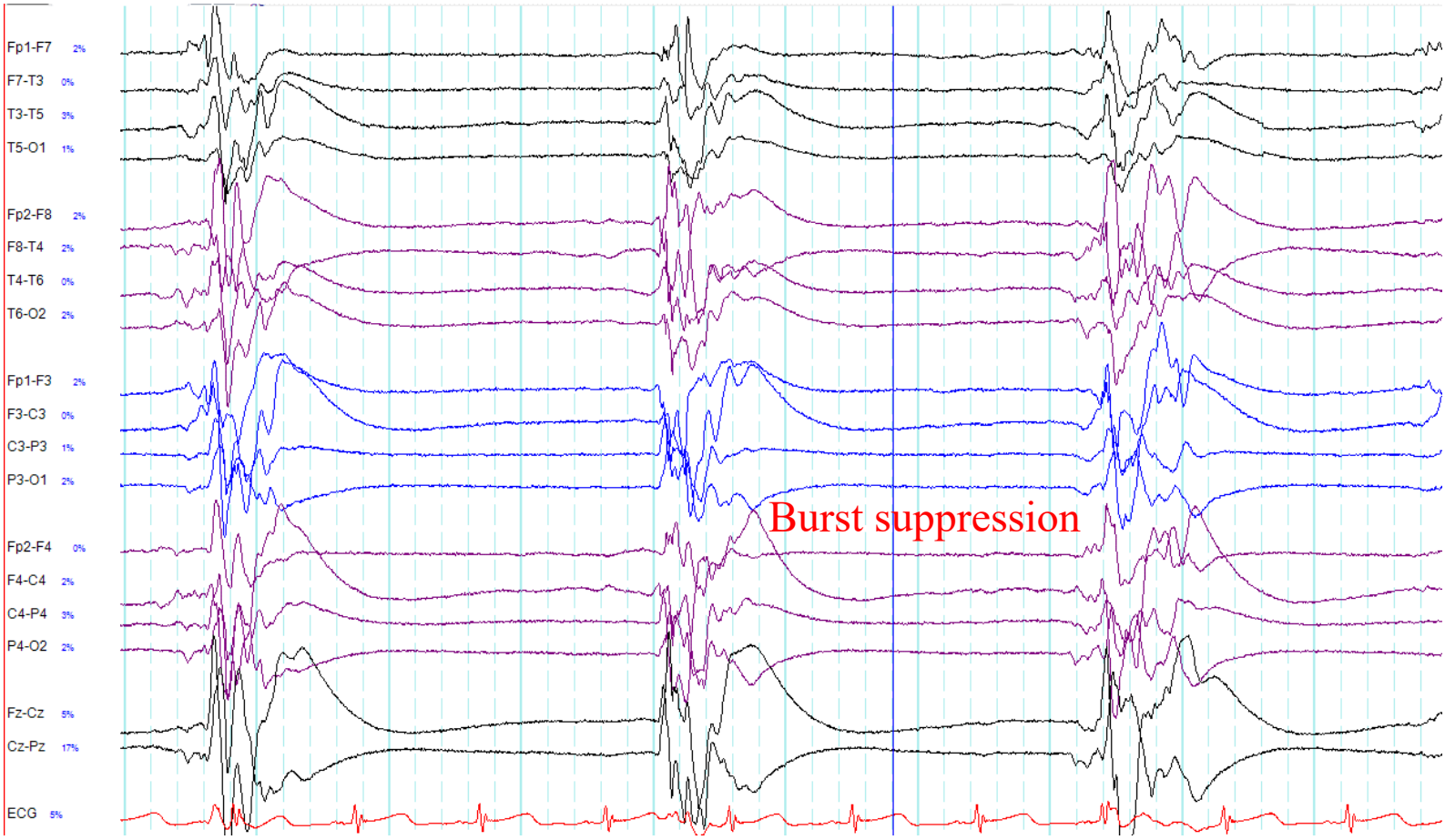
- A burst-suppression pattern is one in which there are generalized, synchronous bursts of high-voltage, mixed-frequency activity alternating with periods of suppression of EEG activity
- There are four major etiologies
  - anoxic encephalopathy
  - intoxication with sedative drugs
  - anesthetic use
  - hypothermia

# Adult with status epilepticus → CIV anesthetic agents





# Adult with postanoxic coma



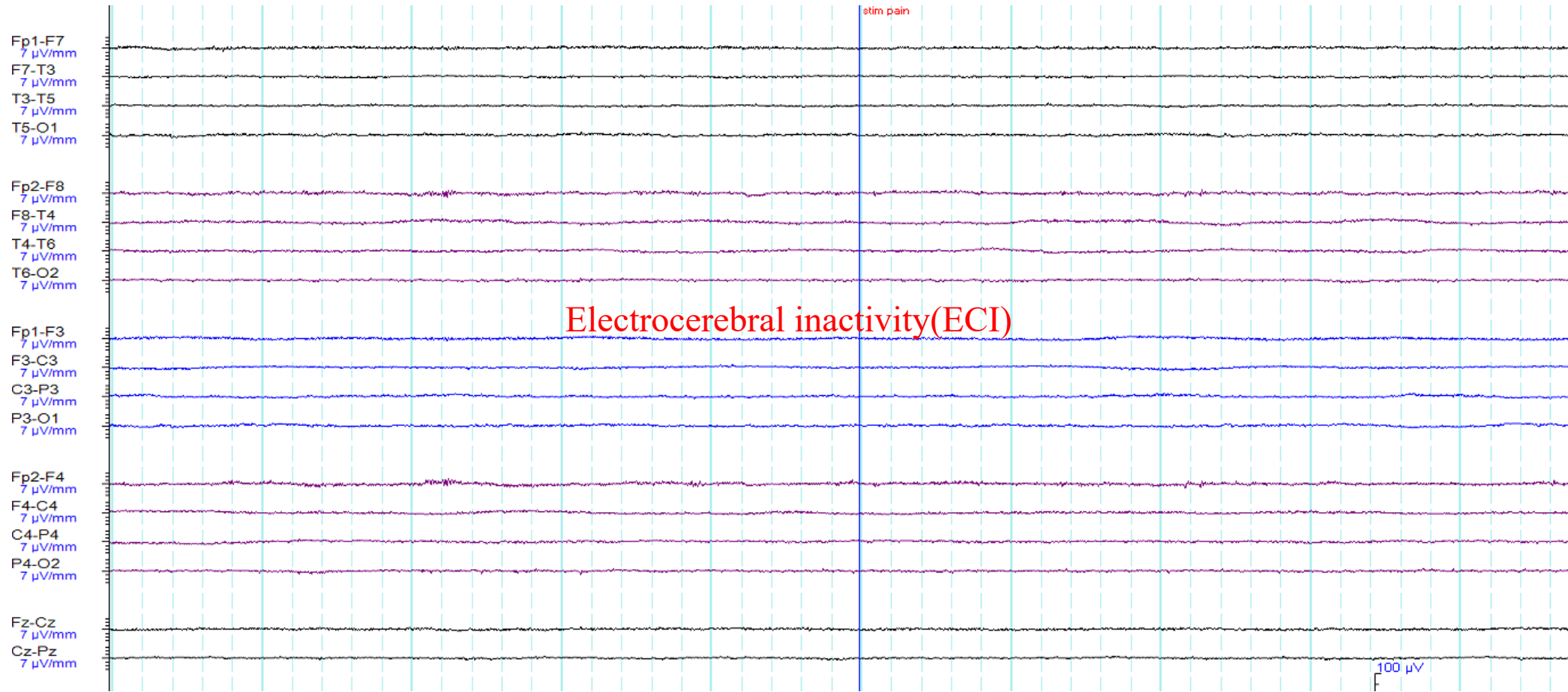
# Low-voltage, slow, nonreactive EEG

- Low-voltage, slow, nonreactive is a descriptive term for an EEG in which the predominant activity is of theta and delta frequencies and the amplitude is less than 20  $\mu\text{V}$ . This activity is persistent and not reactive to stimulation
- **Clinical significance:** widespread cortical and subcortical damage, such as with anoxic encephalopathy and severe head trauma

# Electrocerebral inactivity(ECI)

- Electrocerebral inactivity (ECI) is the term used when there is no discernable EEG activity recordable with scalp electrodes. Discernable EEG activity is activity whose amplitude is greater than 2  $\mu\text{V}$ .

# ECI



# Conclusion

- Usually good correlation between EEG and depth of encephalopathy.
- EEG findings are rarely etiology-specific.
- Electro-clinical correlations are very important.

# Thank you

- Wannisa Wongpipathpong, MD
- Worawit Sukpakkit, MD

Thank you