EEG in the ICU: Part I

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July 2012

Objectives

- To outline the importance of EEG monitoring in the ICU
- To briefly review the neurophysiological basis of EEG
- To introduce formal EEG and subhairline EEG
  - Lead placement
- To present normal features of formal and subhairline EEG
- To discuss the limitations of subhairline EEG

Why is continuous EEG monitoring in the ICU useful?

- To detect nonconvulsive seizures
  - 19-50% of patients with acute neurological conditions have seizures
- To characterise fluctuating or paroxysmal spells
  - e.g. posturing, tremors, agitation
- To identify silent neurological events
  - e.g. ischemic infarction, vasospasm

Jette and Hirsch. *Curr Neuro Neurosci Rep* 2005:;5:312.

What are some common conditions to be monitored?

- Convulsive and nonconvulsive status or seizures
- Coma or encephalopathy of unknown etiology
- Intracerebral hemorrhage
- Ischemic stroke
- Subarachnoid hemorrhage
- Traumatic brain injury

Jette and Hirsch. *Curr Neuro Neurosci Rep* 2005:;5:312.

How long should patients be monitored with cEEG?

- Varies based on clinical situation
- If no particular events then suggest 48 hours
  - 50% of seizures (convulsive or nonconvulsive) are detected within one hour of cEEG
  - 87% within 24 hours
  - 93% within 48 hours

Claassen et al. *Neurology 2004;62:1743*.

What EEG features are most helpful in the ICU?

- Presence of seizures or spikes
- Focal abnormalities (e.g. unilateral suppression or PLEDs)
- Variability
  - Spontaneous variation in waveforms seen
- Reactivity
  - Change in EEG pattern in response to afferent stimulus

Neurophysiological Basis of EEG

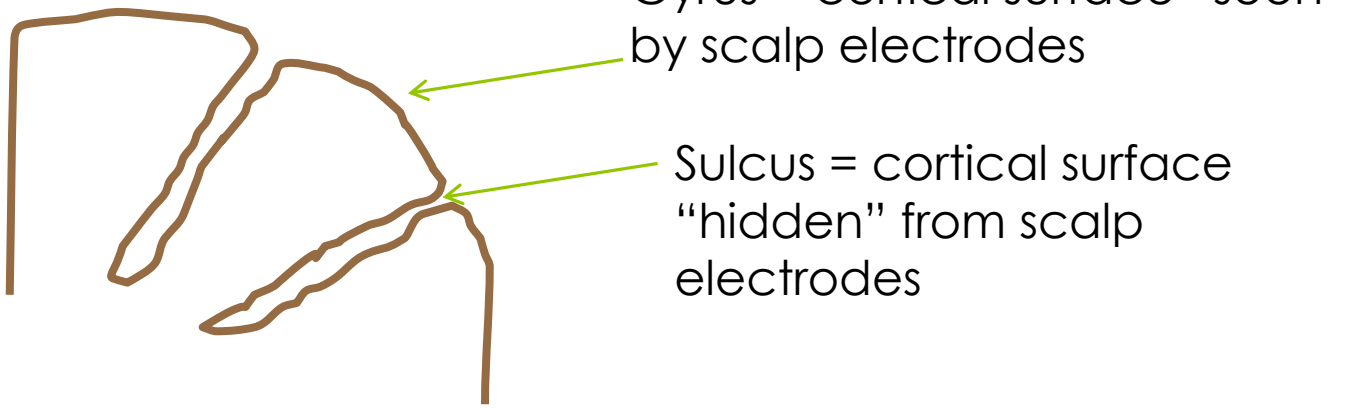
- EEG reflects the electrical activity emanating from the surface of the cortex
- Scalp electrodes detect the sum of neuronal activity
  - The EEG displays the sum of neuronal post-synaptic potentials
  - These post-synaptic potentials consist of either excitatory or inhibitory post-synaptic potentials

Neurophysiological Basis of EEG

- Many neurons must be active together in order to detect their electrical activity on the scalp
  - The electrical activity is dampened as it passes through the CSF, the skull and the soft tissues of the scalp
  - The electrical signal is then amplified by the EEG machine so that it can be read on the digital display

Neurophysiological Basis of EEG

- Not all cortical potentials can be well-detected on the scalp surface
- This is due to the convoluted surface of the brain



Neurophysiological Basis of EEG

- The most important contributor to the EEG activity seen on the scalp is the portion of the cortex parallel with the scalp surface
  - The activity within the sulci is largely 'hidden' from the scalp electrodes

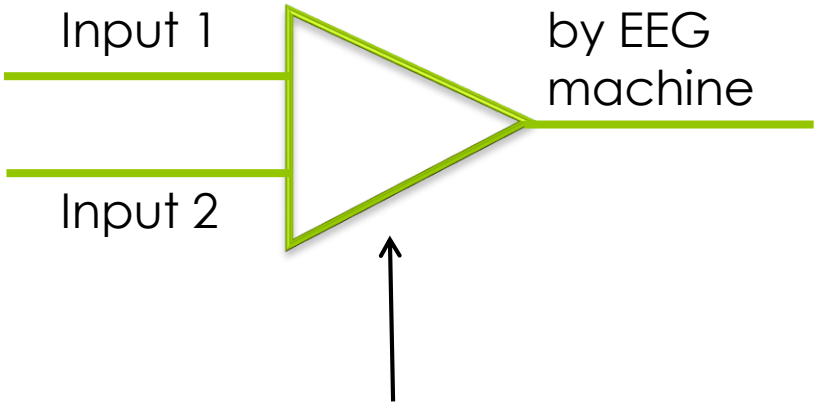
Neurophysiological Basis of EEG

- The most important neurotransmitters responsible for generating neuronal activity include
  - Excitatory = glutamate
  - Inhibitory = GABA
    - GABA = gamma-aminobutyric acid

Differential Amplifiers

- The electrical signal recorded on the scalp is generated using a differential amplifier
- Differential amplifiers have two input electrodes
  - Input 1
  - Input 2
- Any signal common to both inputs is rejected by the amplifier
- Any signal that is different in the two inputs is amplified and displayed on the monitor

Differential Amplifiers

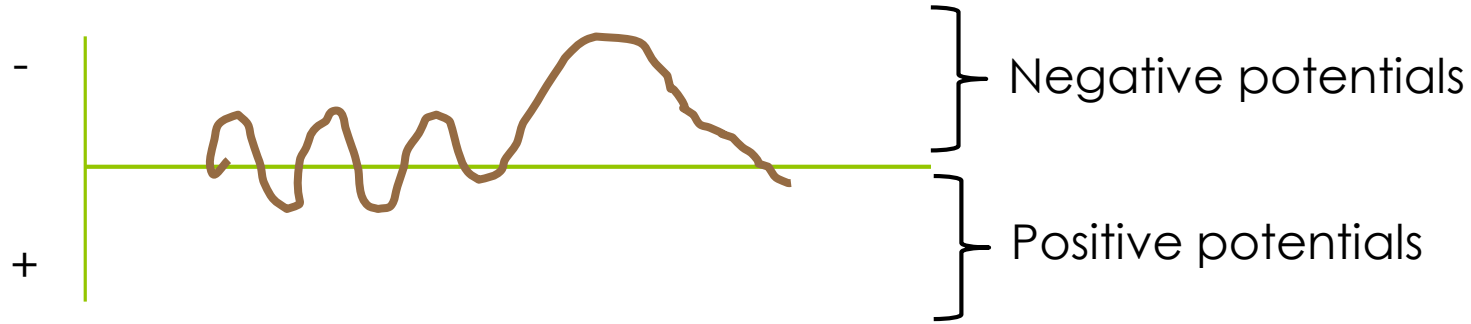


EEG output displayed on the monitor

Differential amplifier:
Rejects signals common to both inputs and amplifies signals that are different in both inputs

Differential Amplifiers

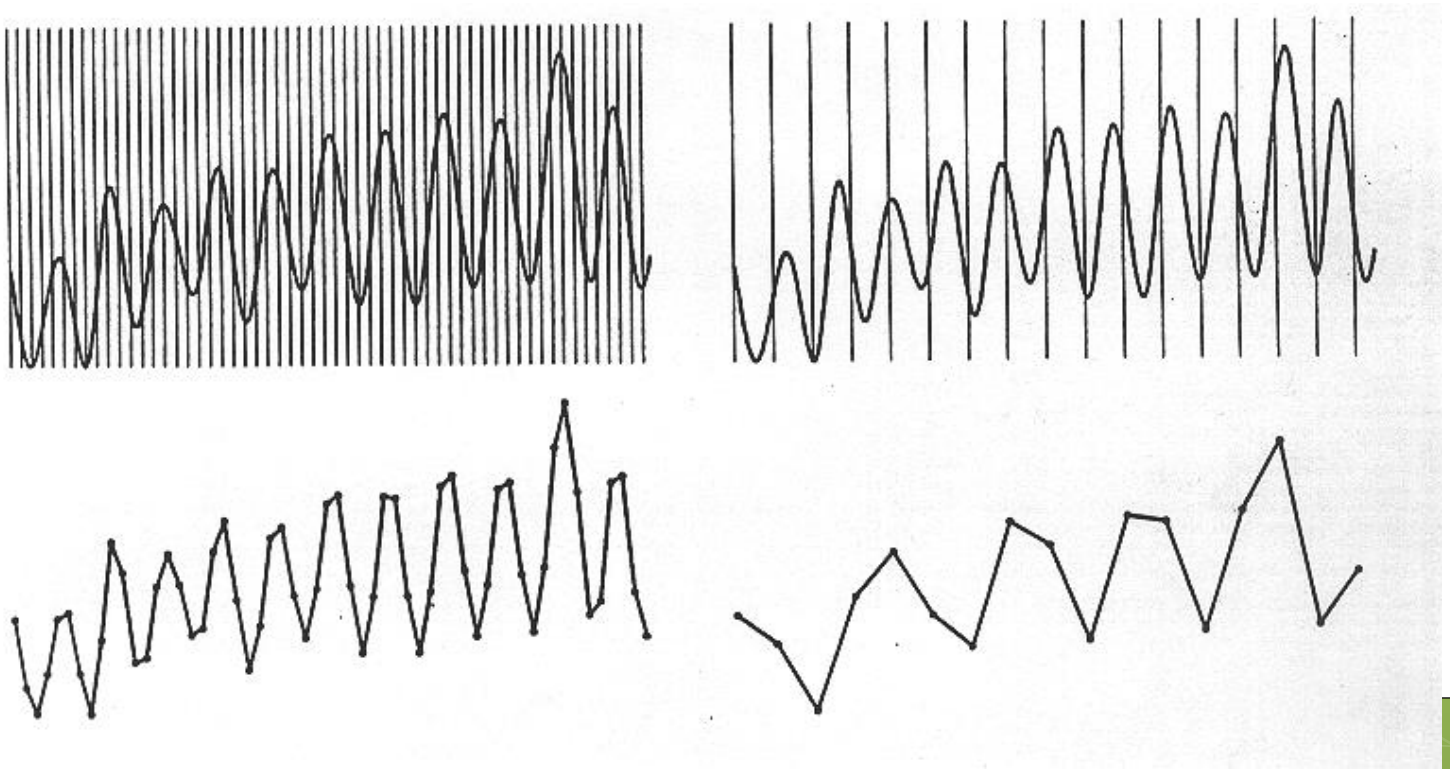
- By convention
  - All negative amplifier outputs result in an upward deflection on the EEG
  - All positive amplifier outputs result in a downward deflection on the EEG



Sampling Rate

- Sampling rate: how often the digital recording apparatus records a data point each second
  - Important for accurate waveform representation (also called aliasing)
- Formal EEG samples data at 250 samples per second
- Subhairline EEG samples data at 100 samples per second

- If the same waveform is sampled at two different sampling rates it will look different
- If the sampling rate is too low then the output waveform will appear slower than it really is → this is *aliasing*
- This waveform is alpha, but looks like delta



Formal EEG

- In order to understand the subhairline EEG, a basic understanding of the formal EEG is required

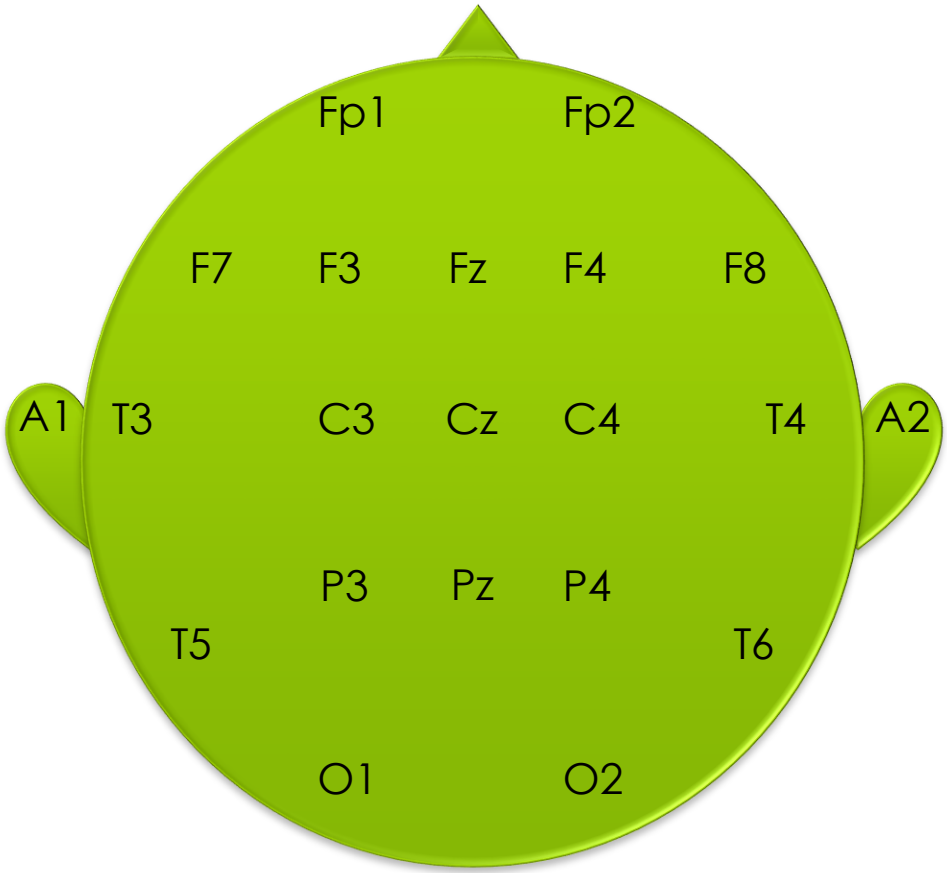
EEG electrodes

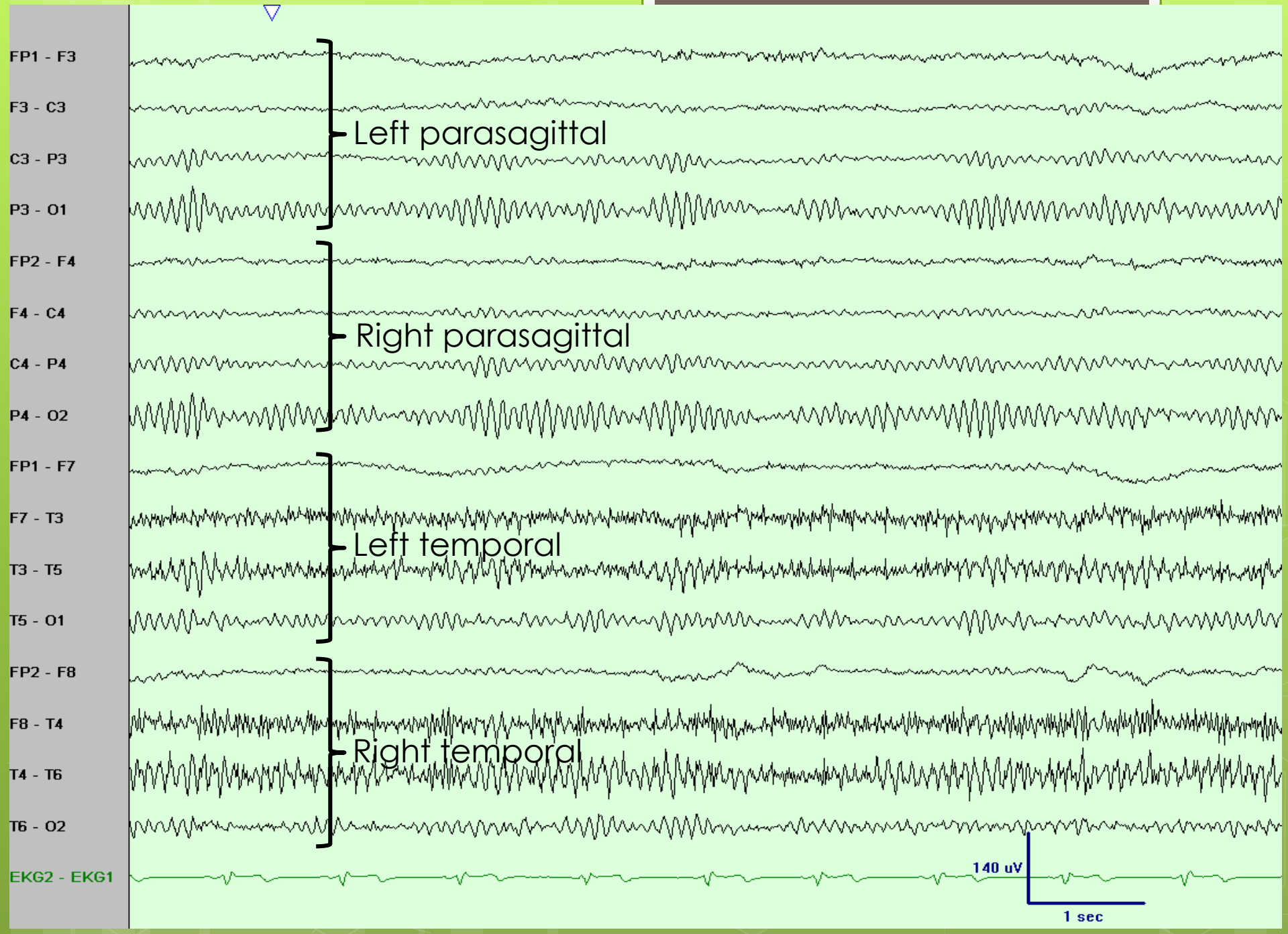
- EEG electrodes are adhered to the scalp using a special conducting electrode gel
- There are several important steps:
  1. The skin must be cleaned to remove any debri
  2. An abrasive gel is used to prepare the skin area
     - This ensures that the electrodes are as closely apposed to the skin as possible which eliminates artifacts
     - NuPrep is used in the ICU

EEG Electrodes

3. Electrode paste is applied to the electrodes
4. Electrodes are placed onto the scalp in a specific position
   - Formal EEGs use the 10-20 system
   - The 10-20 system is a precise measurement of the head with specific subdivisions that guide electrode placement
   - This ensures that EEGs can be compared from recording to recording
     - e.g. before and after removing electrodes for and MRI

10-20 System




FP1 - F3
F3 - C3
C3 - P3
P3 - O1
Left parasagittal
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
Right parasagittal
FP1 - F7
F7 - T3
T3 - T5
T5 - O1
Left temporal
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
Right temporal
EKG2 - EKG1
140 uV
1 sec

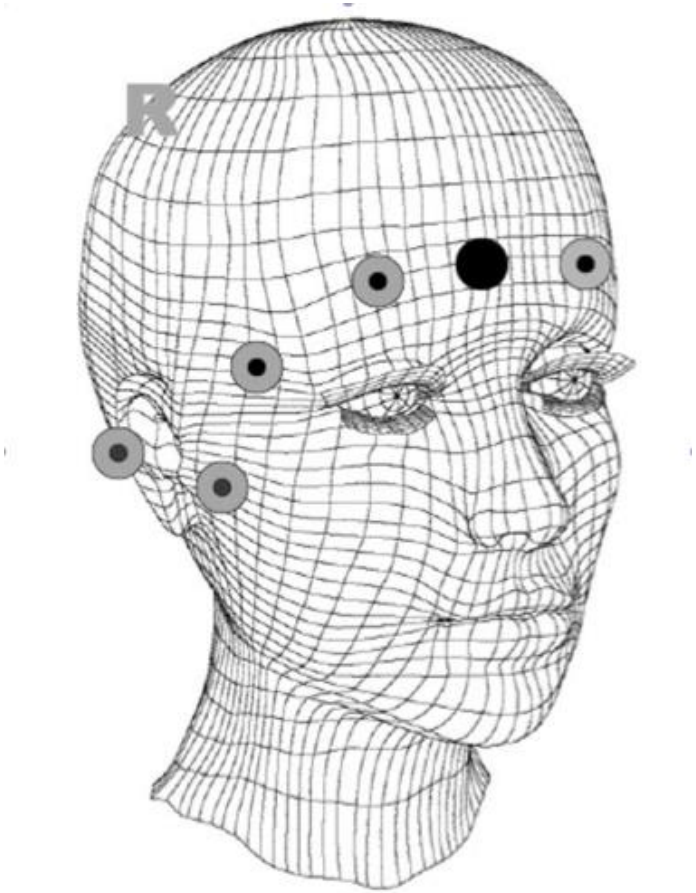
EEG Electrodes

- Subhairline EEG
- This EEG montage is designed for ease of application with a minimum of EEG expertise
- It uses sticker electrodes on non-hairy surfaces instead of the metal electrodes applied to the full scalp surface using the 10-20 system

EEG Electrodes

- The skin is prepared in the same way for the subhairline EEG, but electrode paste is not required because the stickers are self-adhesive
- 9 electrodes are placed symmetrically on the forehead, anterior to the ear and immediately posterior to the ear
  - Placement is based on anatomical landmarks

Subhairline EEG



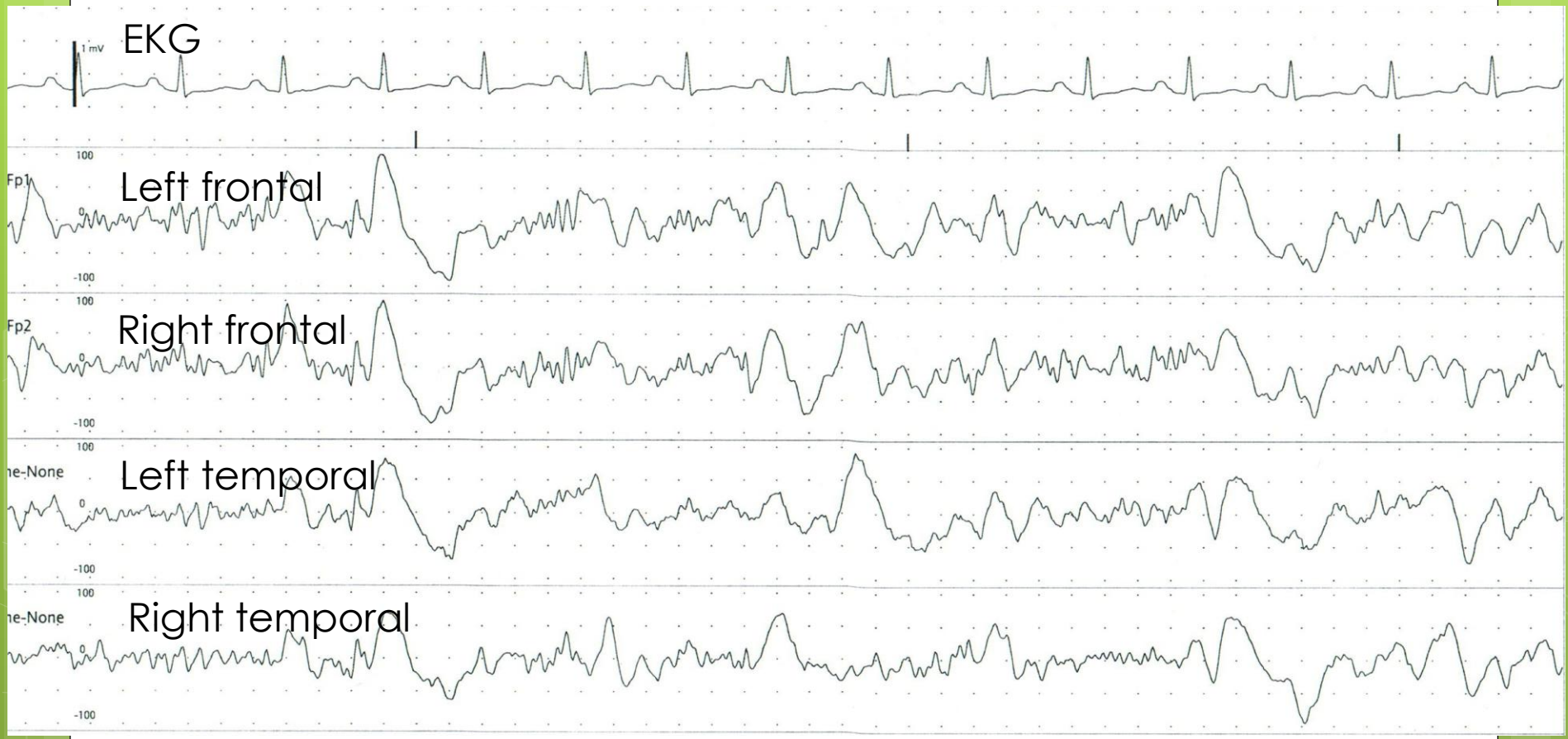
- First channel = left frontal
- Second channel = right frontal
- Third channel = left temporal
- Fourth channel = right temporal

Subhairline EEG

- Young et al 2009
  - Continuous subhariline EEG monitoring detects 70% of non-convulsive seizures when compared to formal EEG
  - But, 98% specificity when seizures are seen
- The lower sensitivity for seizures is due to the fact that only some of the cerebral lobes of the brain are covered by the subhairline electrodes

Subhairline EEG

Subhairline EEG



	10-20 System	Subhairline EEG
Number of electrodes	Minimum 21 electrodes	9 electrodes
Lobes covered	All lobes (except the cerebellum)	Frontal lobes Anterior temporal lobes
Electrode application	conductive paste	Self-adhesive electrodes
Ease of use	Require certified technologist	Many staff can be trained
Sensitivity for seizures	Gold standard	68%
Specificity for seizures	Gold standard	98%
Sensitivity for spikes/PLEDs	Gold standard	39%
Specificity for spikes/PLEDs	Gold standard	92%

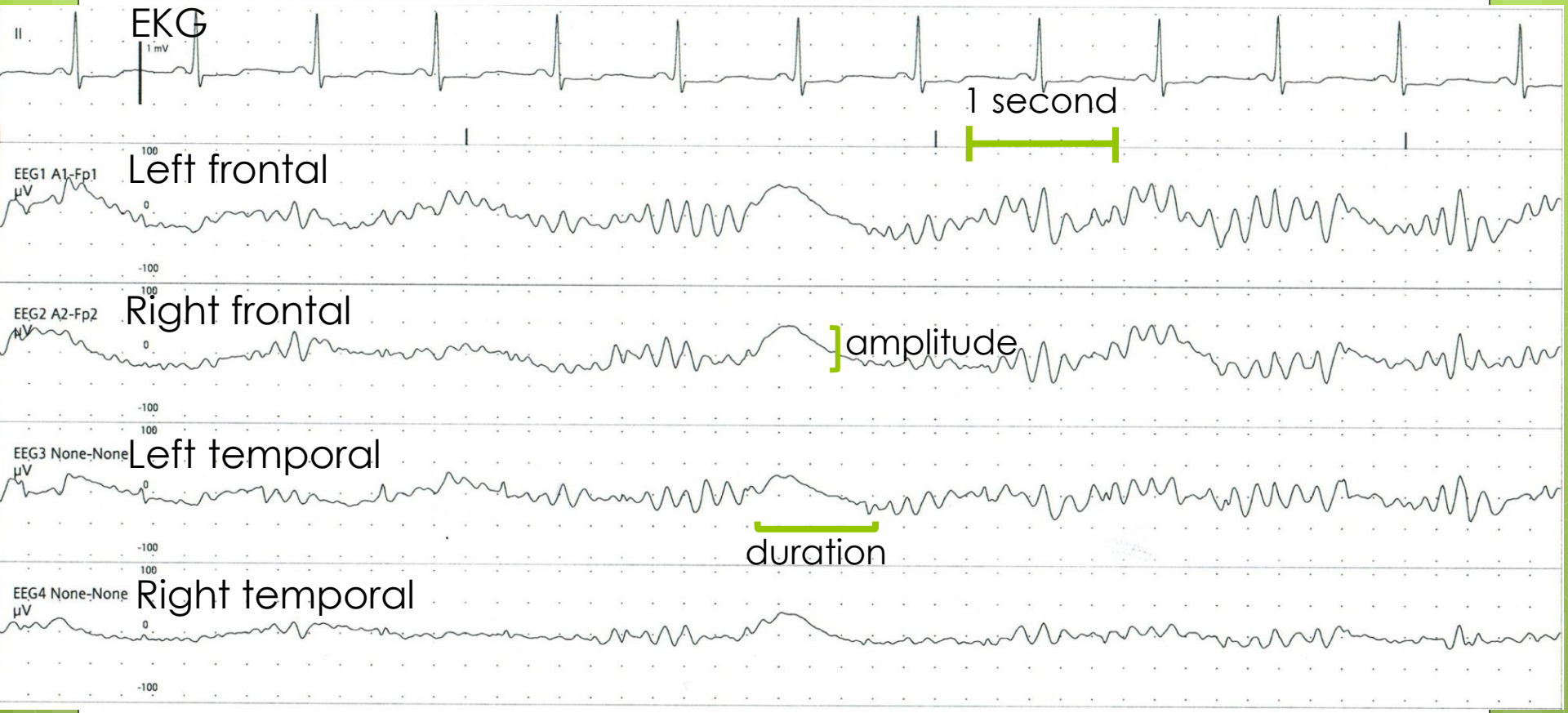
Advantages of Subhairline EEG

- Available when formal EEG may not be
- Allows for a very rapid assessment of cerebral function
- Greater capacity for continuous continuous EEG recording
  - only 2 formal EEG machines available
  - Subhairline EEG available at each bedside

Limitations of Subhairline EEG

- Poor scalp coverage
- Detects only 68% of non-convulsive seizures
- Continuous recording NOT continuous monitoring
- Data only stored for previous 24 hours
- Poor sampling rate
  - Degraded quality of waveforms on display
  - Potential for misrepresentation of waveforms (aliasing) and misinterpretation of displayed information

Looking at the Subhairline EEG



Normal Features of EEG

- EEG waveforms are divided infrequency bands

1. Beta – >13Hz
2. Alpha – 8-13Hz
3. Theta – 4-7Hz
4. Delta – <4Hz

fastest

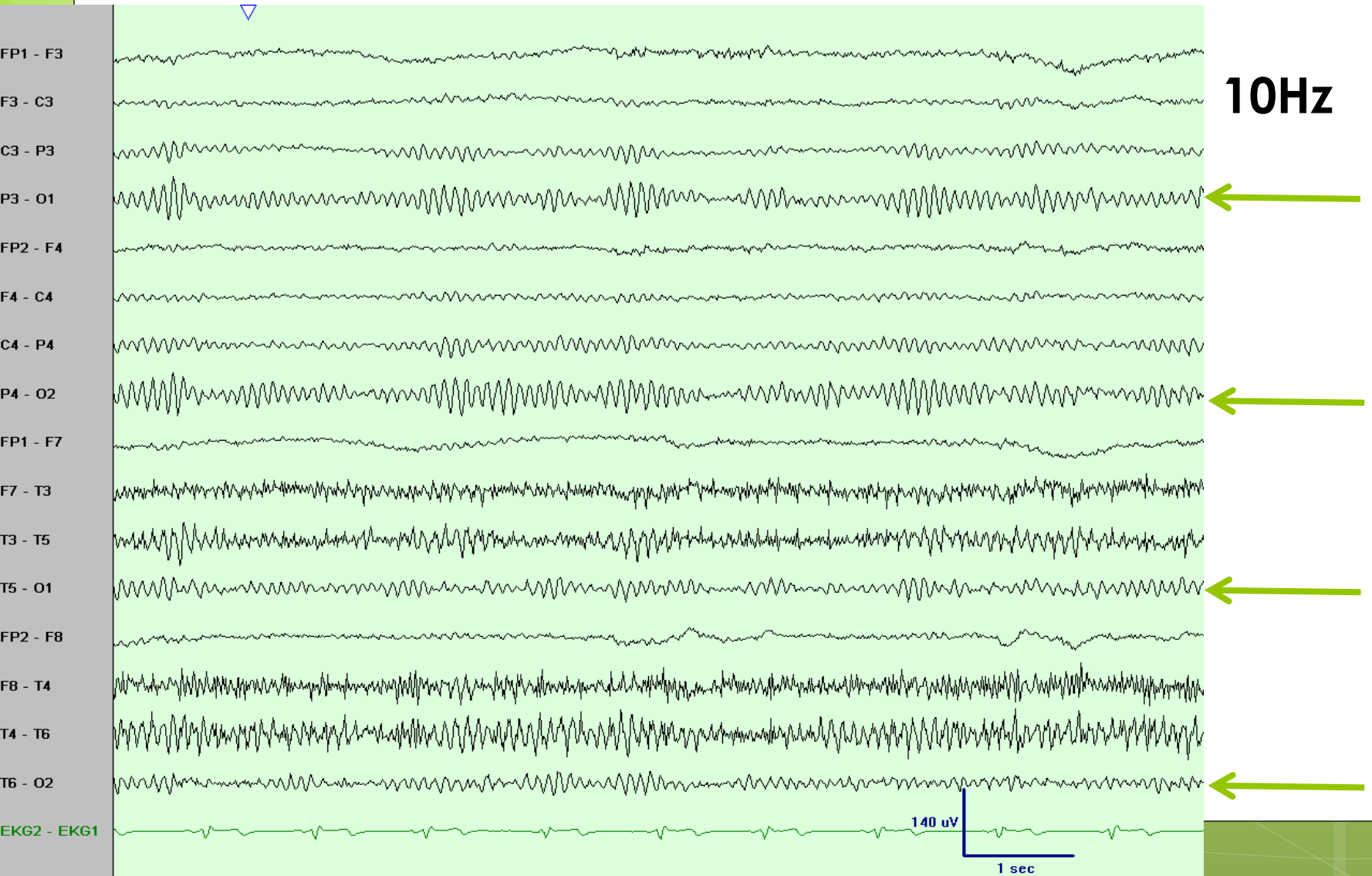
slowest

Normal Features of EEG

- Dominant rhythm
  - This is the most prominent posterior rhythm seen in the EEG
  - It is most consistent in the occipital regions and usually falls within the **alpha** range

- This will **not** be seen on the subhairline EEG because the subhairline EEG does not cover the posterior portion of the head

Alpha Rhythm

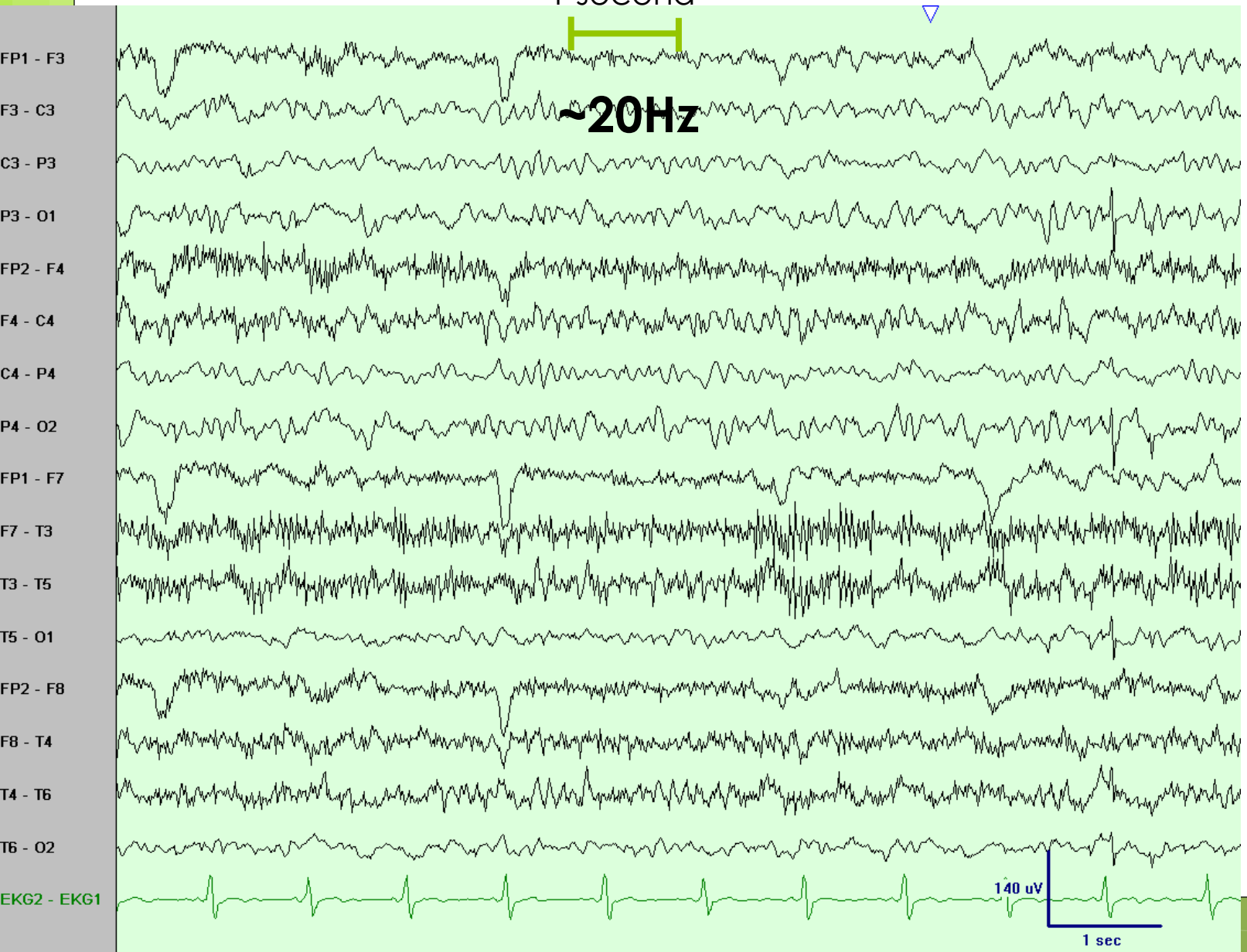


Beta

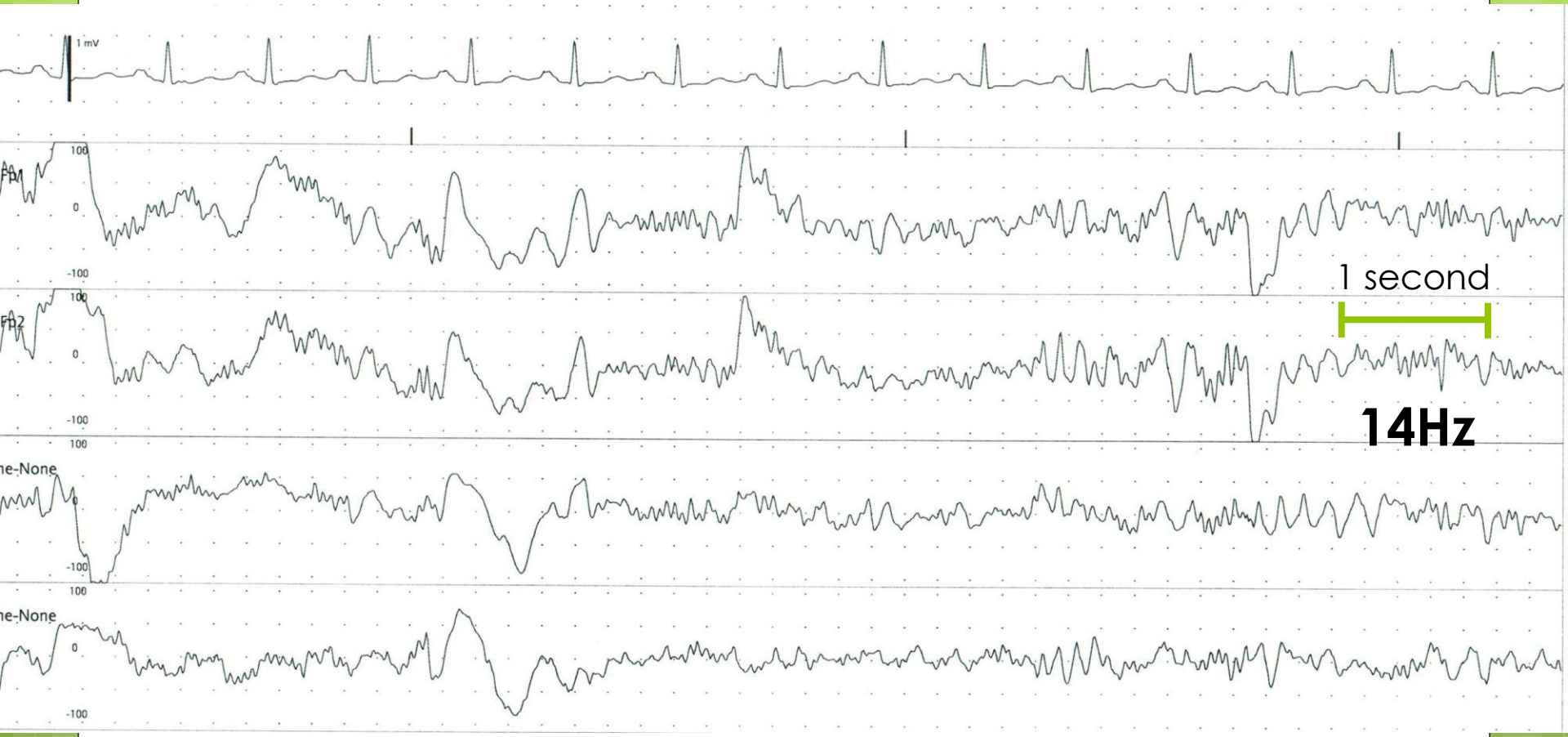
- Most commonly seen in the frontal regions or diffusely
- May be caused by medication
  - Barbiturates, benzodiazepines
- May be seen in patients with an overdose

- This is not seen often on the subhairline EEG because the sampling rate is too low and there is likely aliasing of beta into other waveforms

Beta


1 second
~20Hz
FP1 - F3
F3 - C3
C3 - P3
P3 - O1
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
FP1 - F7
F7 - T3
T3 - T5
T5 - O1
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
EKG2 - EKG1
140 uV
1 sec

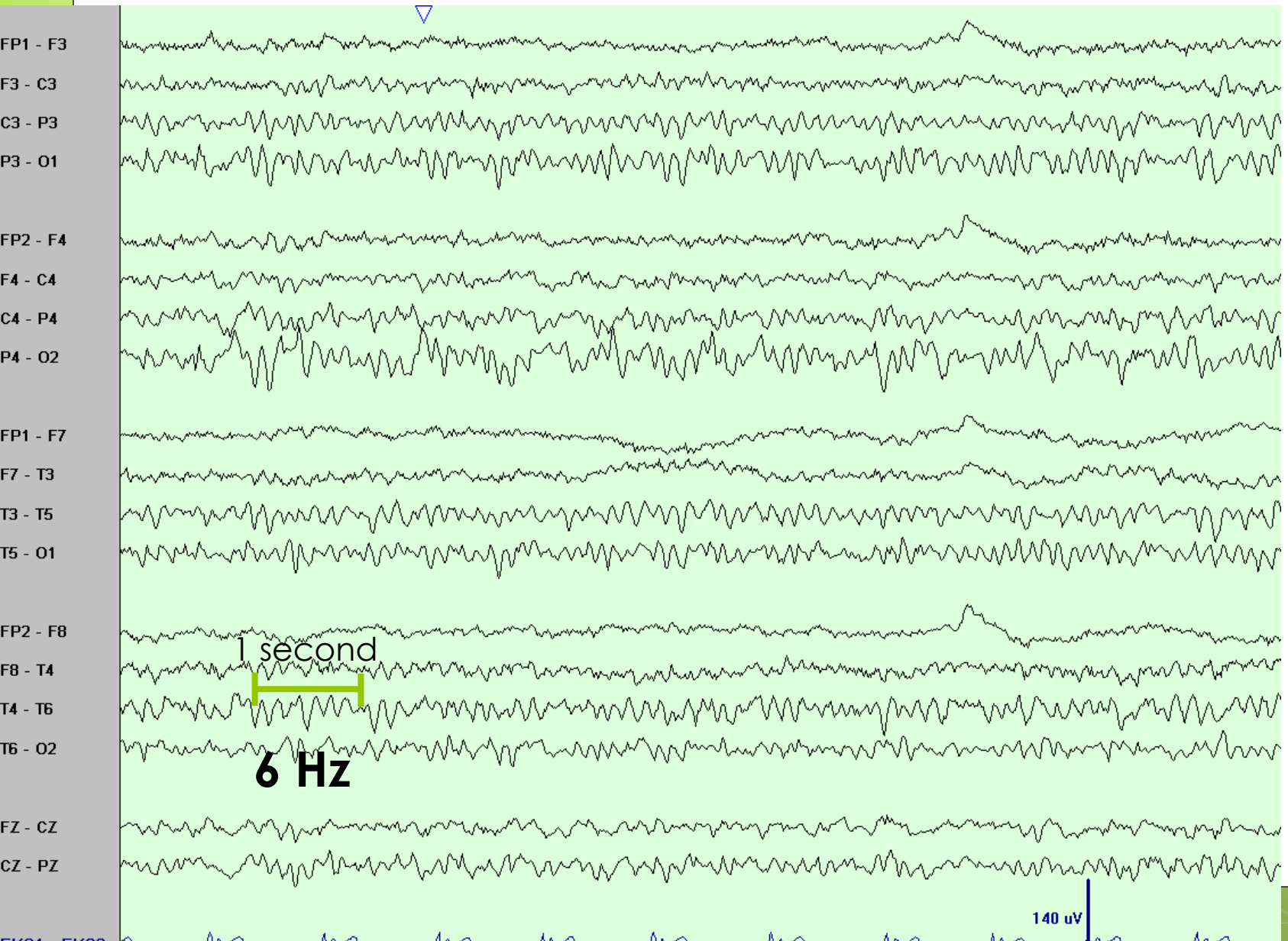
Beta – Subhairline EEG



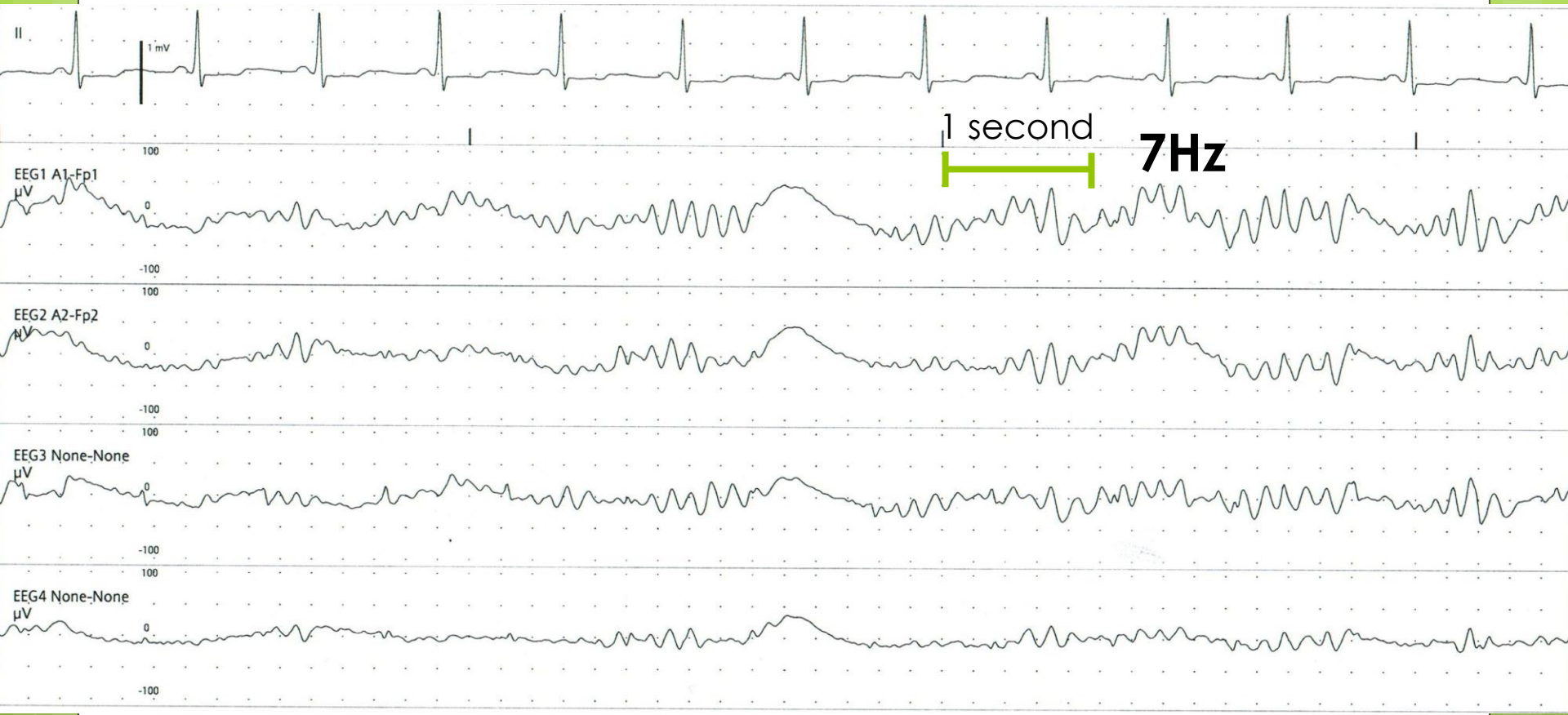
Theta

- May be generalised or focal
- Not seen in normal adults
- Generalised theta is associated with coma or light sedation
- Focal theta is associated with a structural abnormality such as ischemia, infarction, tumour or hemorrhage

Theta


FP1 - F3
F3 - C3
C3 - P3
P3 - O1
FP2 - F4
F4 - C4
C4 - P4
P4 - O2
FP1 - F7
F7 - T3
T3 - T5
T5 - O1
FP2 - F8
F8 - T4
T4 - T6
T6 - O2
1 second
6 Hz
FZ - CZ
CZ - PZ
140 uV

Theta –Subhairline EEG

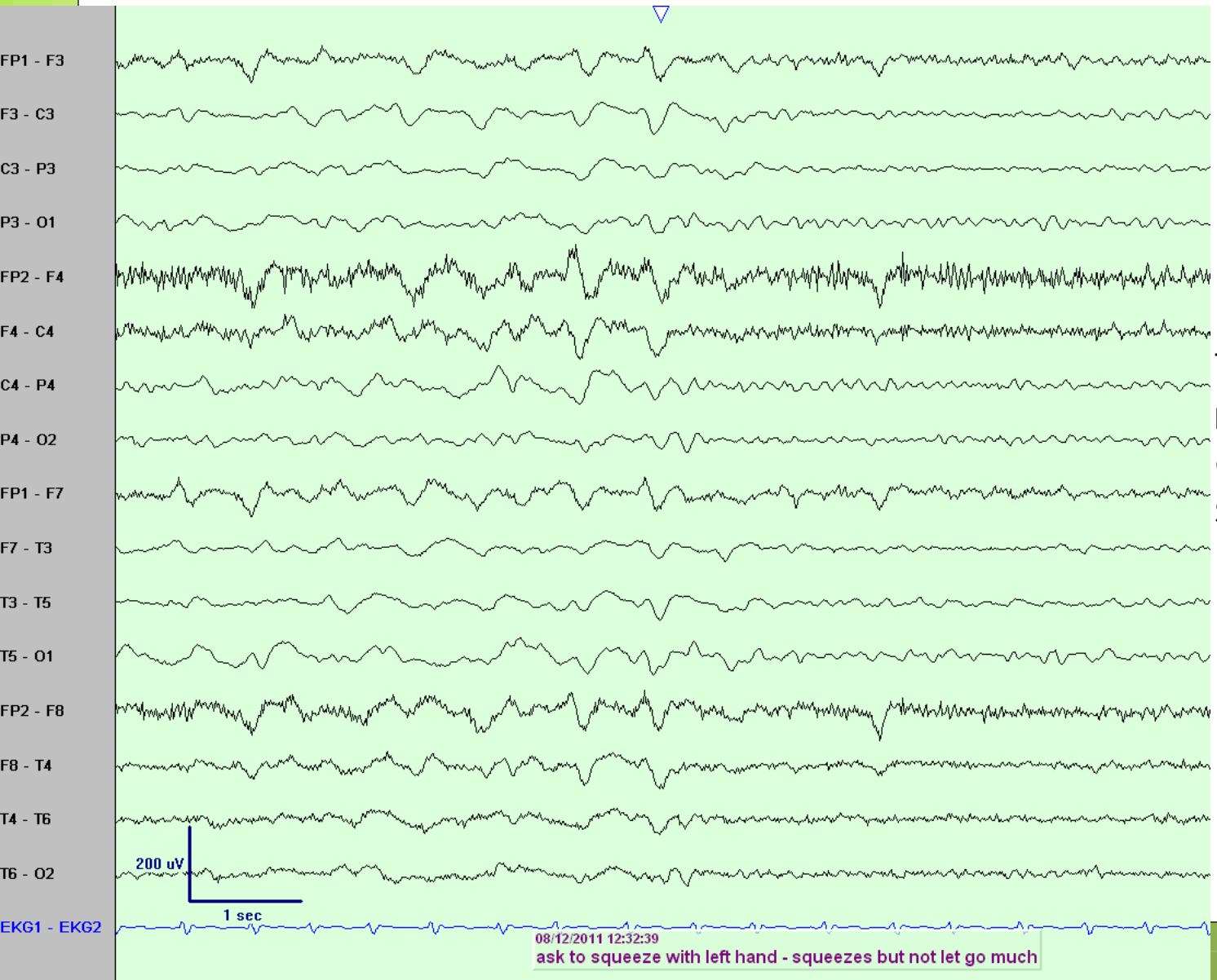


Delta

- May be generalised or focal
- Not seen in normal adults
- Generalised dela is associated with coma or anaesthesia
- Focal delta is associated with a structural abnormality such as ischemia, infarction, tumour or hemorrhage

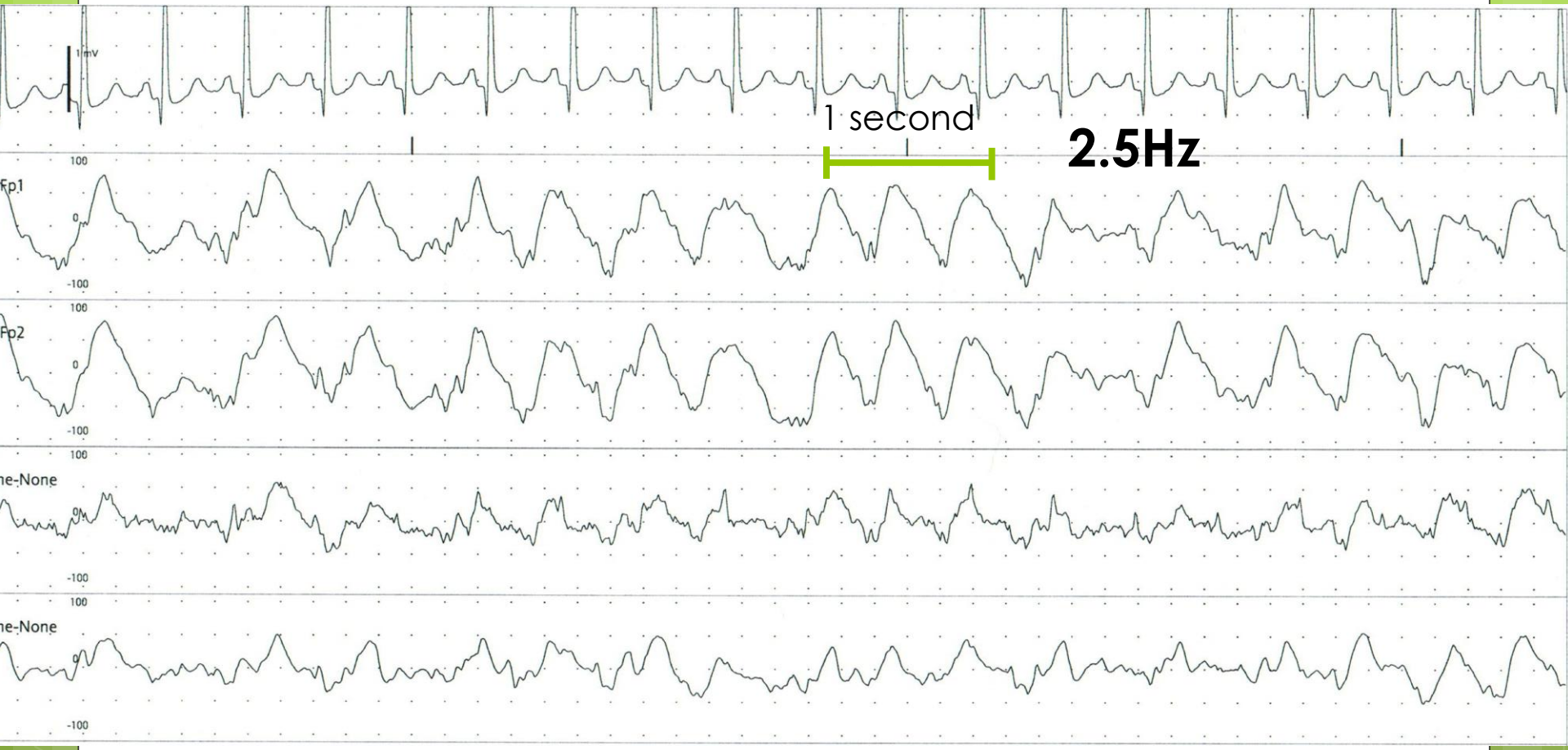
- Delta is slower than theta and usually reflects more severe cerebral dysfunction

Delta



The dominant rhythm is delta (prior to stimulation).

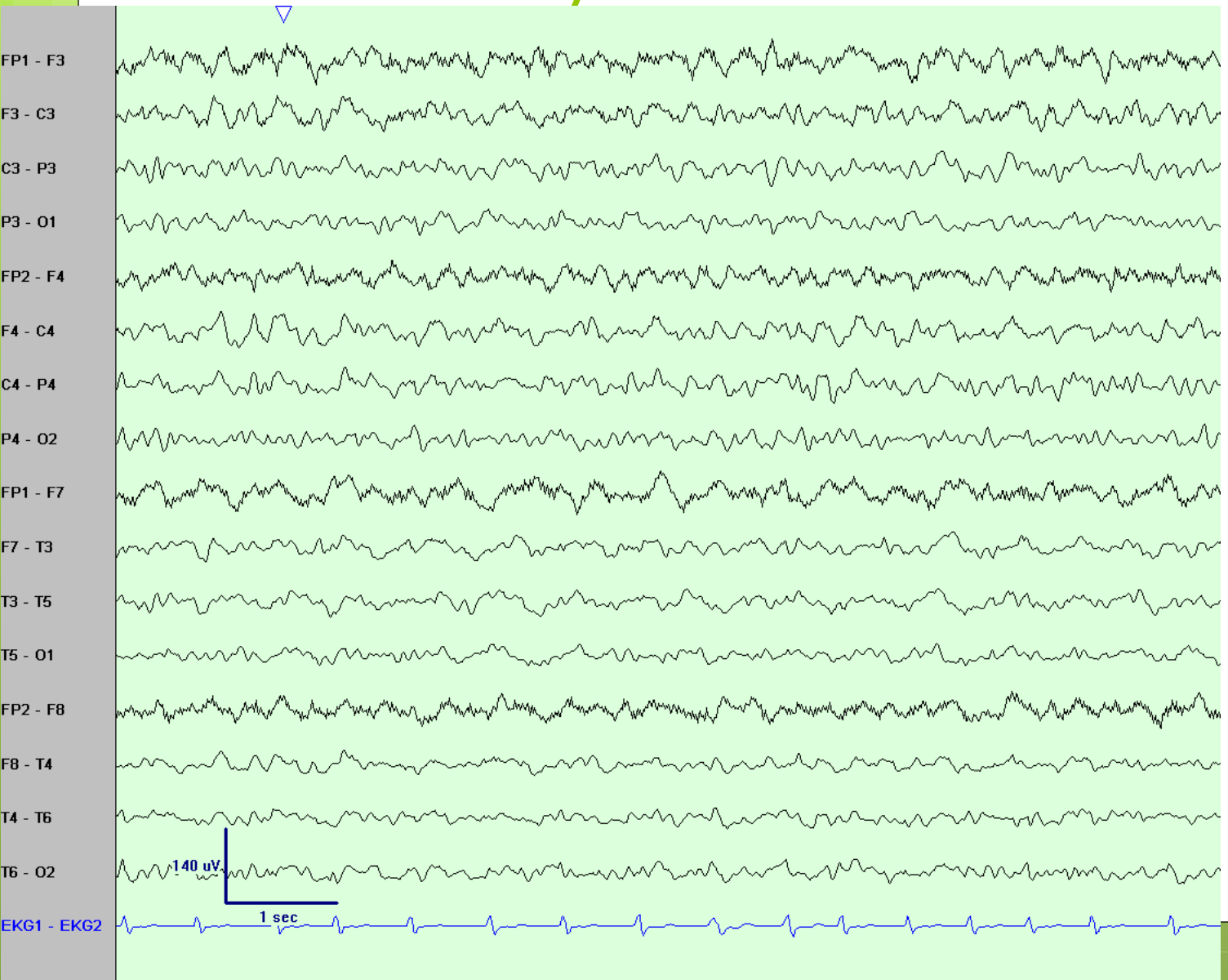
Delta – Subhairline EEG



Variability

- This reflects the number of different waveforms spontaneously produced by the cerebrum
- Greater variability usually reflects a better prognosis

Variability



Note the spontaneous presence of waveforms of higher and lower frequencies.

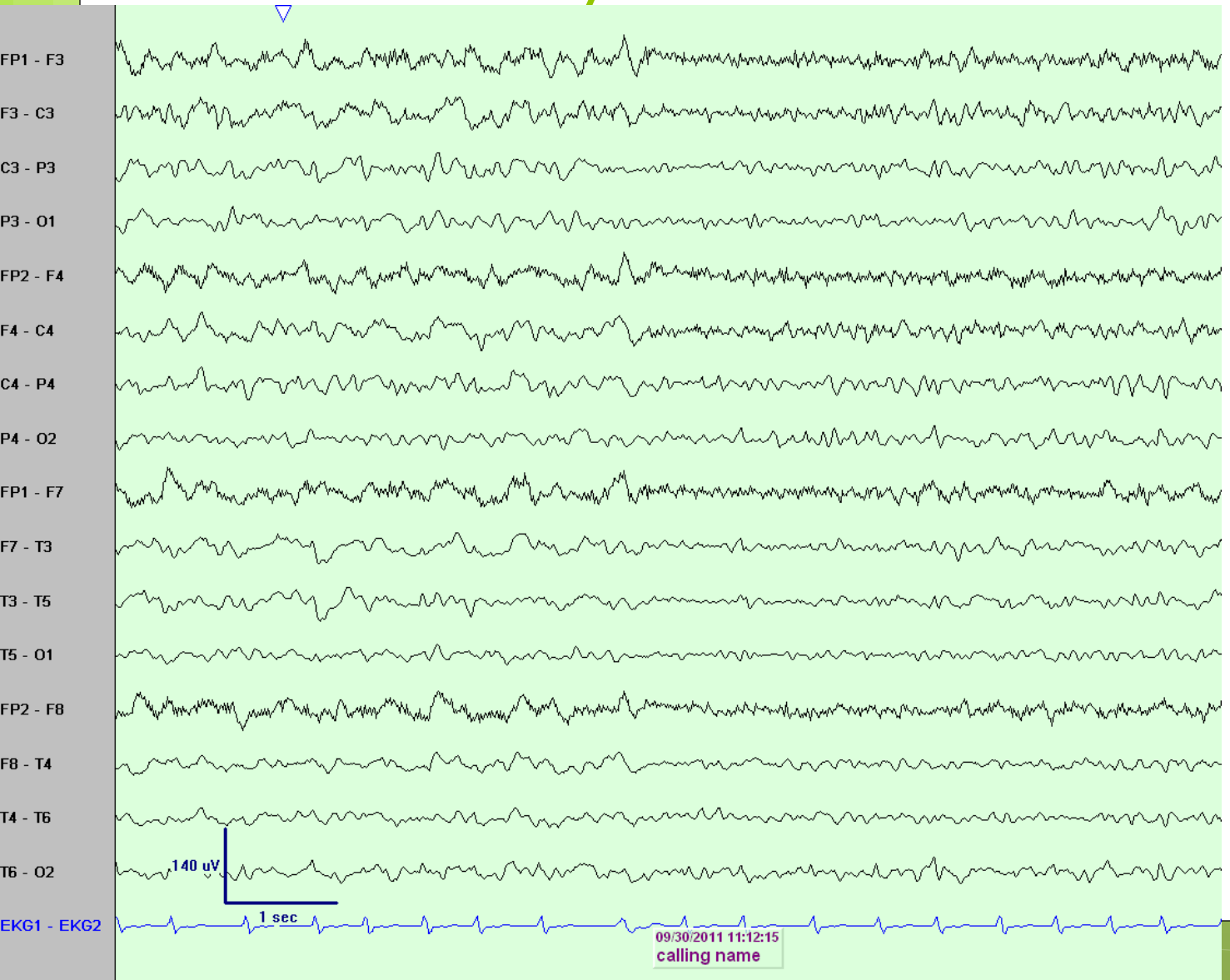
Variability – Subhairline EEG

This patient shows good variability: delta, theta and rare beta frequencies can be seen.

Reactivity

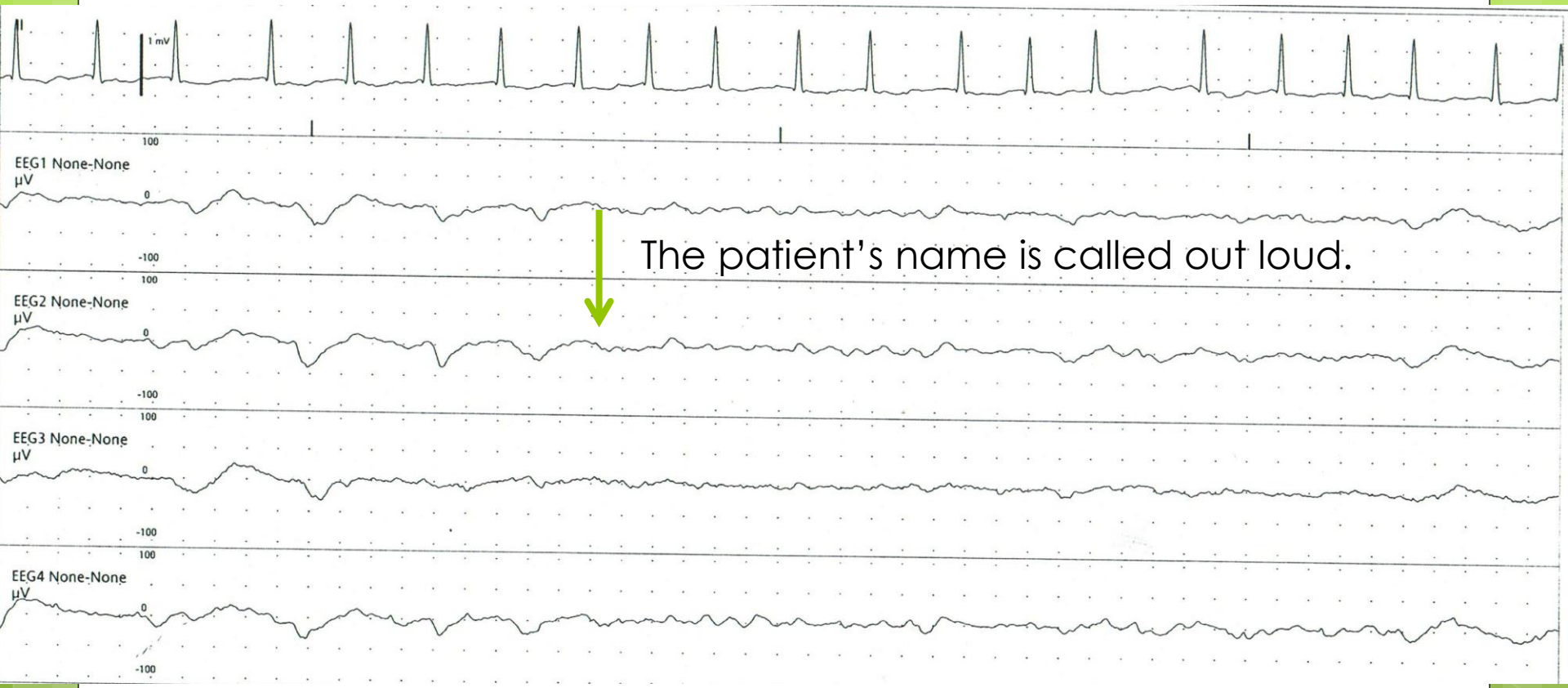
- This reflects a change in the EEG following afferent stimulus
- The presence of reactivity suggests that the brain is processing the stimulus at some level
- The presence of reactivity is prognostically favourable

Reactivity



Note the change in amplitude and frequency of the EEG when the patient hears their name being called.

Reactivity – Subhairline EEG



There is a change in the voltage and frequency of cerebral waveforms after the stimulus, which indicates reactivity. This is a favourable sign on EEG.