2023 GW Epilepsy Board Review & Best Practices

AMBULATORY AND VIDEO EEG

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DISCLOSURES

- **Disclosure of Financial Relationships**
  - **None**
- **Off-Label Usage**
  - **None**

Objectives

- Uses of video-EEG monitoring
- Options for EEG monitoring
- Yield of EEG monitoring
- Activation procedures used to increase yield
- Comparison of different types of EEG monitoring

Uses of Video-EEG monitoring

- Diagnosis (epileptic vs. non-epileptic)
- Interictal Epileptiform Discharges
- Classification and Localization
- Medication Adjustment
- Seizure / Discharge Quantification
- Surgical Candidacy Evaluation

Options for EEG monitoring

- Short-term – inpatient or outpatient
  - Routine video-EEG (20-60 min)
  - Prolonged/Extended video-EEG (1-4 hours)
- Long-term – outpatient
  - Ambulatory EEG
  - Home video-EEG – a growing trend
- Long-term – inpatient
  - Portable continuous video-EEG (usu. ICU) – a.k.a. cEEG*
  - Hard-wired continuous video-EEG (usu. Epilepsy Monitoring Unit) – a.k.a. EMU*

*some ICUs are hard-wired, some EMUs are portable

What is the typical yield of a routine outpatient EEG study in adults? (chance of capturing an epileptiform abnormality in a patient with suspected epilepsy)

A. 25%
B. 33%
C. 50%
D. 66%
E. 80%

Methods of increasing EEG Yield

- Single routine EEG: 40-50% yield* in epileptic patients
- Repeat and 2-4 hour extended EEGs increase yield* to 80-90%
- Remaining Cases: Long-term monitoring (cEEG, EMU, Ambulatory EEG)

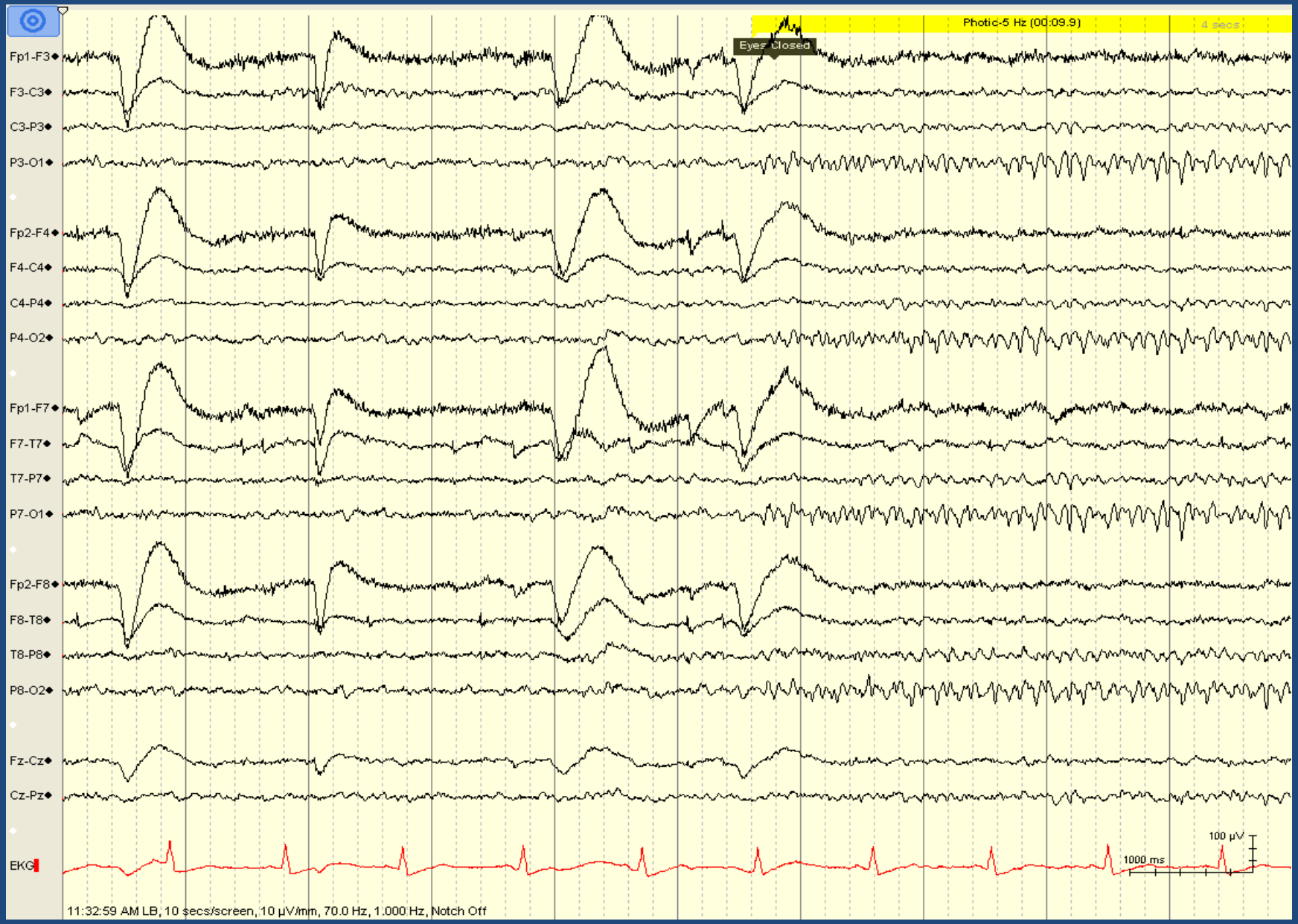
*this yield is for interictal epileptiform discharges (not diagnostic of epilepsy)

Activating Procedures

- Hyperventilation and Photic Stimulation
  - Mostly for generalized epilepsies
  - Lack of slow activity or driving still normal
- Drowsiness and Sleep

Harmonic driving

- Driving response that is a multiple or factor of the flash frequency
- Can be half, double, triple, etc.
- Can have a “notched” appearance (multiple fused frequencies)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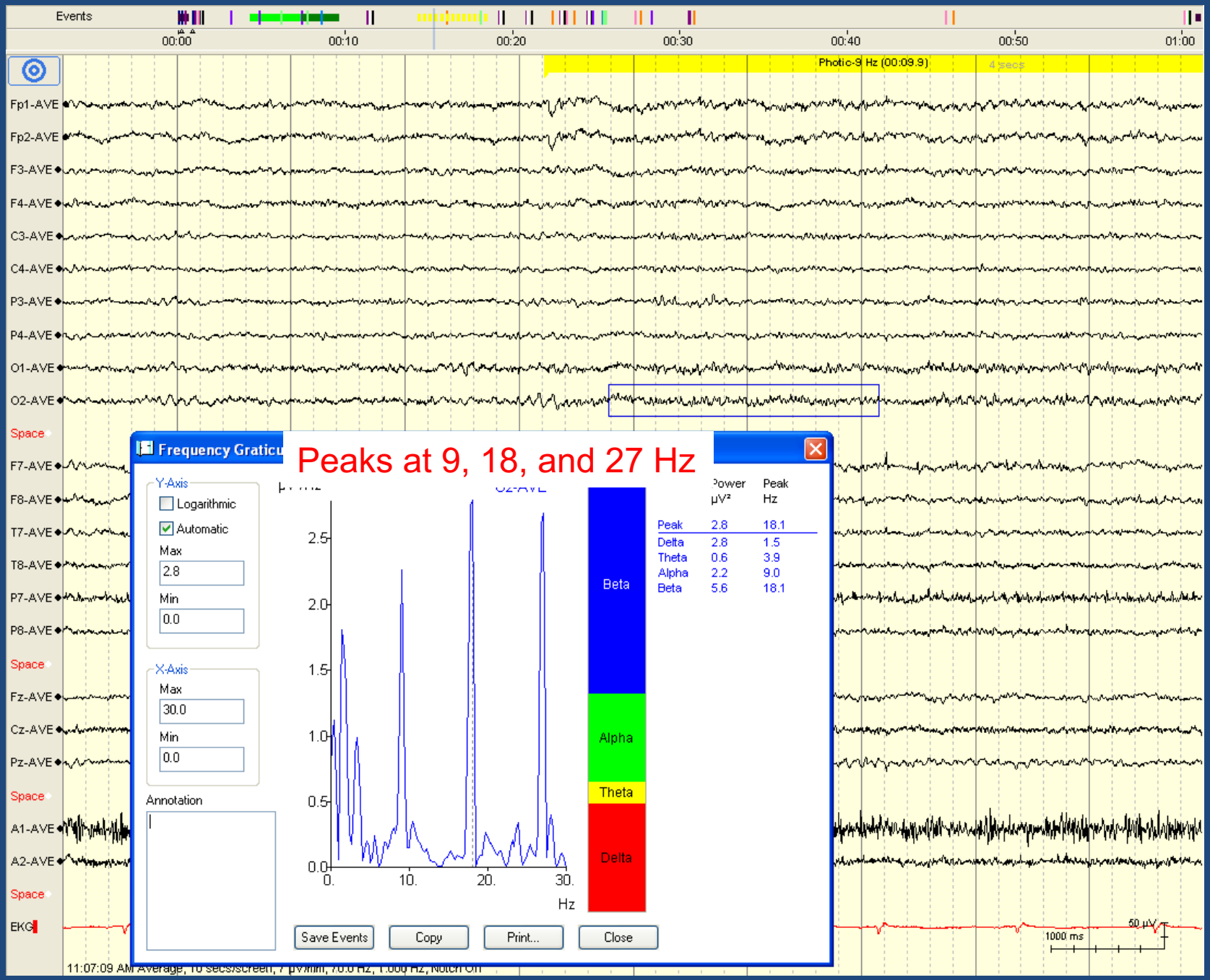
Eyes Closed
Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp2-F8
F8-T8
T8-P8
P8-O2
Fz-Cz
Cz-Pz
EKG
100 µV
1000 ms
11:32:59 AM LB, 10 secs/screen, 10 µV/mm, 70.0 Hz, 1.000 Hz, Notch Off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00:00
00:10
00:20
00:30
00:40
00:50
01:00
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4 secs
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Fp2-AVE
F3-AVE
F4-AVE
C3-AVE
C4-AVE
P3-AVE
P4-AVE
O1-AVE
O2-AVE
Space
F7-AVE
F8-AVE
T7-AVE
T8-AVE
P7-AVE
P8-AVE
Space
Fz-AVE
Cz-AVE
Pz-AVE
Space
A1-AVE
A2-AVE
Space
EKG
Frequency Graticu
Peaks at 9, 18, and 27 Hz
Y-Axis
Logarithmic
Automatic
Max
2.8
Min
0.0
X-Axis
Max
30.0
Min
0.0
Annotation
2.5
2.0
1.5
1.0
0.5
0.0
0.
10.
20.
30.
Hz
Beta
Alpha
Theta
Delta
Power µV²
Peak Hz
Peak 2.8 18.1
Delta 2.8 1.5
Theta 0.6 3.9
Alpha 2.2 9.0
Beta 5.6 18.1
Save Events
Copy
Print...
Close
50 µV
1000 ms
11:07:09 AM Average, 10 secs/screen, 7 µV/mm, 70.0 Hz, 1.000 Hz, Notch On

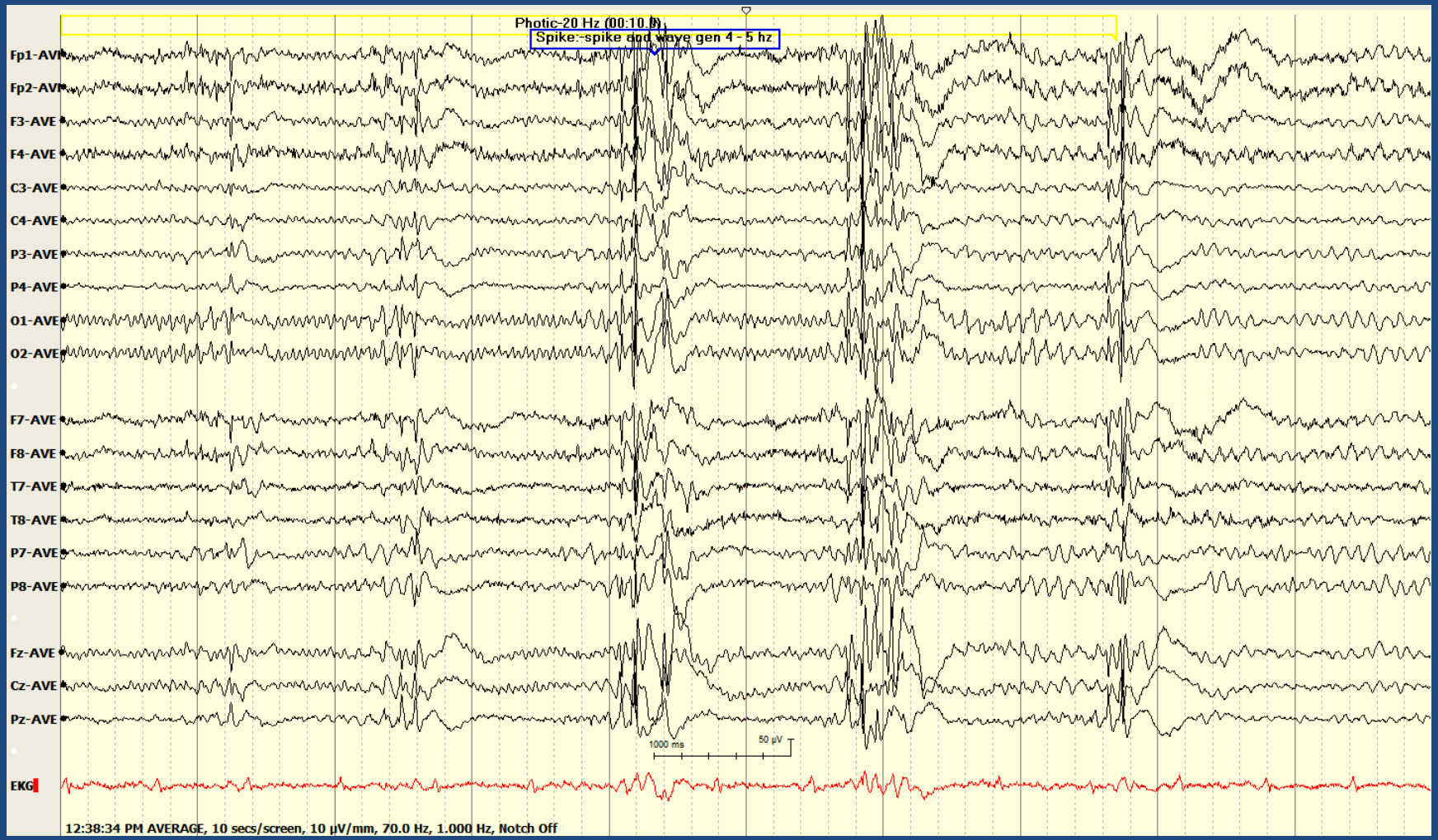
Which of the following responses is abnormal during photic stimulation?

A. Photoconvulsive response
B. Photomyogenic response
C. Photomyoclonic response
D. Photovoltaic response
E. Photocell response

Photoparoxysmal response

- a.k.a. photoconvulsive response*
- Assoc. with generalized epilepsy
  - Usu. generalized / bifrontally predominant
  - May be bioccipitally predominant
  - May have assoc. absence, myoclonic, or generalized tonic clonic (GTC) seizures
- Assoc. with occipital epilepsy if unilateral (rare)

*controversial: some say photoconvulsive implies that discharges outlast the flash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Spike:-spike and wave gen 4 - 5 hz
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Fp2-AVE
F3-AVE
F4-AVE
C3-AVE
C4-AVE
P3-AVE
P4-AVE
O1-AVE
O2-AVE
F7-AVE
F8-AVE
T7-AVE
T8-AVE
P7-AVE
P8-AVE
Fz-AVE
Cz-AVE
Pz-AVE
1000 ms
50 µV
EKG
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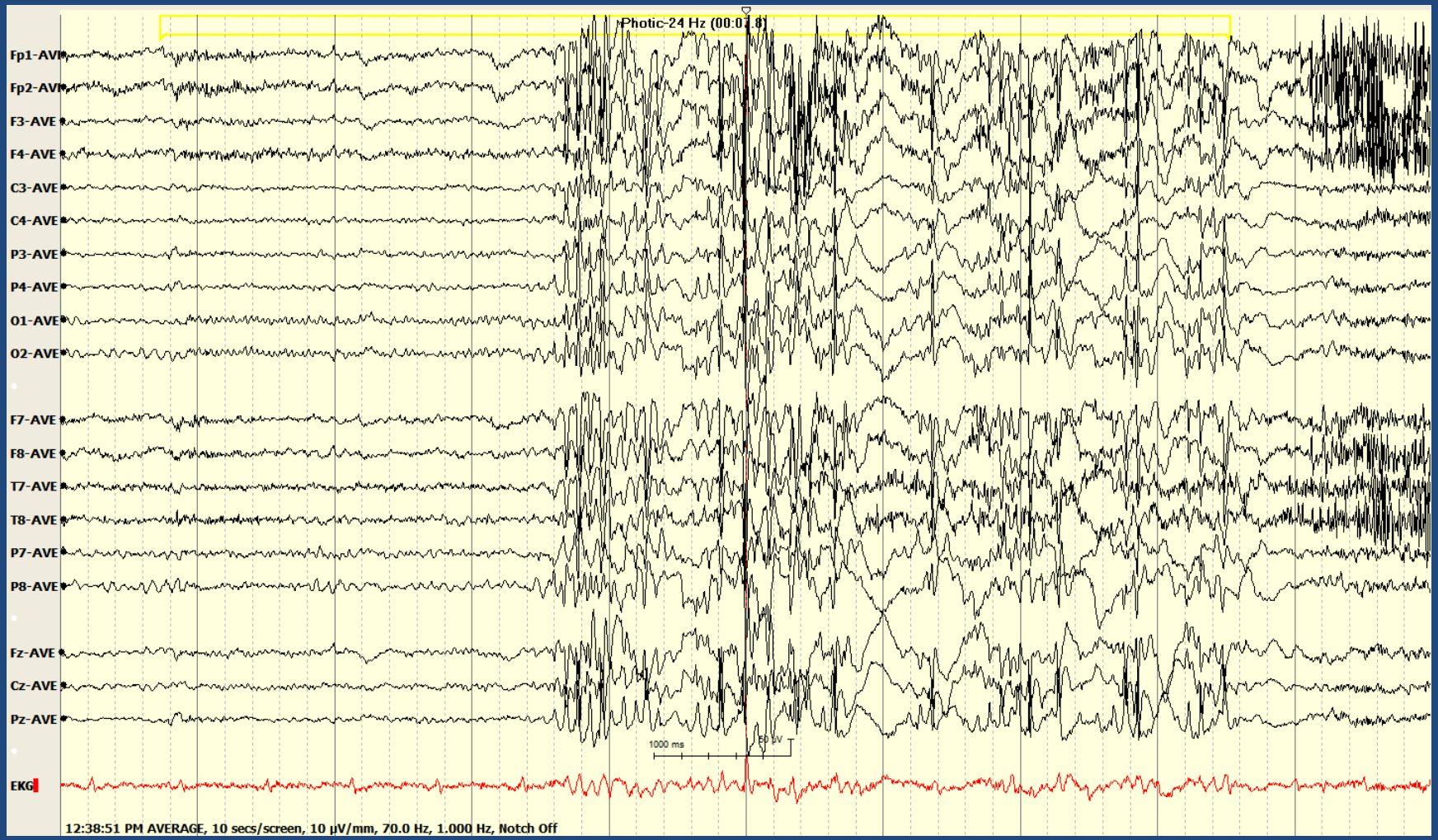
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Fp2-AVE
F3-AVE
F4-AVE
C3-AVE
C4-AVE
P3-AVE
P4-AVE
O1-AVE
O2-AVE
F7-AVE
F8-AVE
T7-AVE
T8-AVE
P7-AVE
P8-AVE
Fz-AVE
Cz-AVE
Pz-AVE
EKG
1000 ms
50 µV
12:38:51 PM AVERAGE, 10 secs/screen, 10 µV/mm, 70.0 Hz, 1.000 Hz, Notch Off

Photomyogenic response

- a.k.a. photomyoclonic response

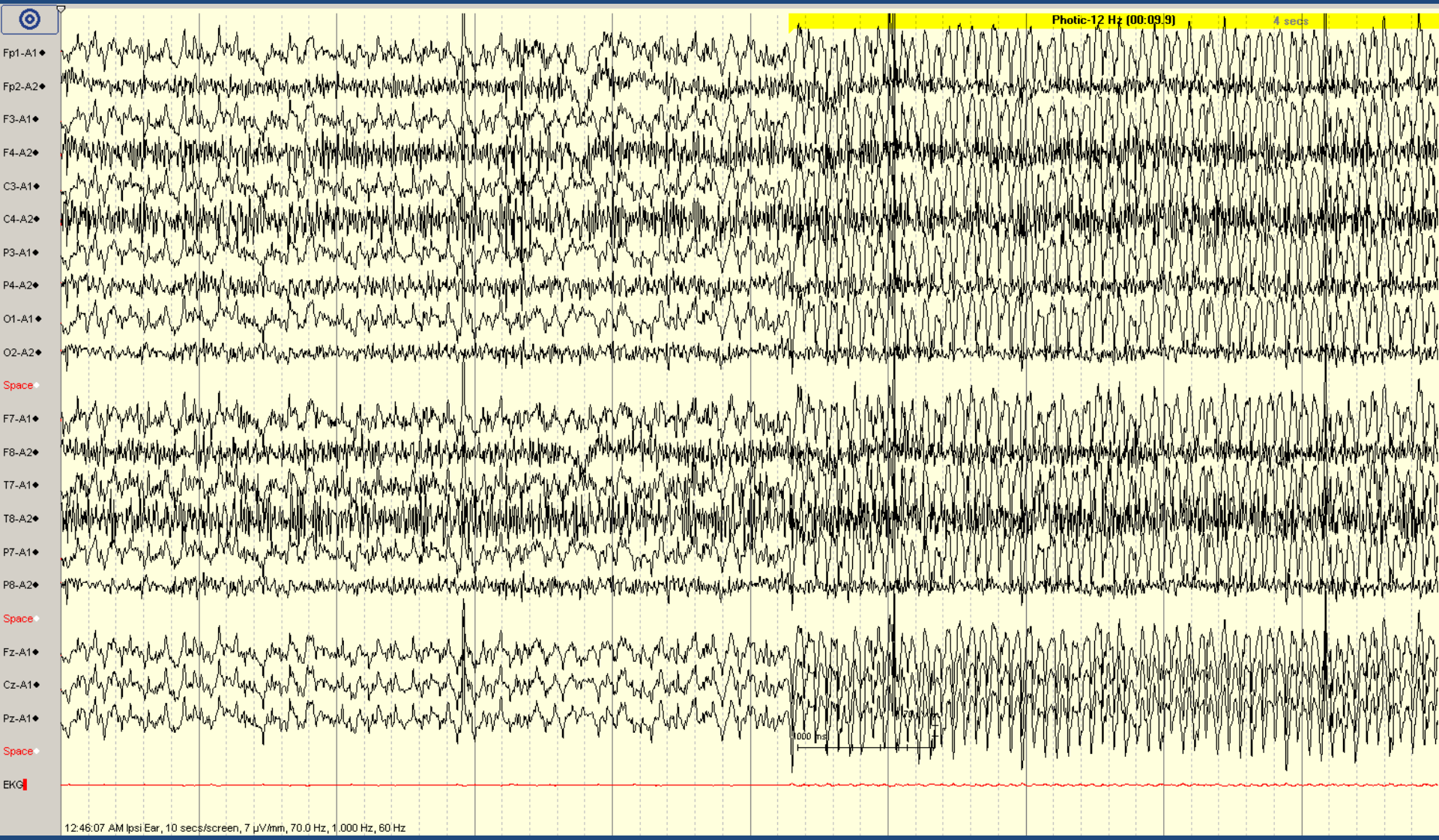
- this is benign
- don’t let “myoclonic” fool you

- EMG potentials (frontal) time-locked to the flash frequency


1 Fp1-AV
2 Fp2-AV
3 F3-AV
4 F4-AV
5 C3-AV
6 C4-AV
7 P3-AV
8 P4-AV
9 O1-AV
10 O2-AV
11 F7-AV
12 F8-AV
13 T1-AV
14 T2-AV
15 T7-AV
16 T8-AV
17 P7-AV
18 P8-AV
19 Fz-AV
20 Cz-AV
21 Pz-AV
22 EKG1-E
M
PHOTO 7Hz

Photovoltaic (photocell) artifact

- high impedance electrode creates a “cell” or “battery” capable of storing charge
- released with each photic flash, resulting in a time locked spiky response on EEG
- only specifically in the electrode with the high impedance.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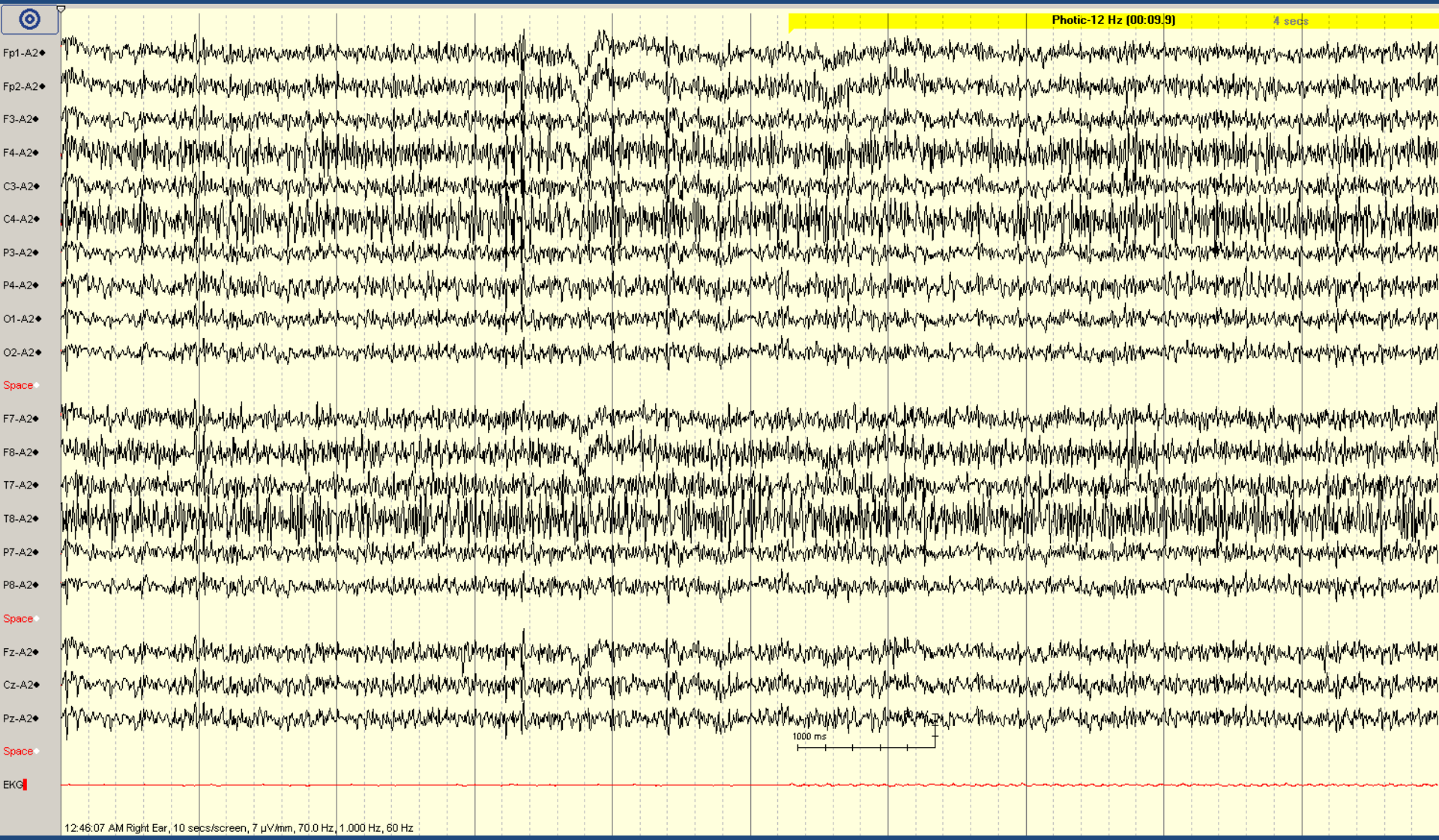
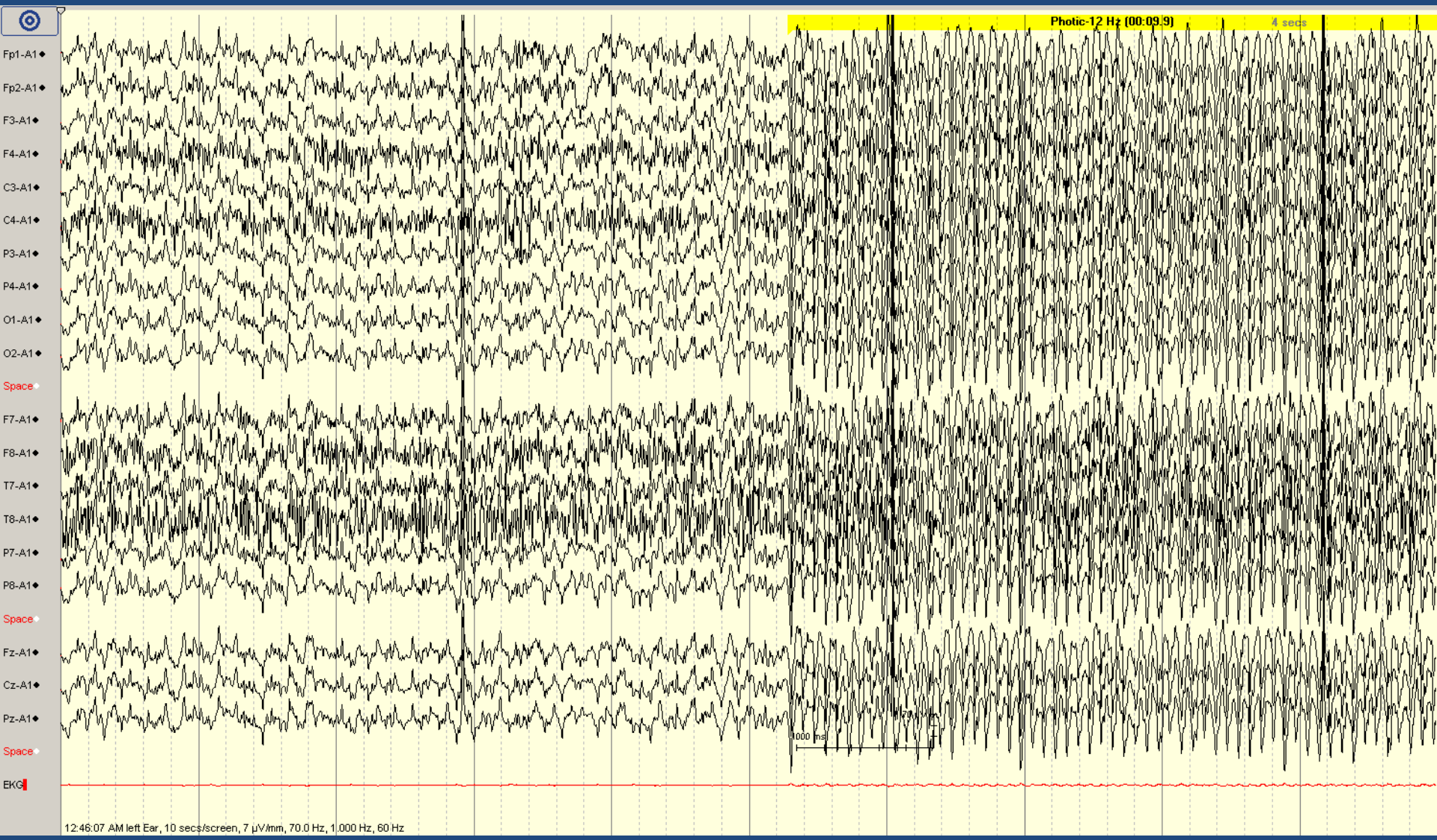
Fp2-A2
F3-A1
F4-A2
C3-A1
C4-A2
P3-A1
P4-A2
O1-A1
O2-A2
Space
F7-A1
F8-A2
T7-A1
T8-A2
P7-A1
P8-A2
Space
Fz-A1
Cz-A1
Pz-A1
Space
EKG
1000 ms
12:46:07 AM Ipsi Ear, 10 secs/screen, 7 µV/mm, 70.0 Hz, 1.000 Hz, 60 Hz


Photic-12 Hz (00:09.9)
4 secs
Fp1-A2
Fp2-A2
F3-A2
F4-A2
C3-A2
C4-A2
P3-A2
P4-A2
O1-A2
O2-A2
Space
F7-A2
F8-A2
T7-A2
T8-A2
P7-A2
P8-A2
Space
Fz-A2
Cz-A2
Pz-A2
Space
EKG
1000 ms
12:46:07 AM Right Ear, 10 secs/screen, 7 µV/mm, 70.0 Hz, 1.000 Hz, 60 Hz


Photic-12 Hz (00:09.9)
4 secs
Fp1-A1
Fp2-A1
F3-A1
F4-A1
C3-A1
C4-A1
P3-A1
P4-A1
O1-A1
O2-A1
Space
F7-A1
F8-A1
T7-A1
T8-A1
P7-A1
P8-A1
Space
Fz-A1
Cz-A1
Pz-A1
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EKG
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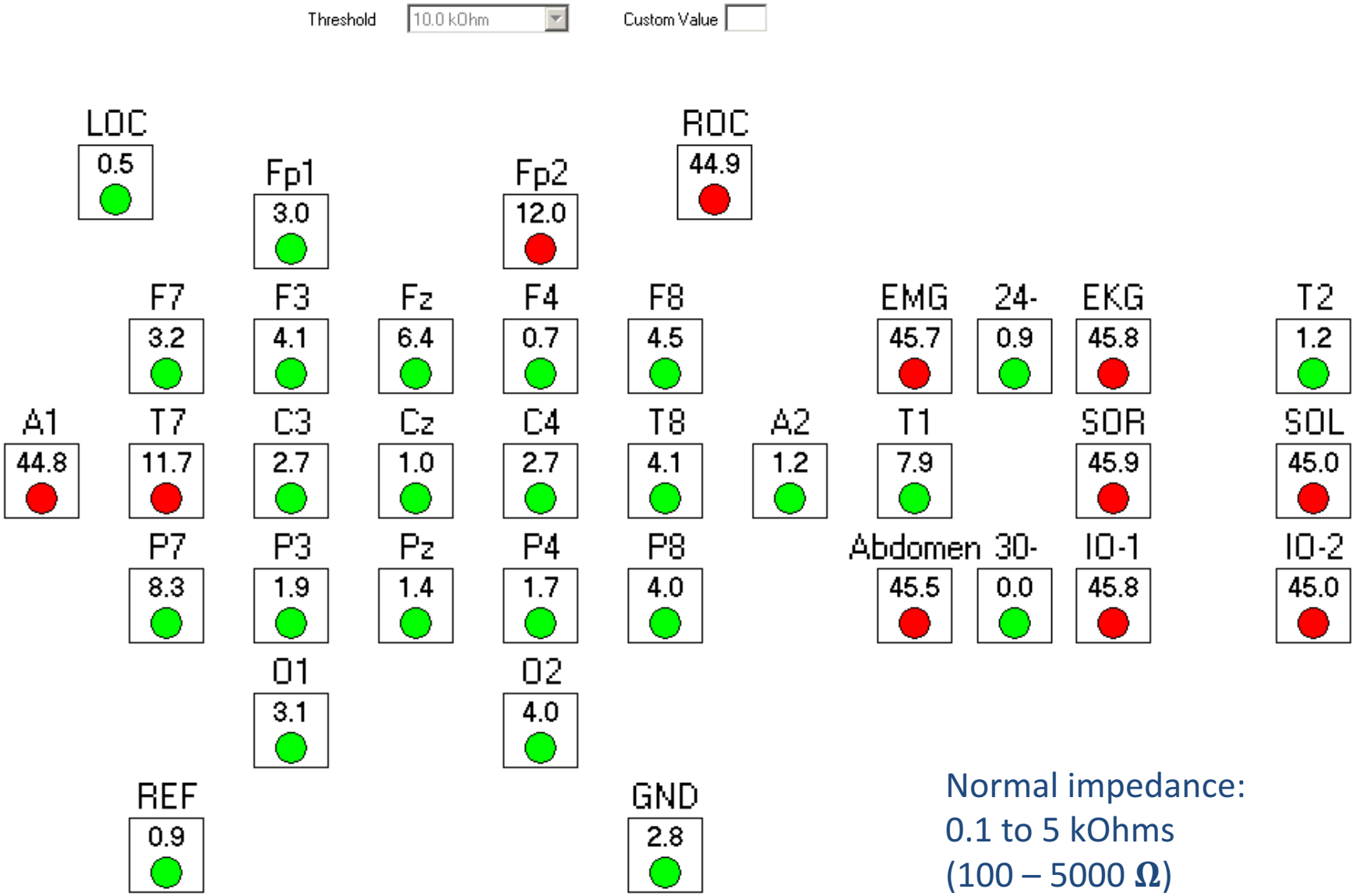


Normal impedance:
0.1 to 5 kOhms
(100 – 5000 Ω)

Ambulatory EEG

- Home-based EEG recording
- May have a daily patient visit to fix electrodes and download data
- Patient must push button or record in diary
- Cheaper and more widely available than EMU

Ambulatory EEG – Uses

- Event capture – yield is 40-70%
- Interictal yield – 48 hours captures 95% of such patients
- Nocturnal disorders (frontal seizures, sleep disorders, ESES/CSWS)
- Quantifying subclinical / subtle clinical seizures
- Determining recurrence risk when considering seizure medication withdrawal

Faulkner et al, Clin Neurophysiol, 2012; Lawley et al, Epilepsy and Behavior, 2015

Ambulatory EEG

- Advantages
  - minimal interference with patient activities
  - natural environment to trigger events/seizures
- Disadvantages
  - prone to artifacts
  - no video or real-time monitoring (in most cases)
  - cannot examine patient during event
  - cannot safely withdraw medications

Importance of Video

- Semiology analysis
- Correlation to patient / witness history
- Assessment for artifact
- Diagnosis (esp. when EEG is normal)

Long-term video-EEG monitoring

- EMU remains the diagnostic “gold” standard

- Ideally requires:
  - Ictal EEG, video, and exam
  - Interictal EEG recording with med withdrawal
  - Correlation to history *(confirm all of patient’s full blown and typical event types were captured)*

Long-term video-EEG monitoring

- Advantages
  - invasive monitoring
  - ictal functional imaging
  - medication adjustment
- Disadvantages
  - high cost (techs, nursing, physicians, hospital)
  - disrupts patient's normal activities and work/school
  - risk of nosocomial infections
  - risk of physical and psychological harm/injury

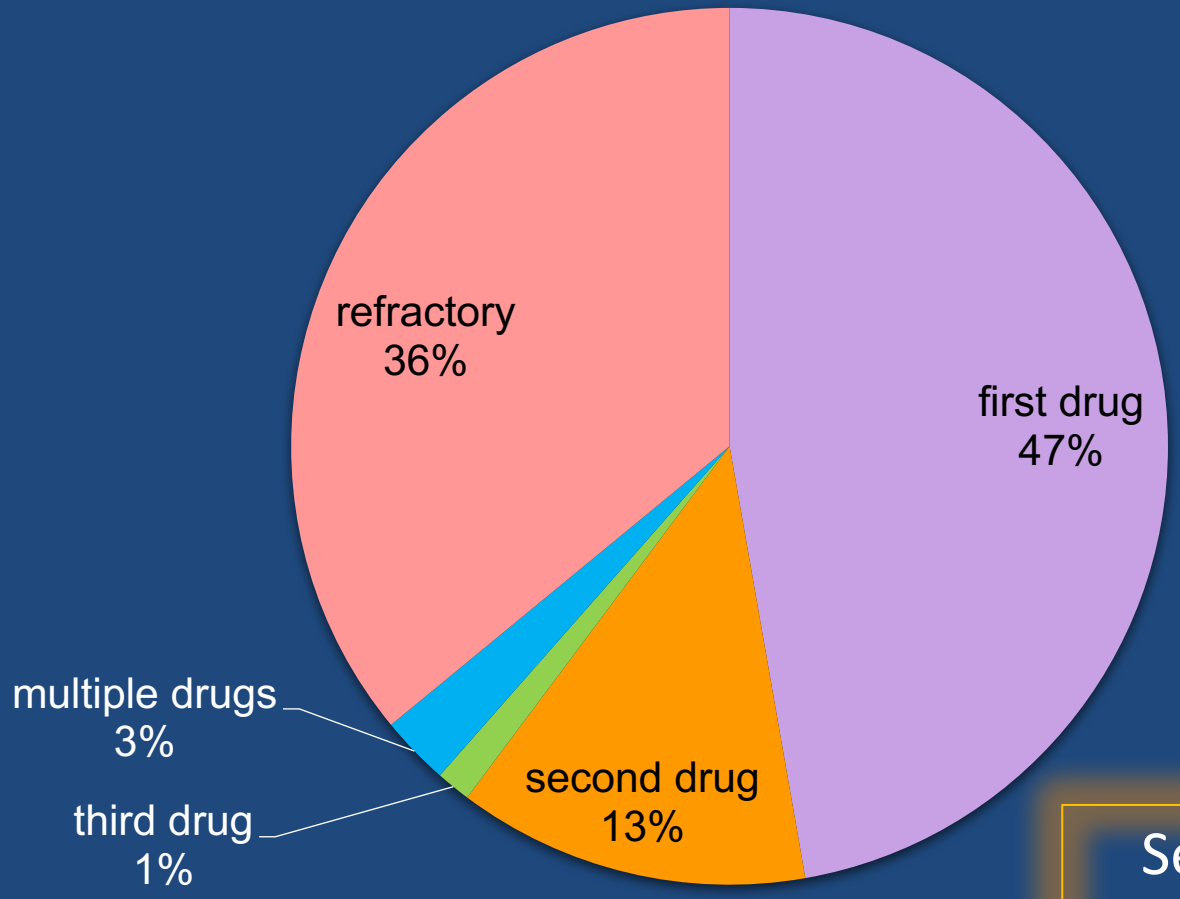
Refer refractory cases!

- Why?
  - To confirm diagnosis of epilepsy
  - For alternative treatment options (surgery, etc.)
  - To avoid inappropriate treatments
- What defines refractory?
  - Lack of seizure control with two properly dosed medications
  - NOT failed due to side effects

A 28-year-old man develops new onset partial seizures. Treatment with levetiracetam is initiated, and the dose is titrated up to 1500 mg twice daily without seizure recurrence. However, he does not tolerate this medication due to worsening depression. The medication is tapered off and lamotrigine is titrated upward. What is the patient's chance of seizure freedom with lamotrigine?

A. ~75%
B. ~66%
C. ~50%
D. ~33%
E. ~15%

Chances of Seizure Freedom



Seizure-free with surgery (in the right cases): up to 70%

Kwan and Brodie, NEJM, 2000.
Chen, Brodie, Liew, and Kwan, JAMA Neurology, 2018.

In a patient with epilepsy, how many medications should be failed due to lack of seizure control prior to considering referral to an epilepsy center (or epilepsy monitoring unit)?

A. One
B. Two
C. Three
D. Four
E. Five

Unnecessary VNS in PNES

- 60 consecutive VNS patients in EMU
- 13 had PNES exclusively (none had prior EMU)
  - all on 2-4 medications
  - all discharged off medications
  - duration of VNS therapy: 0.5 – 5 yrs
  - mean latency to PNES diagnosis: 2.8 yrs
- Over-interpretation of outpatient EEGs?

Arain et al, Epilepsy and Behavior, 2011

Diagnostic usefulness and duration of the inpatient long-term video-EEG monitoring

- 234 consecutive LTM studies over 2 yrs (221 patients)
- Diagnostically useful in 44% (typical event previously not captured)
  - Not different between age groups
  - Not different between referral groups [diagnostic (41%), classification (41%) and presurgical (55%)]
- Duration of successful LTM significantly longer in the presurgical group (mean: 3.5 days) vs. diagnostic and classification groups (2.4 and 2.3 days, respectively)

Alving and Beniczky, Seizure, 2009

courtesy of Dr. Abou-Khalil

What is the typical diagnostic yield (chance of capturing a patient's typical events) during epilepsy monitoring unit (EMU) admission?

A. 20-25%
B. 40-45%
C. 60-65%
D. 80-85%
E. 90-95%

Non-diagnostic EMU studies

- Diagnostic yield of 1st EMU study: 82-85%
- Diagnostic yield of 2nd EMU study: 42-53%
- Factors associated with non-diagnostic study:
  - younger age (in adults)
  - longer duration of monitoring
  - normal outpatient EEG
  - absence of epilepsy risk factors

Elgavish and Cabaniss, J Clin Neurophysiol, 2011: ~3600 patients
Robinson et al, Epilepsy and Behavior, 2011: ~2400 patients

Co-existent epilepsy and PNES

- Occurrence has “decreased” historically
  - possibly due to wider use of video-EEG monitoring
  - estimated to be 5-15%

- Key factors in successful monitoring
  - duration (5 days suggested as optimal*)
  - Seizure medication withdrawal
  - capture of all typical event types

*Foong and Seneviratne, J Clin Neurosci, 2016

Continuous EEG (cEEG) in the ICU

- Non-convulsive seizures / status epilepticus have a typical combined incidence of 20-25%
- May vary (8-48%) depending on the study
- 40-92% of seizures on cEEG are nonconvulsive

NCS/NCSE: When to consider cEEG

- Altered mental status (esp. unexplained)
- History of epilepsy or recent seizures (esp. GTCS)
- Subtle twitching, eye deviation, nystagmus
- Recent CNS procedure, infections, stroke, neoplasms (esp. when pt is worse than expected)
- Chronic focal cortical injury

In critically ill, non-comatose patients undergoing continuous EEG monitoring, what duration of monitoring is recommended to capture a seizure in the majority (95%) of patients who will develop seizures in the ICU?

A. 1 hour
B. 6 hours
C. 12 hours
D. 24 hours
E. 48 hours

Continuous EEG in critically ill patients

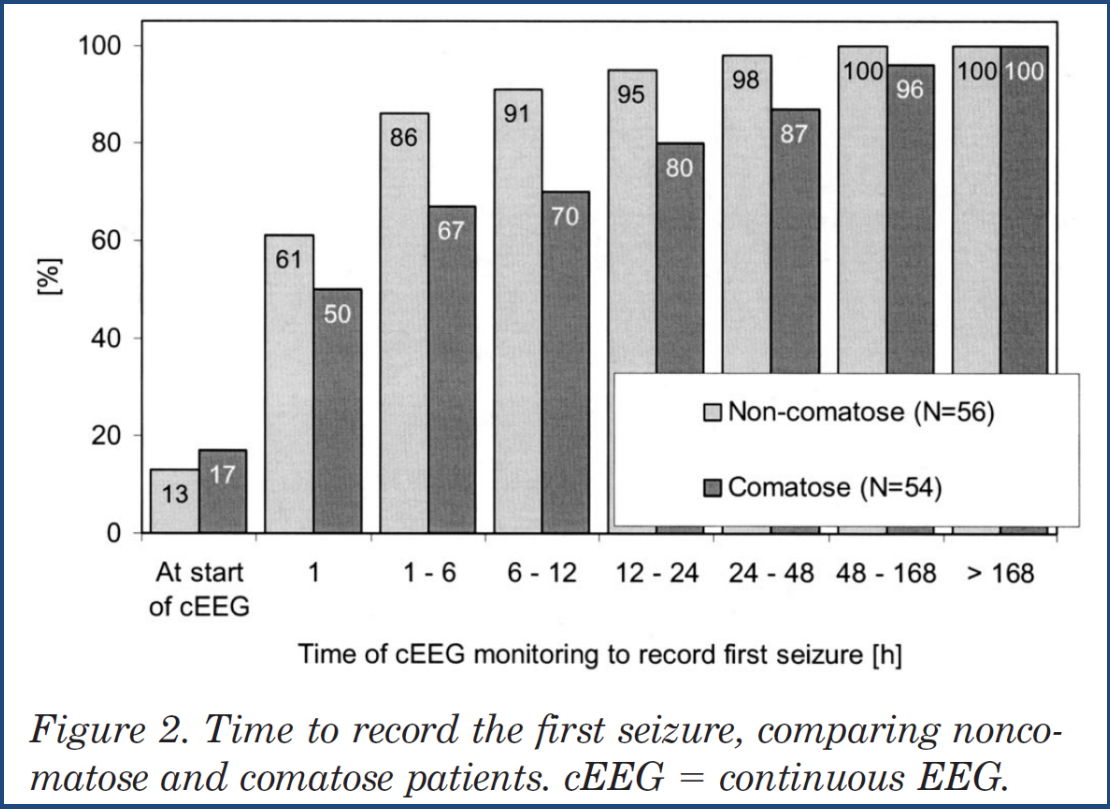


Figure 2. Time to record the first seizure, comparing noncomatose and comatose patients. cEEG = continuous EEG.

570 patients with altered mental status

Longer cEEG duration required in comatose patients

To capture most seizures:

Noncomatose → 24 hrs

Comatose → 48 hrs

Claassen et al., Neurology 2004;62:1743–8.

	Routine EEG	Extended EEG	Continuous portable EEG	Long-term EEG (EMU)	Ambulatory EEG	Home vEEG
Availability	+	+	-	-	+	--
Duration	--	-	++	++	+	+
Video	+	+	+	+	-	+
Ictal EEG	--	-	+	++	+	+
Examination	+	+	-	++	--	--
EEG quality	+	+	+	++	-	+
Surgery	-	-	+	++	-	-
Natural environment	-	-	-	-	+	+
Acute use	+	+	++	+	--	--
Med change	-	-	+	++	-	-
Hx correlate	-	-	+	++	-	-
Quantify sz	-	+	++	++	+	+
Sleep EEG	-	+	++	++	++	++
HV/Photic	+	+	+	+	-	-
Affordability	++	+	--	--	+	-

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