EEG nel COMA

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Dichiarazione sul Conflitto di Interessi

Dichiaro che negli ultimi due anni ho avuto i seguenti rapporti anche di finanziamento (compensi per relazioni/moderazioni a Congressi, FAD, Expert Meeting, etc) con soggetti portatori di interessi commerciali in campo sanitario:

- Arvelle/Angelini
- BIAL
- EISAI
- GW
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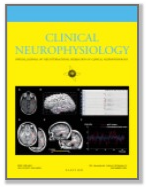
- UCB

O. Mecarelli (22.11.2021)

Clinical Neurophysiology
Volume 133, January 2022, Pages 68-70



Letter to the Editor

One EEG, one read – A manifesto towards reducing interrater variability among experts

Fábio A. Nascimento ✉, Jin Jing, Sándor Beniczky, Selim R. Benbadis, Jay R. Gavvala, Elza M.T. Yacubian, Samuel Wiebe, Stefan Rampp, Michel J.A.M. van Putten, Manjari Tripathi, Mark J. Cook, Peter W. Kaplan, William O. Tatum, Eugen Trinka, Andrew J. Cole, M. Brandon Westover

Electroencephalography (EEG) plays a major role in routine clinical care for patients with seizures and epilepsy. Accurate and reliable EEG interpretation are crucial as they guide clinical management in many circumstances (Fisher et al., 2014). Misinterpretation is a significant problem when EEGs are reviewed by neurologists without specialty training (Amin and Benbadis, 2019). Nonetheless, there is another important issue which has attracted less attention by our community: the same EEG may be interpreted differently by experts (i.e., neurologists with clinical neurophysiology and/or epilepsy fellowship training).

Expert interrater reliability (IRR) is imperfect in routine EEG interpretation (Jing et al., 2020). A recent multicenter study recruited eight experts to rate 13,262 candidate interictal epileptiform discharges (IEDs), extracted from routine 1,063 EEGs from patients of all ages, as IEDs or non-IEDs. Experts' IRR was fair (chance-corrected agreement, κ: 48.7%). Expert IRR appears to be better for determining whether an EEG contains any IEDs vs. none (κ: 69.4%). Nevertheless, overall reliability is limited by the quality of judgements regarding single IEDs, and the interpretation of an EEG in clinical practice often boils down to a single IED.

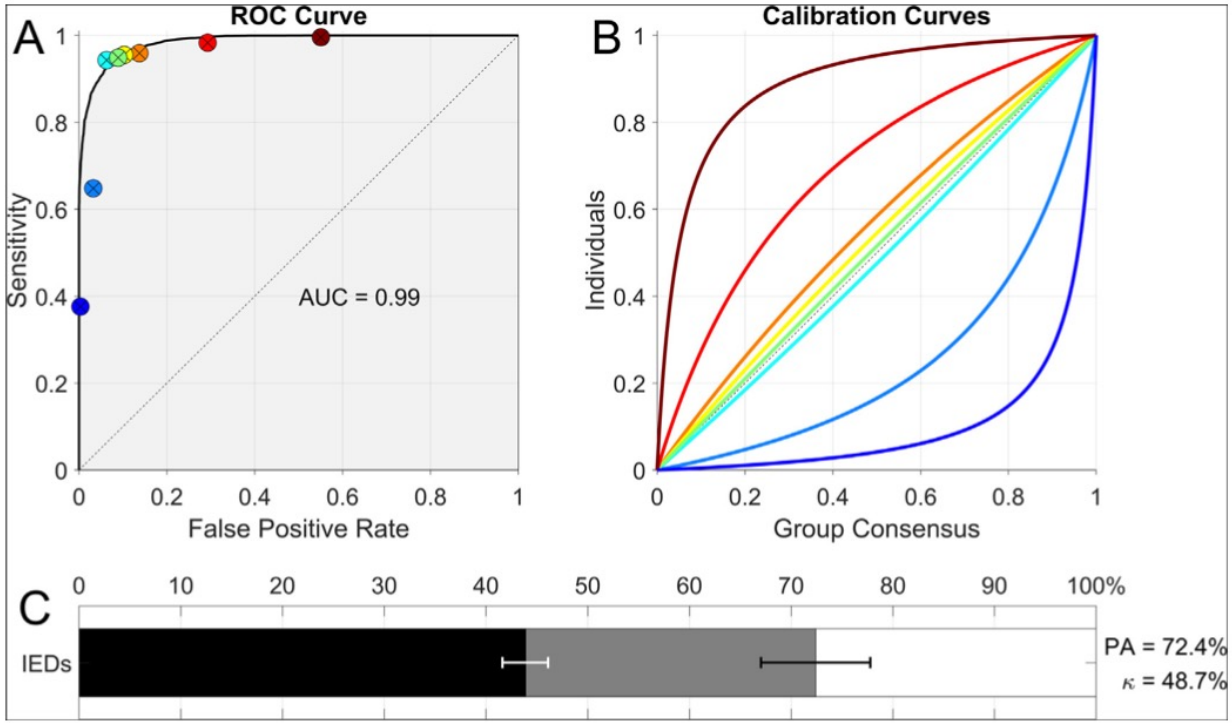


Fig. 1. A: Receiver operating characteristic curve fit to all experts' scores, with the operating point (false-positive rate = 1 − specificity and sensitivity) of each expert indicated by a solid circle. B: Parametric calibration curve fit to the binary scores of each export, indicating the probability of that expert marking events within a given bin as IEDs. These curves allow assessment of the variation among experts relative to the group consensus. Colors are ordered from maximal under calling (blue) to maximal over calling (red). C: Inter-rater reliability (IRR): Kappa (κ) values in relation to percent agreement. Horizontal bars show the percent agreement (PA, black + gray bars, 95% CI in black error bar), relative to the maximal possible (100%, end of white bar). The length of the black bar shows the percent agreement by chance, PC (95% CI in white error bar). Mathematically, the chance-corrected IRR, κ, is the percentage of this possible beyond-chance agreement that is actually achieved, that is, κ = (PA − PC)/(100 − PC). Graphically, κ is represented as the fraction of the distance between 100% and the end of the black bar that is taken up by the gray bar.

Reliability of expert interpretation of IEDs depends on two types of noise: *pattern noise* and *level noise* (Kahneman et al., 2021). Pattern noise is variability between experts in judgements about which probabilities to assign to candidate IEDs. When such variations are measured relative to a gold standard, pattern noise reflects experts' skill in discriminating IEDs from normal variations, benign variants, and artifacts[1]. Level noise, by contrast, is variability over where to set the threshold above which a candidate IED is considered epileptiform. We can understand the difference between pattern noise and level noise in terms of receiver operating characteristic (ROC) curves. Relative to a gold standard, each expert's performance can be quantified by two numbers: true positive rate (TPR, aka sensitivity) and false positive rates (FPR) (Fig. 1). The set of all possible TPR and FPR values an expert could in principle achieve by varying their choice of threshold is the expert's ROC curve; the area under this curve reflects the individual's pattern noise (lower pattern noise, higher area). By contrast, level noise arises from disagreements over where to place the threshold dividing positive and negative decisions (i.e., raters' different operating points on the ROC curve).

Pattern Noise:
variability between experts in judgements about wich probabilities to assign to candidate IEDs

Level Noise:
variability over where to set the threshold above which a candidate IED is considered epileptiform

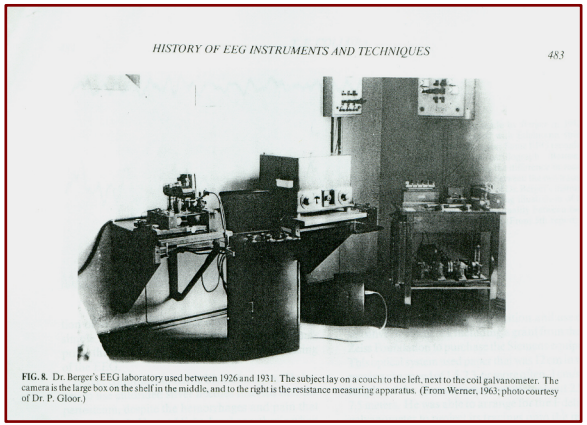
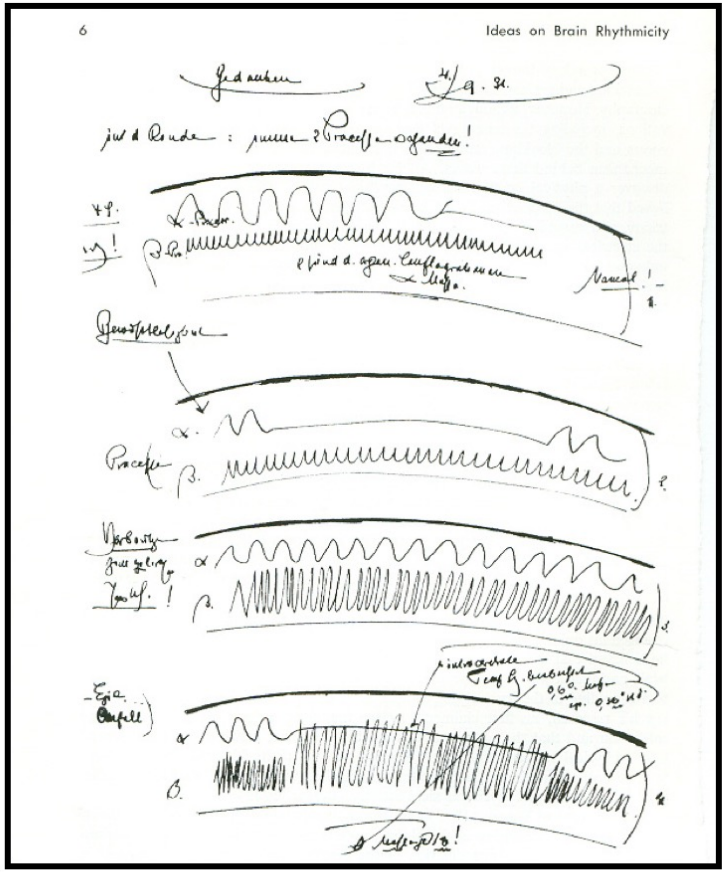


FIG. 8. Dr. Berger's EEG laboratory used between 1926 and 1931. The subject lay on a couch to the left, next to the coil galvanometer. The camera is the large box on the shelf in the middle, and to the right is the resistance measuring apparatus. (From Werner, 1963; photo courtesy of Dr. P. Gloor.)



H. Berger, 1931

normal

unconsciousness

epileptic aura

epileptic seizure

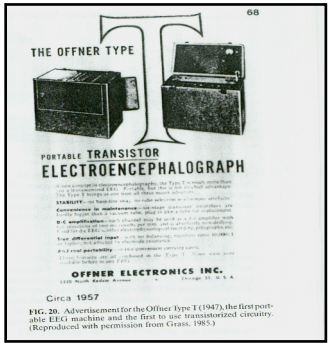
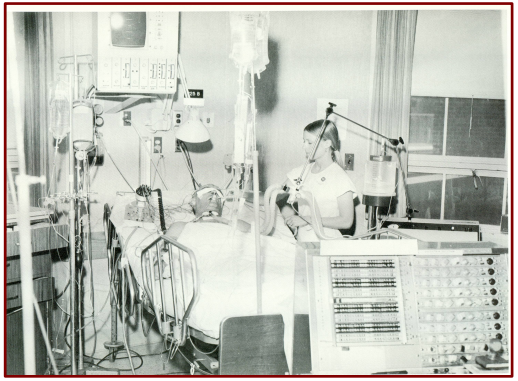
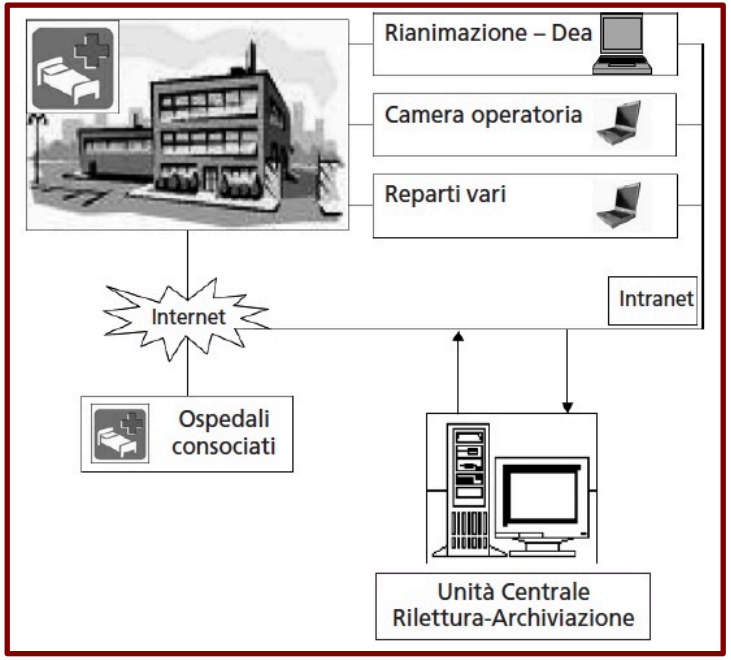


FIG. 20. Advertisement for the Offner Type T (1947), the first portable EEG machine and the first to use transistorized circuitry. (Reproduced with permission from Grass, 1985.)





Neurofisiologia in Area Critica:

1. Utile/Indispensabile in:
Rianimazione – Terapie Intensive specializzate –
Stroke Unit - DEA - Reparti spec. (Malattie Infettive, etc)

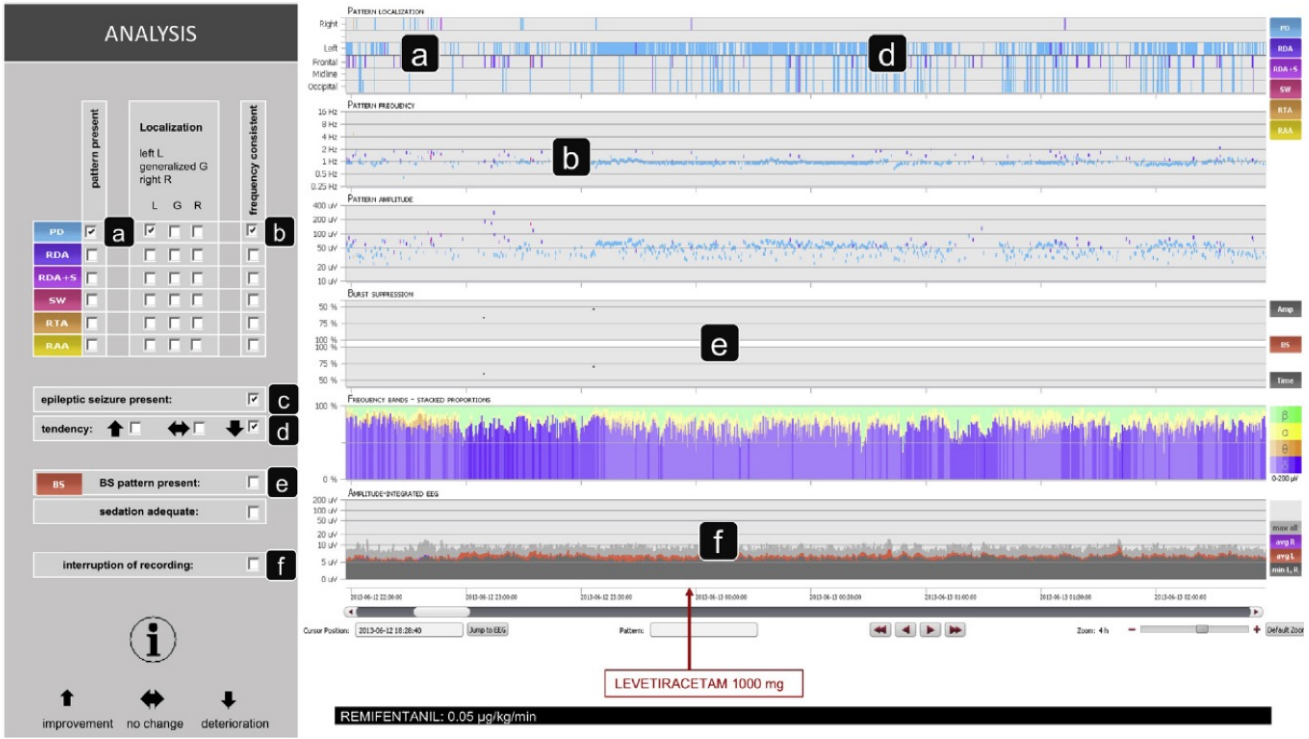
2. Neuromonitoraggio multimodale
(con apparecchiature e sistemi di connessione evoluti)
- **Monitoraggio EEG continuo** (cEEG) (+ poligrafia)
- **Potenziali Evocati**: - PES - BAEPs - PE lunga latenza - ERPs
- Doppler Transcranico
- Monitoraggio PIC ed altri sistemi di monitoraggio flusso ematico cerebrale
- etc

3. Necessità di Tecnici e Neurofisiologi esperti e in numero tale da coprire il Servizio h24, 7g/7, con possibilità di visualizzazione e refertazione da remoto.

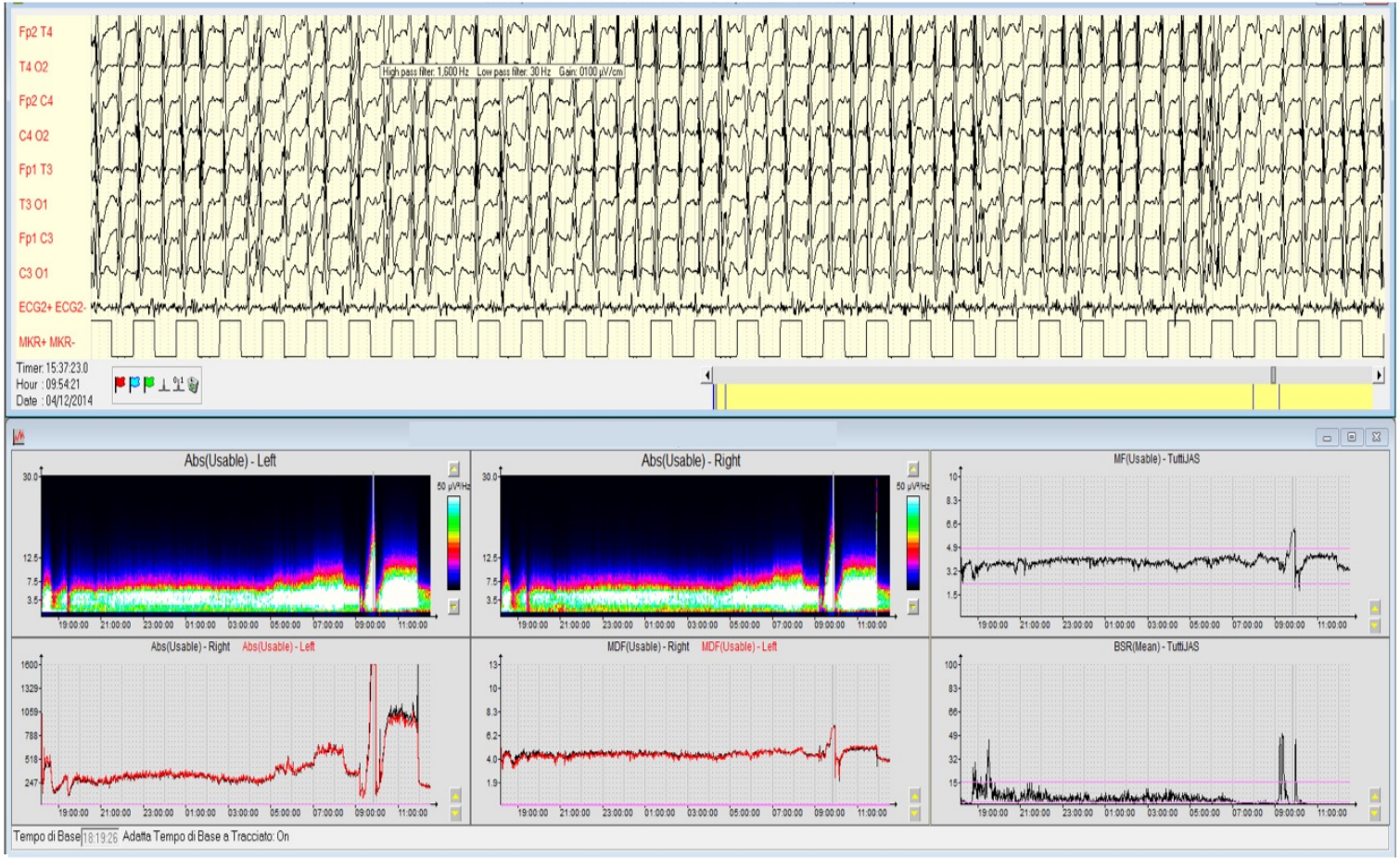
Applicability of NeuroTrend as a bedside monitor in the neuro ICU

J. Herta [a,*], J. Koren [b], F. Fürbass [c], A. Zöchmeister [a], M. Hartmann [c], A. Hosmann [a], C. Baumgartner [b,d], A. Gruber [a]

J. Herta et al. / Clinical Neurophysiology 128 (2017) 1000–1007

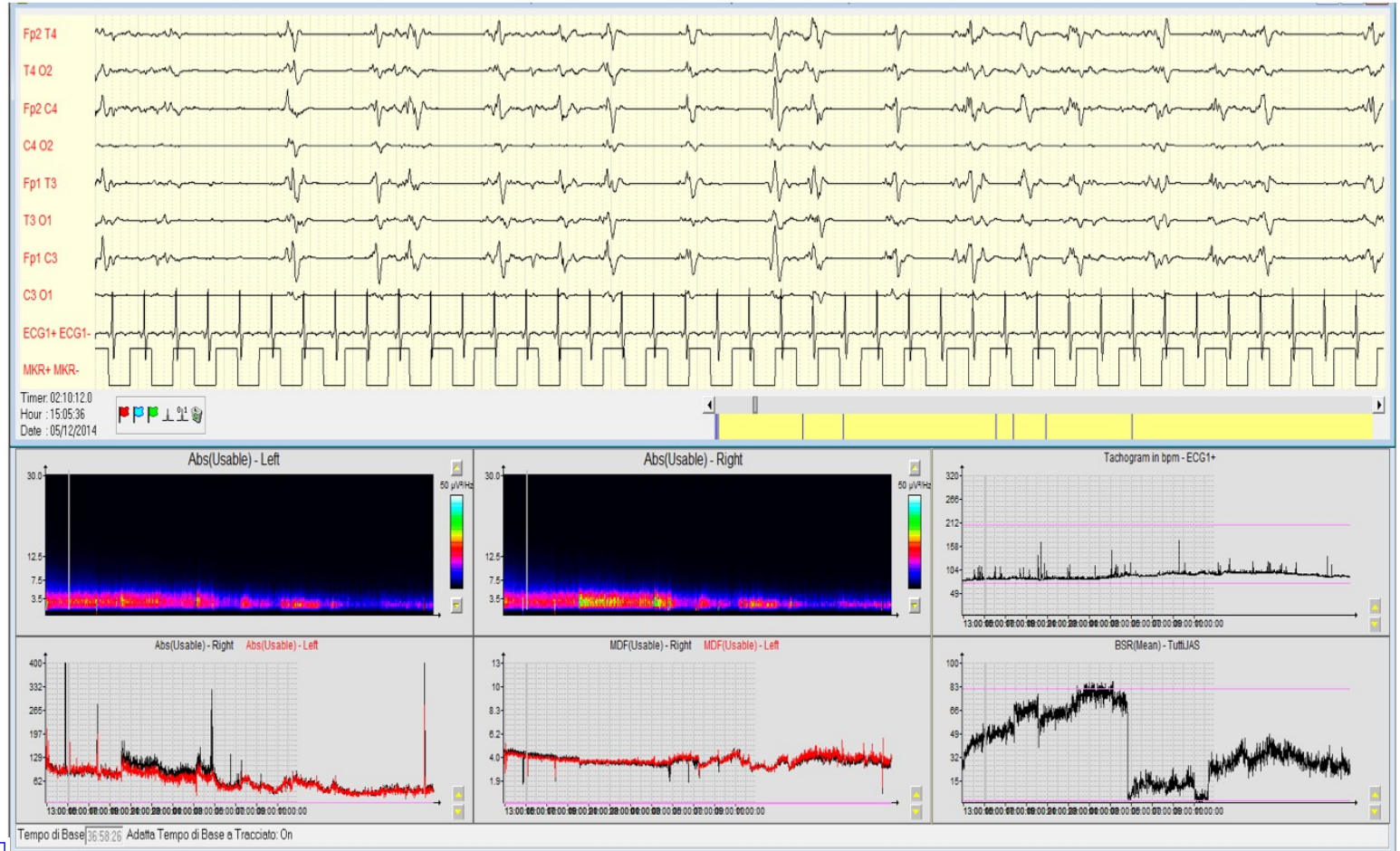


A.S. aa 44 Monitoraggio EEG 1° giorno



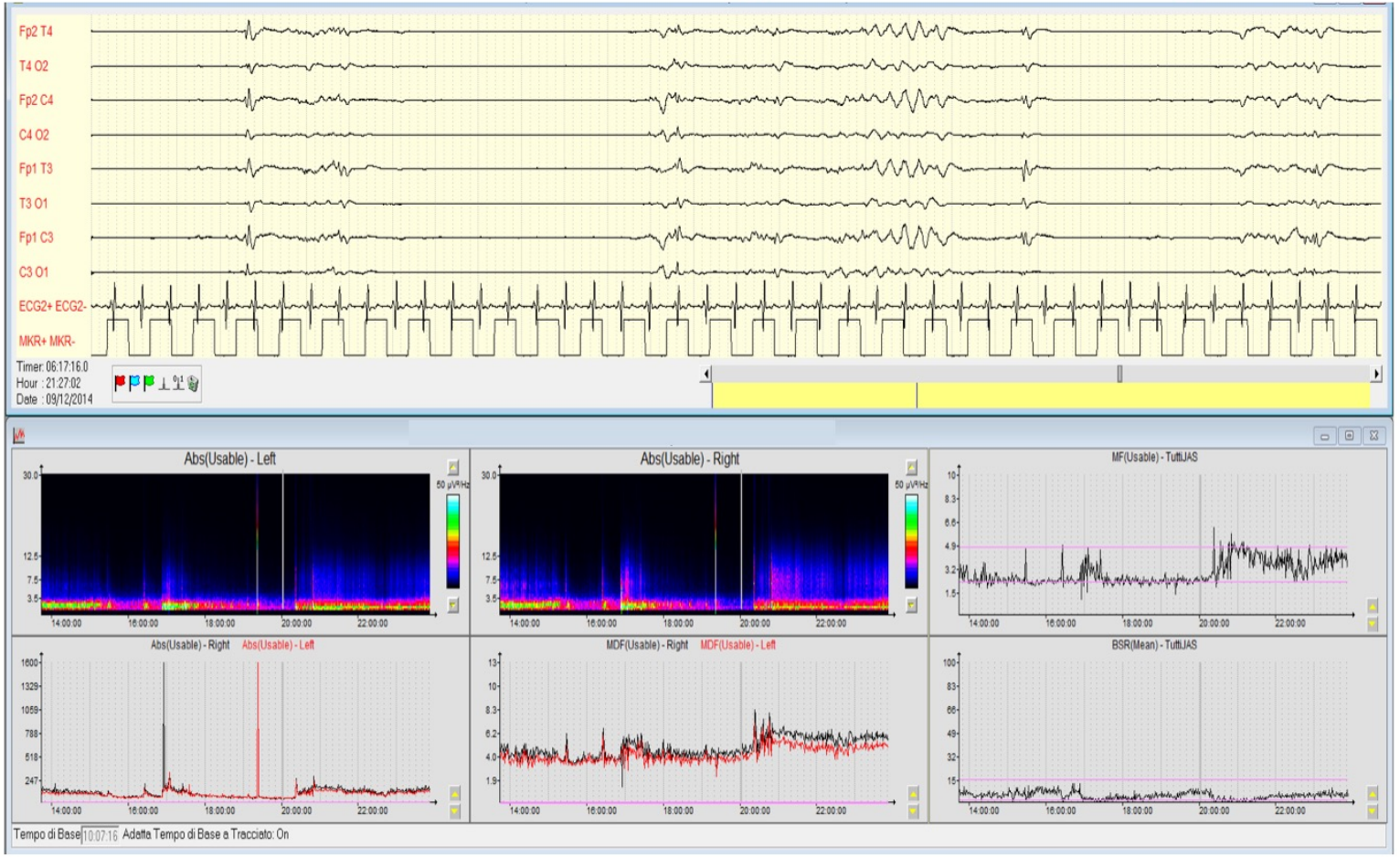
No sedazione

A.S. aa 44 Monitoraggio EEG 2° giorno



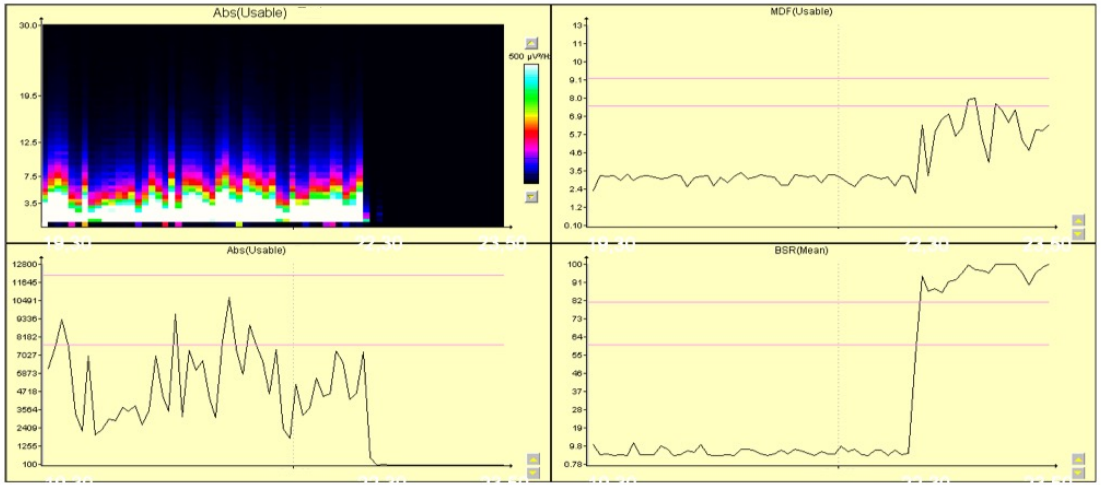
Infusione continua di Propofol

A.S. aa 44 Monitoraggio EEG 6° giorno

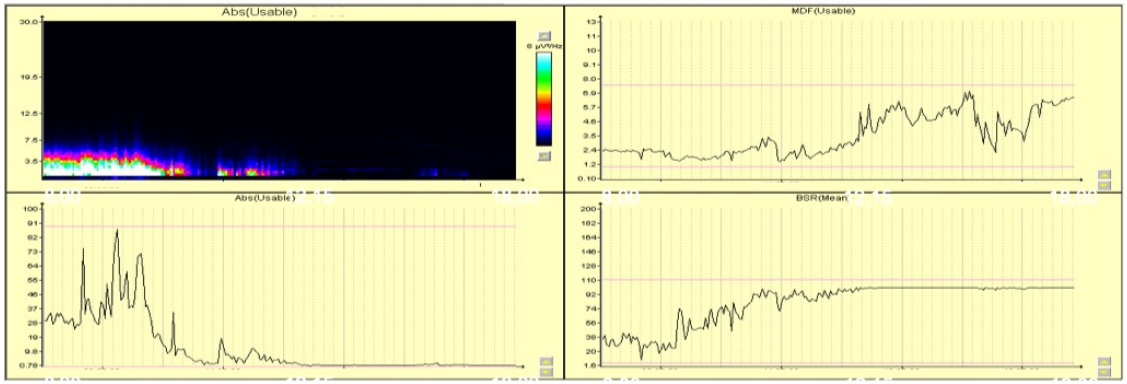


Interrotta sedazione

Trends



Monitoraggio dalle 19,30 alle 23,50 (Arresto Cardiaco alle 22,30)



Monitoraggio dalle 8,00 alle 18,00: BS che evolve in morte cerebrale (EEG piatto dalle h. 12,15)

Perché l'EEG è utile per il monitoraggio della funzionalità cerebrale in Rianimazione ?

1) l'EEG è una risultante multifattoriale, cui concorrono sistemi intracellulari, interneuronali e neurono-gliali:
   pur non essendo specifico è quindi un indicatore altamente sensibile di disfunzione cerebrale

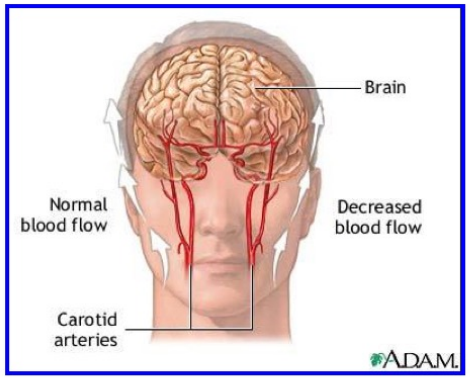
2) l'EEG è generato principalmente dai neuroni piramidali e quindi mostra subito i segni di ipossia o ischemia cerebrale

3) l'EEG correla con la topografia cerebrale

4) l'EEG permette di evidenziare la disfunzione cerebrale anche a livelli reversibili

Physiologic Derangements that may cause Hypoxic Encephalopathies

Brain Ischemia (diffuse or focal)
Deficit Oxygenation



Insufficient Cerebral Blood Flow (diffuse or focal):

1) Severe blood loss/Severe anemia
2) Vascular insufficiency/occlusion:
   - Intracranial hypertension
   - Coagulopathy
   - Systemic Lupus Erythematosus
   - Fat embolism,
   - Cerebral Malaria
   - Cardiopulmonary bypass
   - CADASIL
   - etc
3) Cardiac Insufficiency/Arrest
4) Insufficient oxygen supply (Hypoventilation, Co intoxication, respiratory insufficiency, decreased atmospheric oxygen pressure)
5) Decreased peripheral vascular resistance (syncope, etc)
6) Increased Vascular resistance (hyperventilation, Hypertensive enceph, hyperviscosity, vasospasms)

Mod. by Sutter & Kaplan, J Clin Neurophysiol 2013

Manuale Teorico Pratico di Elettroencefalografia

ISBN 978-88-7556-427-8

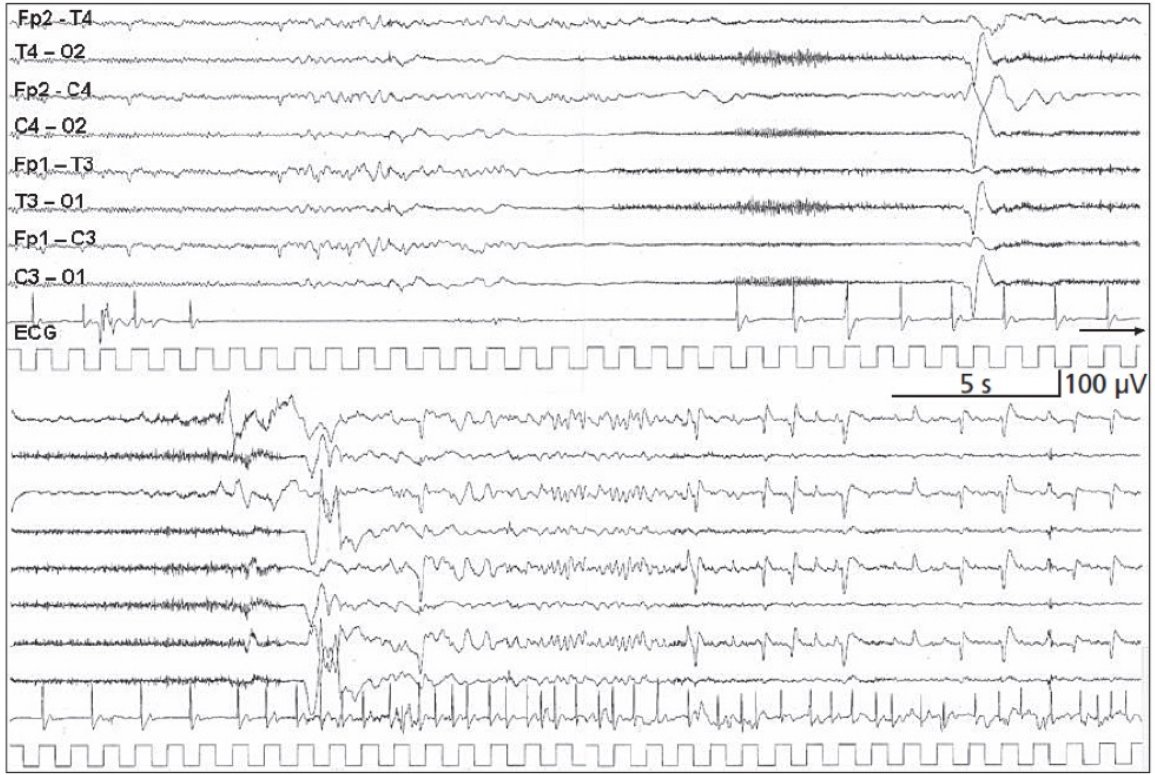
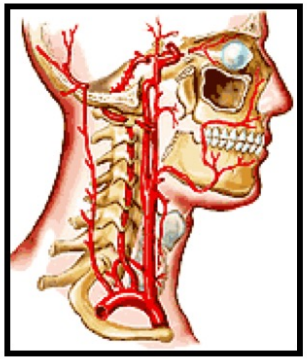


Figura 2. Pattern EEG corrispondente a una cosiddetta sincope convulsiva, registrato in un paziente di 36 anni con crisi sincopali ricorrenti neuromediate. L'esordio della sintomatologia sincopale coincide con la scomparsa dell'alfa seguita da sequenze lente diffuse, prima theta e poi delta. Dopo circa 10 s di asistolia, il tracciato EEG appare depresso e il paziente mostra ipertonia e qualche clonia. Con il ritorno del battito cardiaco (pur aritmico), il tracciato torna, con un percorso inverso, al ripristino del fisiologico ritmo alfa.

Flusso Ematico Cerebrale

(valori normali : **50-60** ml/100g/min)

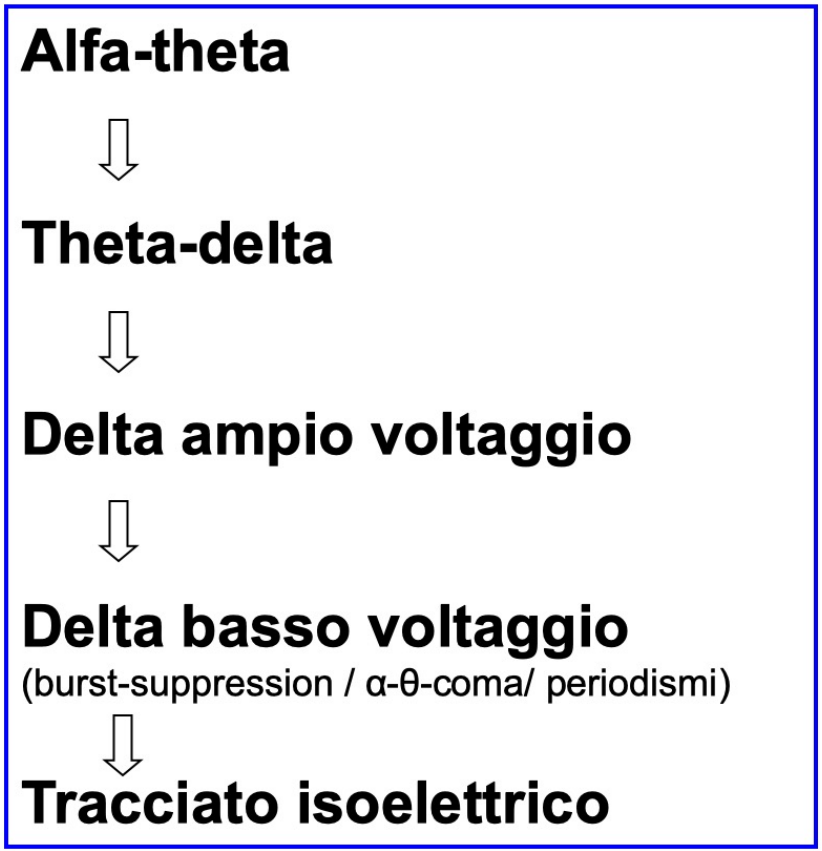


Le **alterazioni EEG** compaiono quando il flusso ematico cerebrale scende a livelli di **20-25** ml/100g/min

La morte cellulare interviene con livelli di flusso di **10-12** ml/100g/min

Tra questi due valori si situa la " finestra terapeutica "

EEG del COMA



15

Glasgow Coma Scale

GCS

3

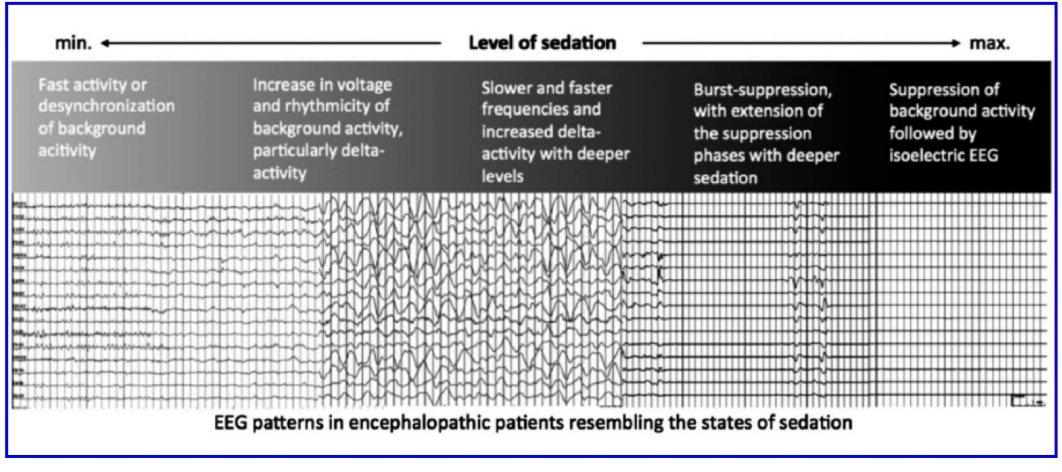
O. Mecarelli (ed.), *Clinical Electroencephalography*, https://doi.org/10.1007/978-3-030-04573-9_2

Fig. 46.2 Changes of background activity during various levels of coma. burst-suppression pattern appears (**d**) and then the background activity is attenuated (**e**) or completely suppressed (**f**) (**a–c**) continuous theta-delta diffuse activity progressively decreases in frequency, synchronisation and amplitude. As coma deep-

Se la **SENSIBILITA'** dell'EEG nelle Encefalopatie è accettata e fuori discussione, molto meno dimostrata è invece la **SPECIFICITA'.**

Le modificazioni EEG da cause "anossiche e/o metaboliche" sono state descritte a partire dagli anni '60 ma un netto incremento degli studi si è osservato solo negli ultimi 20 anni.

Molte differenti eziologie possono produrre le stesse modificazioni EEG.



EEG patterns in encephalopathic patients resembling the states of sedation

FIG. 2. Progressive EEG frequency slowing with progressive anesthesia (adapted from Sutter R, Kaplan P W. Electroencephalographic patterns in coma: when things slow down. *Epileptologie* 2012. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation).

Etiology leading to ICU admission

Epilepsy & Behavior 49 (2015) 250–254

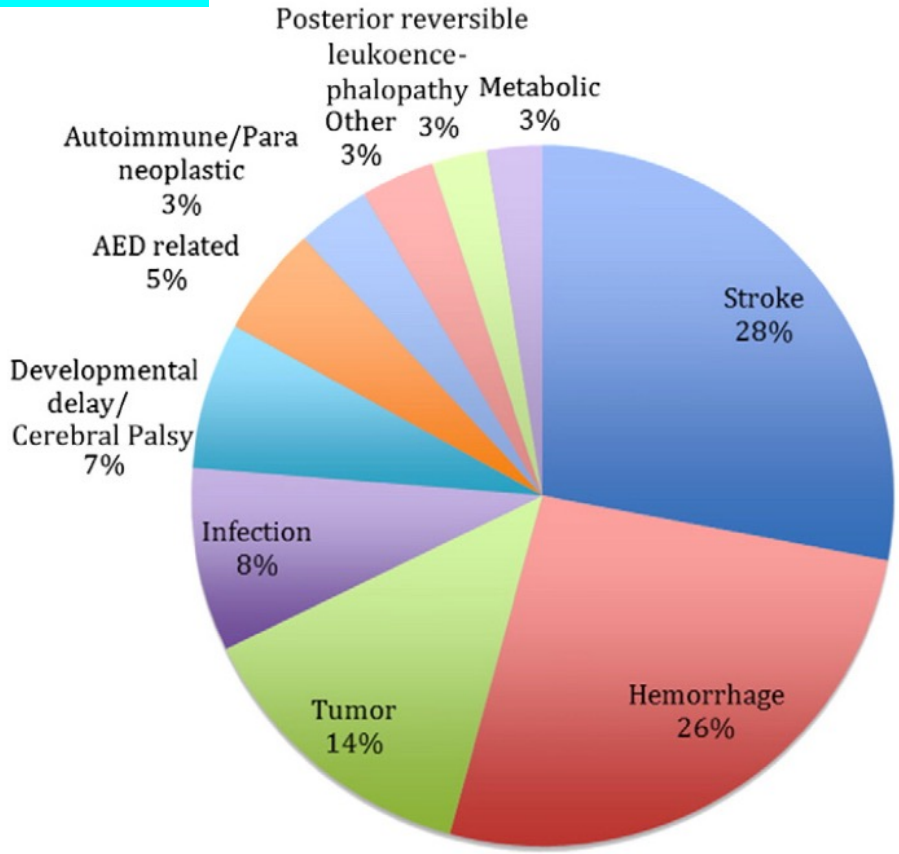


Fig. 2. Overall distribution of etiology.

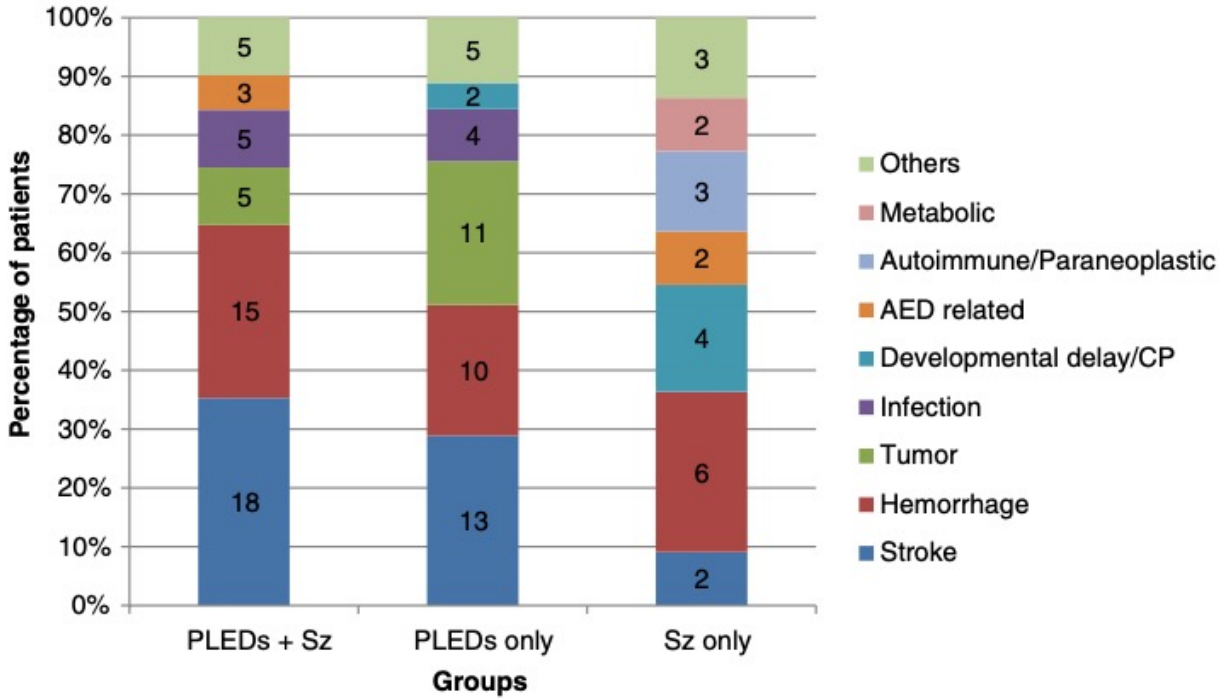


Fig. 3. Percentage distribution of etiology of acute presentation among the three groups (absolute number of patients within each bar, Sz = Seizure).

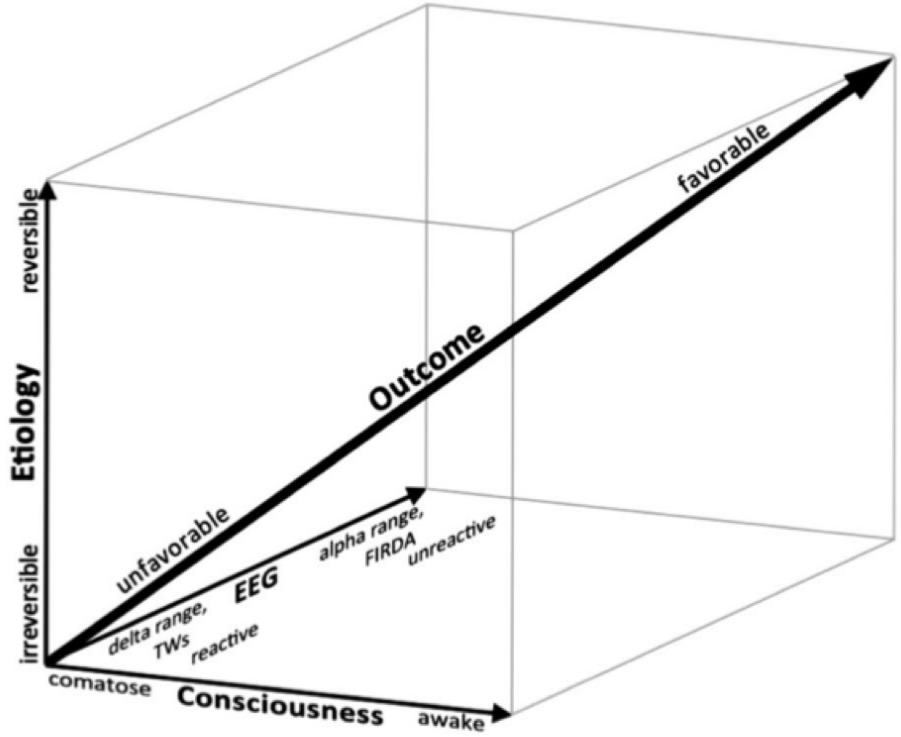


FIG. 4. Proposed paradigm for prognostication of outcome in encephalopathy. TWs, triphasic waves; FIRDA, frontal intermittent rhythmic delta activity.

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Crit Care Med. 2012 Oct;40(10):2867-75.

Continuous electroencephalography monitoring for early prediction of neurological outcome in postanoxic patients after cardiac arrest: a prospective cohort study.

Cloostermans MC[1], van Meulen FB, Eertman CJ, Hom HW, van Putten MJ.

Conclusions: In patients treated with hypothermia, electroencephalogram monitoring during the first 24 hrs after resuscitation can contribute to the prediction of both good and poor neurological outcome. Continuous patterns within 12 hrs predicted good outcome. Isoelectric or low-voltage electroencephalograms after 24 hrs predicted poor outcome with a sensitivity almost two times larger than bilateral absent somatosensory evoked potential responses.

1. Continuous EEG Patterns within 12 h: ⊆ good outcome

2. Discontinuous EEG Patterns after 24 h: ⊆ poor outcome

Cloostermans et al, 2012

5 min EEG epochs automatically selected every hour during the first 48 h

Each epochs classified into one category:

1) Continuous EEG Patterns:

diffuse slowing with a dominant frequency < 8 Hz

2) Discontinuous EEG Patterns:

a) Burst Suppression

b) Low Voltage

c) Isoelectric

Crepeau AZ et al, Neurology 2013; 80:339-344 (Mayo Clinic, Rochester, MN)

Table 1 EEG grading system for cEEG findings following cardiac arrest

Mild (grade 1)	Moderate (grade 2)	Severe (grade 3)
Excess beta	Diffuse or focal delta slowing	Burst suppression pattern
Theta slowing	SIRPIDS	Low voltage output pattern (≤10 μV)
Anesthetic pattern	ELAE	Alpha/theta coma
	Spindle coma	Focal or generalized seizures
	Interictal epileptiform discharges	Nonreactive to stimuli
	Generalized triphasic waves	GPED
	FIRDA, TIRDA, OIRDA	Status epilepticus
	PLED	

Abbreviations: cEEG = continuous EEG; ELAE = episodic low-amplitude events; FIRDA = frontal intermittent rhythmic delta activity; GPED = generalized periodic epileptiform discharges; OIRDA = occipital intermittent rhythmic delta activity; PLED = periodic lateralized epileptiform discharges; SIRPIDS = stimulation-induced rhythmical, periodic, or ictal discharges; TIRDA = temporal intermittent rhythmic delta activity.

American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology: 2012 version

L. J. Hirsch, S. M. LaRoche, N. Gaspard, E. Gerard, A. Svoronos, S. T. Herman, R. Mani, H. Arif, N. Jette, Y. Minazad, J. F. Kerrigan, P. Vespa, S. Hantus, J. Claassen, G. B. Young, E. So, P. W. Kaplan, M. R. Nuwer, N. B. Fountain, and F. W. Drislane

Journal of Clinical Neurophysiology • Volume 30, Number 1, February 2013

Sporadic Epileptiform Discharges	Background									
Prevalence	Symmetry	Breach effect	PDR	Background EEG frequency	AP Gradient	Variability	Reactivity	Voltage	Stage II Sleep Transients	Continuity
Abundant ≥1/10s	Symmetric	Present	Present Specify frequency	Delta	Present	Present	Present	Normal ≥20μV	Present and normal	Continuous
Frequent 1/min-1/10s	Mild asymmetry ≤50% Amp. 0.5-1/s Freq.	Absent	Absent	Theta	Absent	Absent	SIRPIDs only	Low 10-20μV	Present but abnormal	Nearly continuous: ≤10% periods of suppression (<10μV) or attenuation (≥10μV but <50% of background voltage)
Occasional 1/h-1/min	Marked asymmetry >50% Amp. >1/s Freq.	Unclear		≥Alpha	Reverse	Unclear	Absent	Suppressed <10μV	Absent	Discontinuous: 10-49% periods of suppression or attenuation
Rare <1/h							Unclear			Burst-suppression or Burst-attenuation: 50-99% periods of suppression or attenuation
										Suppression

O. Mecarelli (ed.), *Clinical Electroencephalography*, https://doi.org/10.1007/978-3-030-04573-9_2

Table 13.1 American Clinical Neurophysiology Society's proposed nomenclature for periodic or rhythmic patterns (adapted from Hirsch et al. J Clin Neurophysiol 2013; 30: 1–27)

Main term 1	Main term 2
Generalized (G): any bilateral, bisynchronous, and symmetric pattern, even with restricted field	Periodic Discharges (PDs): repetition of waveform—with relatively uniform morphology and duration—at nearly regular intervals, with a quantifiable interdischarge interval between consecutive waveforms
Lateralized (L): unilateral and bilateral (synchronous but asymmetric) patterns	Rhythmic Delta Activity (RDA): repetition of a waveform with relatively uniform morphology and duration, and without an interval between consecutive waveforms
Bilateral Independent: two independent (asynchronous) L patterns (one in each hemisphere)	Spike-and-Slow-Wave or Sharp-and-Slow- Wave Complex (SSWc): spike, polyspike or sharp wave followed by a slow wave in a regularly and alternating pattern, without an interval between one complex and the next
Multifocal (Mf): at least three independent L patterns (at least one in each hemisphere)	

ACNS GUIDELINE

American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology: 2021 Version

Lawrence J. Hirsch,* Michael W.K. Fong,† Markus Leitinger,‡ Suzette M. LaRoche,§ Sandor Beniczky,‖ Nicholas S. Abend,¶ Jong Woo Lee,# Courtney J. Wusthoff,** Cecil D. Hahn,†† M. Brandon Westover,‡‡ Elizabeth E. Gerard,§§ Susan T. Herman,‖‖ Hiba Arif Haider,§ Gamaleldin Osman,¶¶ Andres Rodriguez-Ruiz,§ Carolina B. Maciel,## Emily J. Gilmore,* Andres Fernandez,*** Eric S. Rosenthal,††† Jan Claassen,‡‡‡ Aatif M. Husain,§§§ Ji Yeoun Yoo,‖‖‖ Elson L. So,¶¶¶ Peter W. Kaplan,### Marc R. Nuwer,**** Michel van Putten,†††† Raoul Sutter,‡‡‡‡ Frank W. Drislane,§§§§ Eugen Trinka,‡ and Nicolas Gaspard‖‖‖‖

TABLE 1. ACNS Standardized Critical Care EEG Terminology: 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, page 7)*
- Identical bursts *(new term: Section A4d, page 6)*

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

- Unilateral Independent (UI) *(new Main Term 1 option: Section C1d, page 10)*
- Lateralized (bilateral asynchronous) *(Main Term 1: Section C1b, page 9)*
  - Patterns that consistently begin in one hemisphere and propagate to the other hemisphere can now be included as a lateralized (bilateral asynchronous) pattern.
- 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, page 24). 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, page 19)*
- Stimulus-Terminated *(new modifier)*

Electrographic and Electroclinical Seizure Activity

- Electrographic seizure (ESz) *(new term: Section D1, page 22)*
- Electrographic *status epilepticus* (ESE) *(new term: Section D2, page 23)*
- Electroclinical seizure (ECSz) *(new term: Section D3, page 24)*
- Electroclinical *status epilepticus* (ECSE) *(new term: Section D4, page 24)*
- *Possible* electroclinical status epilepticus *(new term: Section D4b, page 24)*

Brief Potentially Ictal Rhythmic Discharges (BIRDs) *(new term: Section E, page 24)*

Ictal-Interictal Continuum (IIC) *(new term: Section F, page 25)*

Minor changes

EEG background

- Predominant background frequency
  - Beta (>13 Hz) has now been added (rather than only "alpha or faster")
- 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
- Burst attenuation/suppression
  - Can now also be described by applying the location descriptions of Main term 1
- 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.
- Voltage
  - High (most or all activity ≥ 150 μV) has now been added as a category

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).[17]
  - 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

2021 ACNS CRITICAL CARE EEG TERMINOLOGY

CONTENTS

EEG BACKGROUND

Journal of Clinical Neurophysiology Volume 38, Number 1, January 2021

A. EEG BACKGROUND

1. Symmetry

a. Symmetric.
b. Mild asymmetry (consistent asymmetry in voltage [Fig. 1A] on an appropriate referential recording of <50% or consistent asymmetry in frequency of 0.5 to 1 Hz [Fig. 1B]).
c. Marked asymmetry (≥50% voltage or >1 Hz frequency asymmetry [Fig. 1C]).

NOTE: When any of the following features (Section A2–A10) are asymmetric, they should be described separately for each hemisphere.

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.

3. 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")

a. Present: Specify frequency to the nearest 0.5 Hz.
b. Absent.
c. Unclear.

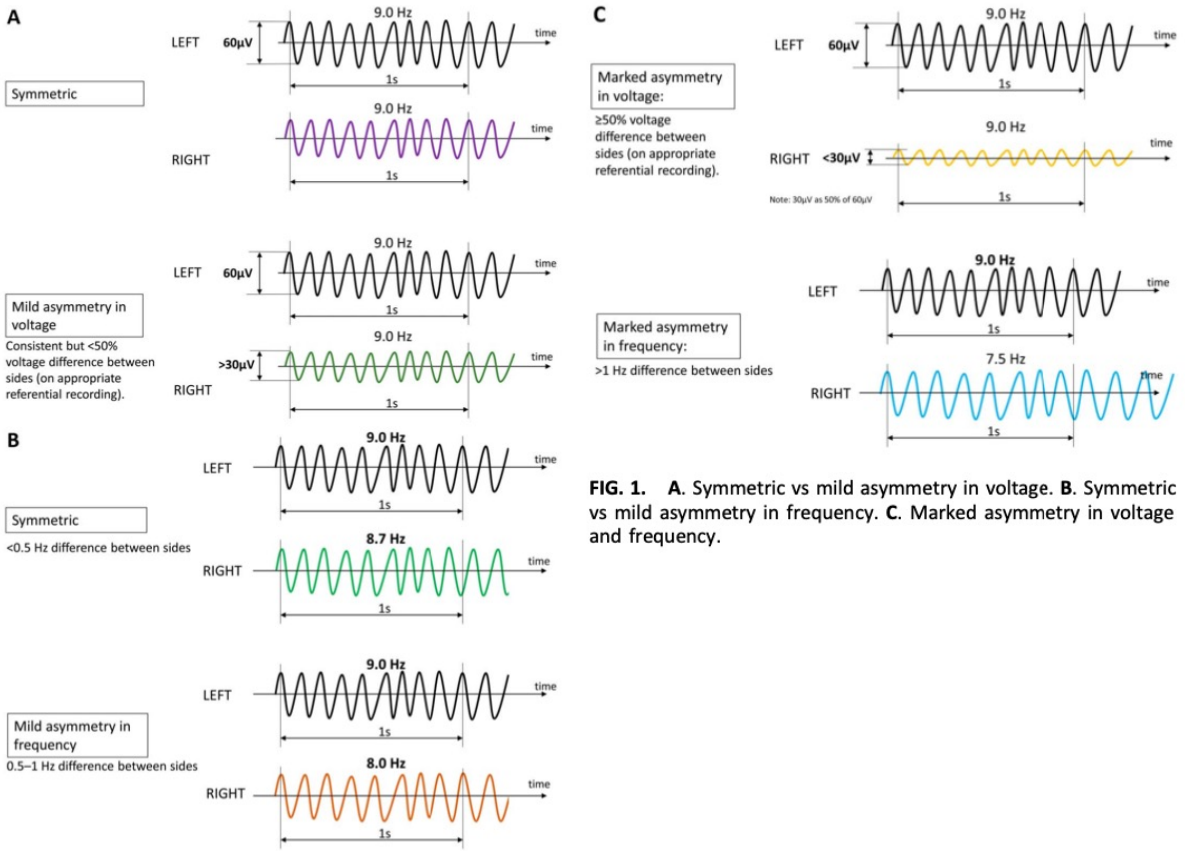


FIG. 1. **A.** Symmetric vs mild asymmetry in voltage. **B.** Symmetric vs mild asymmetry in frequency. **C.** Marked asymmetry in voltage and frequency.

4. Continuity (Fig. 2)

a. *Continuous*

b. *Nearly Continuous*: continuous, but with occasional (1–9% of the record) periods of attenuation or suppression lasting ≥1 second. Describe typical duration of attenuation/suppression.

i. Attenuation: periods of lower voltage are ≥10 μV but <50% of the higher voltage background.

ii. Suppression: periods of lower voltage are <10 μV.

NOTE: If attenuations/suppressions are stimulus-induced, this is referred to as "SI-attenuation" or "SI-suppression."

NOTE: This voltage cutoff, as with other voltages, differs from the ACNS neonatal terminology.[18]

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 (see Supp EEG 1, Supplemental Digital Content 1, http://links.lww.com/JCNP/A134) or suppression (see Supp EEG 2, Supplemental Digital Content 1, http://links.lww.com/JCNP/A134).

NOTE: The term "suppression-burst" is synonymous with "burst-suppression."

EEG BACKGROUND

- CONTINUOUS
- NEARLY CONTINUOUS
- DISCONTINUOUS
- BURST ATTENUATION/ BURST SUPPRESSION

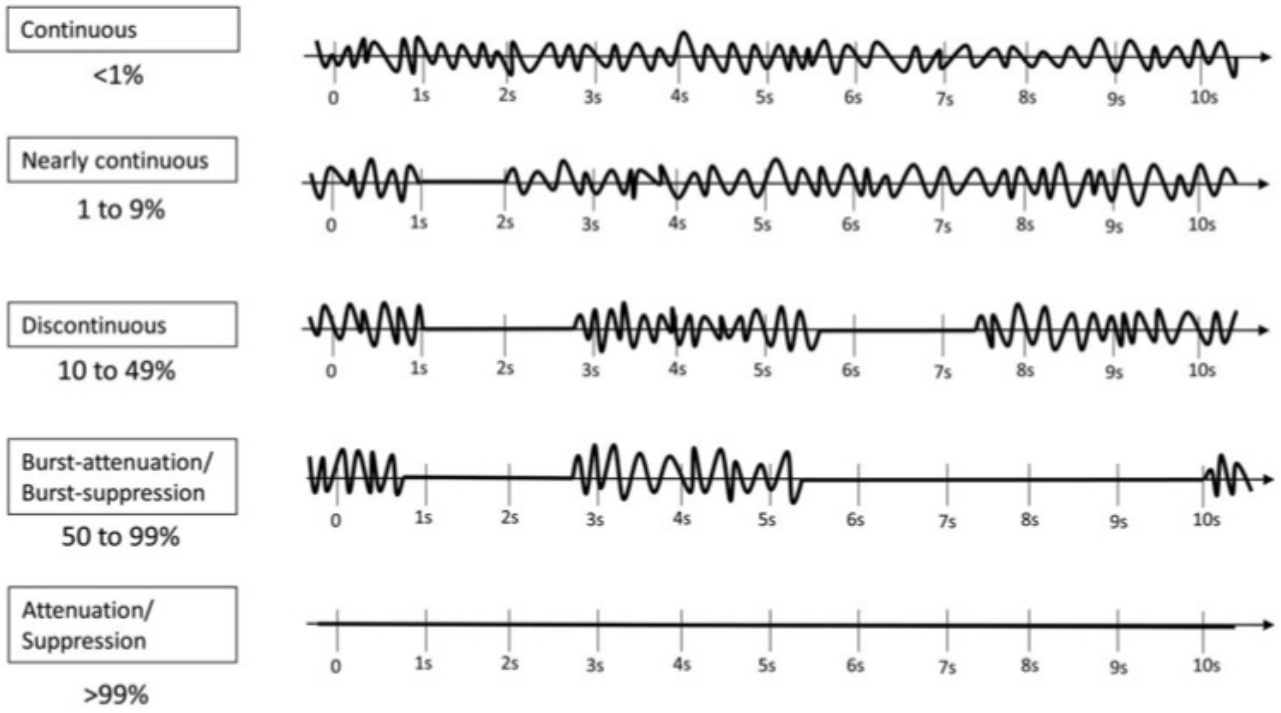


FIG. 2. Continuity. Percentages for each category refer to the percentage of the record that is "attenuated" or "suppressed." How this percentage is derived is demonstrated in Fig. 4, page 6.

EEG BACKGROUND: **Caratteristiche delle bursts: 1. DURATA (≥ 0.5 s)**

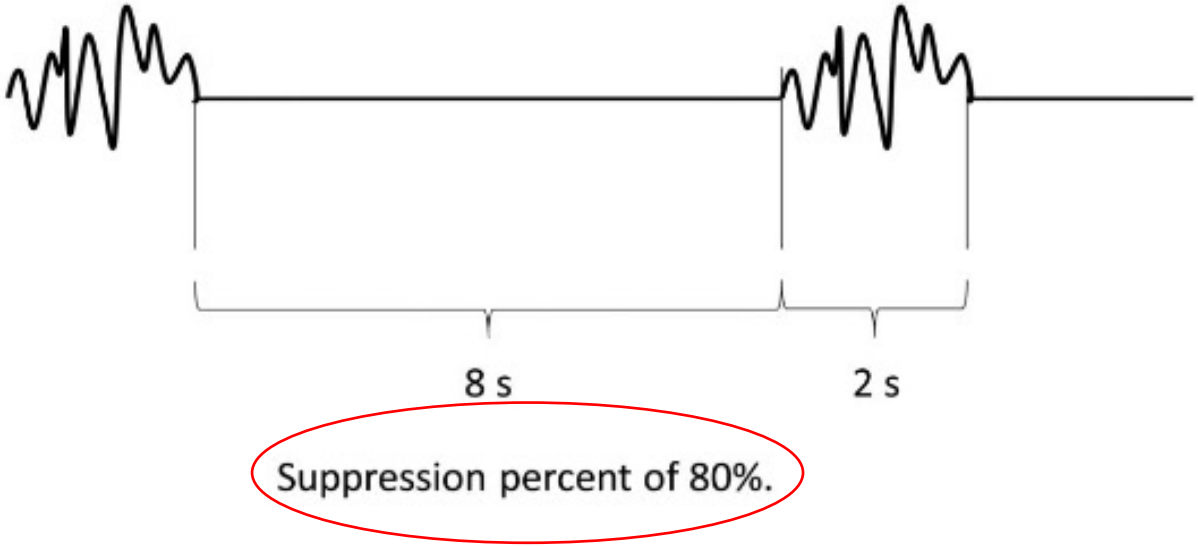


FIG. 4. Attenuation percent or Suppression percent: the percent of the record/epoch that is attenuated or suppressed. This can range from 1% to 99%. If <1%, it is considered continuous. If >99%, it is considered either suppressed or attenuated, but not discontinuous. For example, a record with 2 second bursts alternating with 8 seconds of suppression, as shown here, would be Burst-Suppression with a suppression percent of 80%.

Caratteristiche delle bursts: 2. NUMERO di FASI (≥ 4)

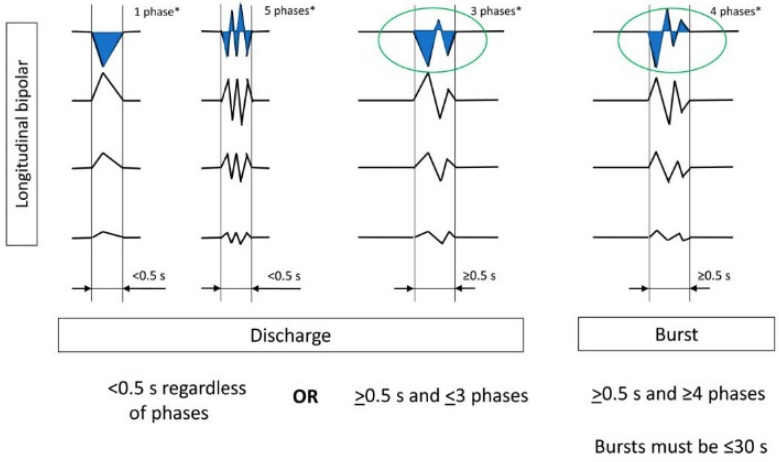


FIG. 3. Discharge vs. Burst. *Phase: an area under the curve on one side of the baseline (see Section C 3d, page 13, and Fig. 23, page 13).

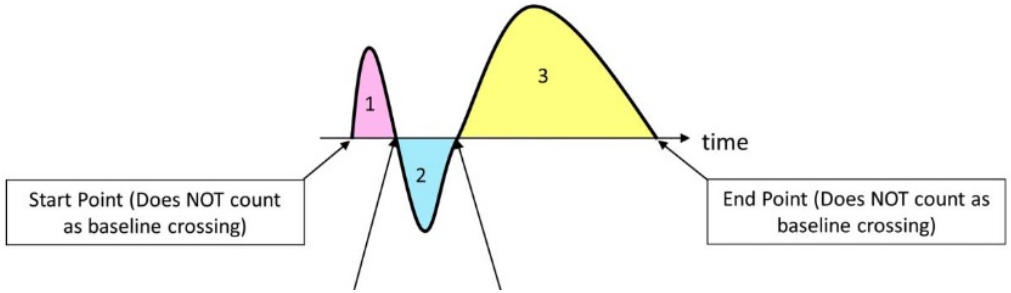


FIG. 23. The Number of Phases. Number of Phases = 1 + number of baseline crossings of the typical discharge. In this case there are a total of 2 baseline crossings, therefore the number of phases is 1 + 2 = 3 phases. A phase is the part of the signal above or below the imaginary baseline. In this case, phase 1 (pink) is above, phase 2 (blue) is below, and phase 3 (yellow) is above again.

Caratteristiche delle bursts: 3. LOCALIZZAZIONE

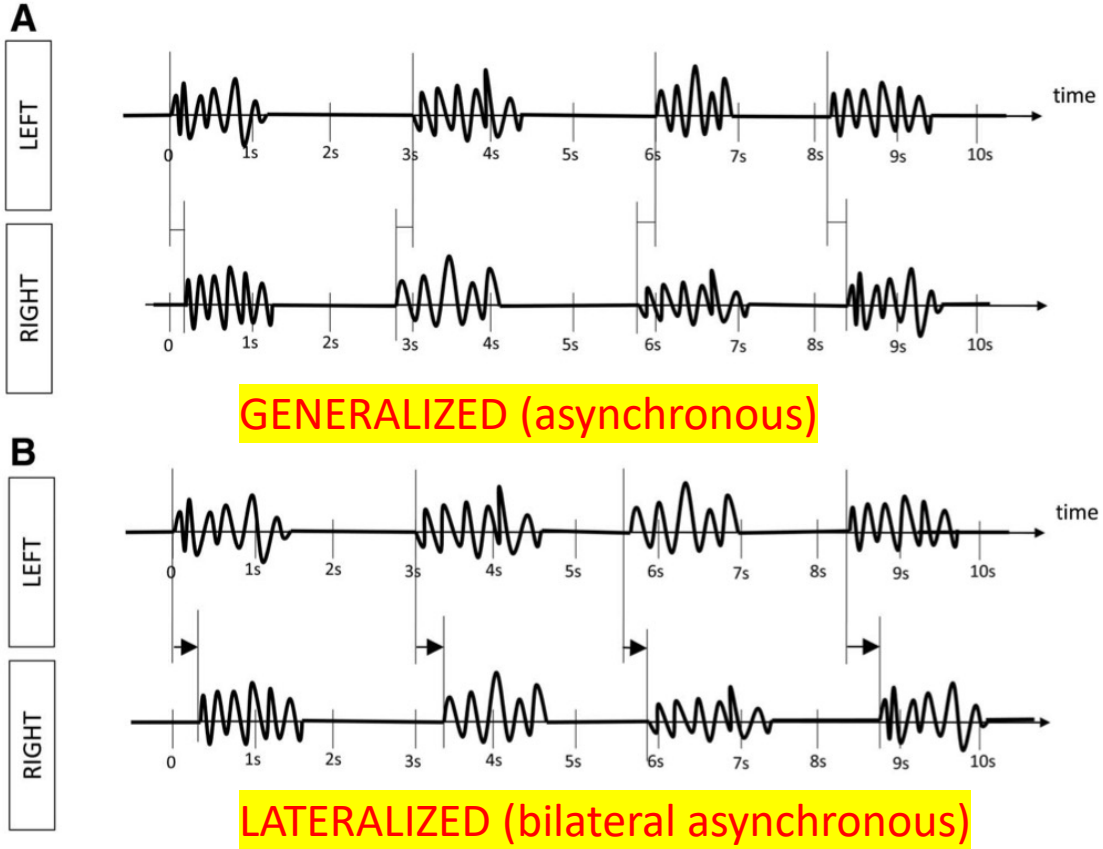


FIG. 5. Localization of bursts. **A.** Generalized bursts, shifting predominance based on asynchrony. Symmetric bursts, at times starting on the left and others on the right, but never consistently the same side. This would be an example of generalized bursts, with shifting predominance based on asynchrony (rather than asymmetry, where they would sometimes be of greater amplitude on the left and other times the right). **B.** Lateralized bursts, bilateral asynchronous. Symmetric bursts consistently starting on the left with a lag before being seen on the right. This is an example of lateralized, bilateral asynchronous bursts. They are not Bilateral Independent (BI) bursts because there is a consistent relationship between the activity between hemispheres, i.e. the patterns are not independent.

Caratteristiche delle bursts: 4. MORFOLOGIA

HIGHLY EPILEPTIFORM BURSTS

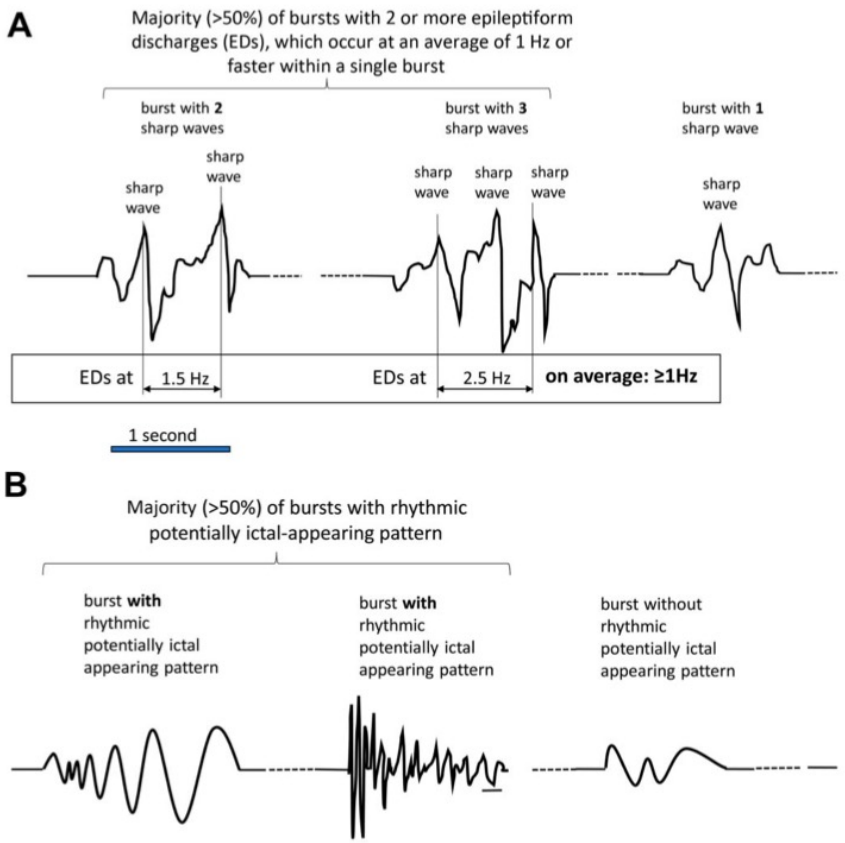


FIG. 6. **A**. Highly Epileptiform Bursts. --- dashed lines represent longer duration of suppression; ED epileptiform discharge. **B.** Highly Epileptiform Bursts. --- dashed lines represent longer duration of suppression.

IDENTICAL vs Non-IDENTICAL BURSTs

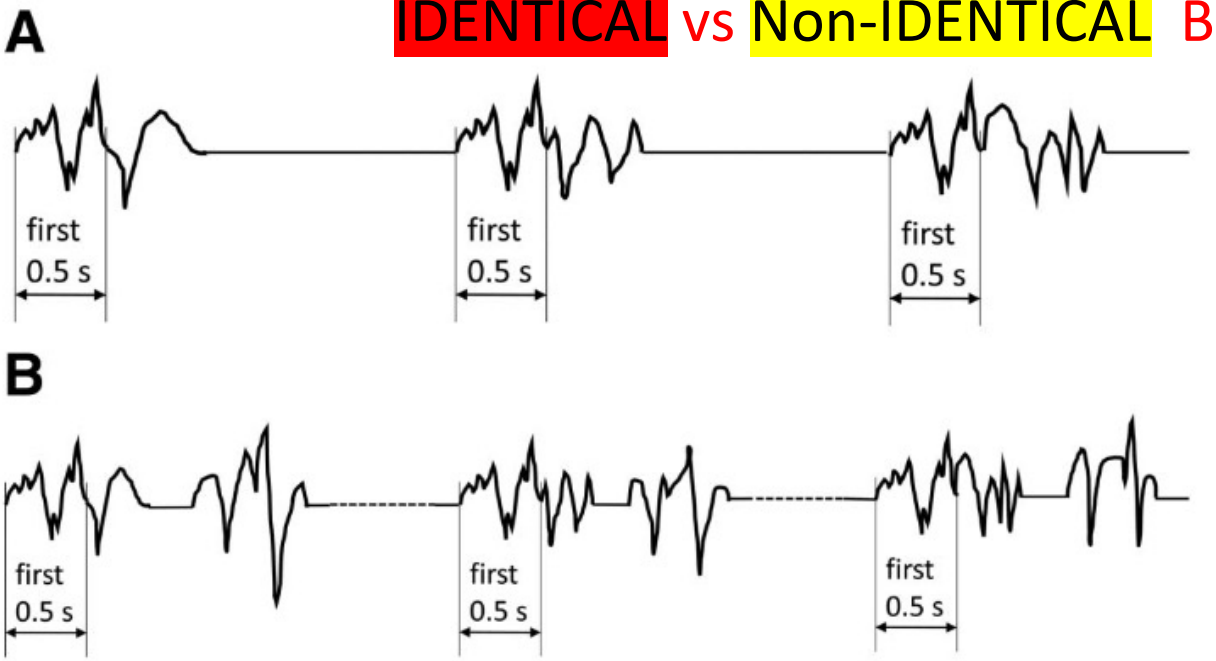


FIG. 7. **A**. Identical Bursts. The first 0.5 seconds or longer of each burst are visually similar in all channels (though only 1 channel shown) in most (>90%) bursts. **B**. Identical Bursts in a Stereotyped Cluster. The first 0.5 seconds or longer of each of 2 or more bursts in a stereotyped cluster are visually similar in all channels (though only 1 channel shown) in most (>90%) bursts.

Identical Bursts:
observed > following CA

↓

POOR OUTCOME

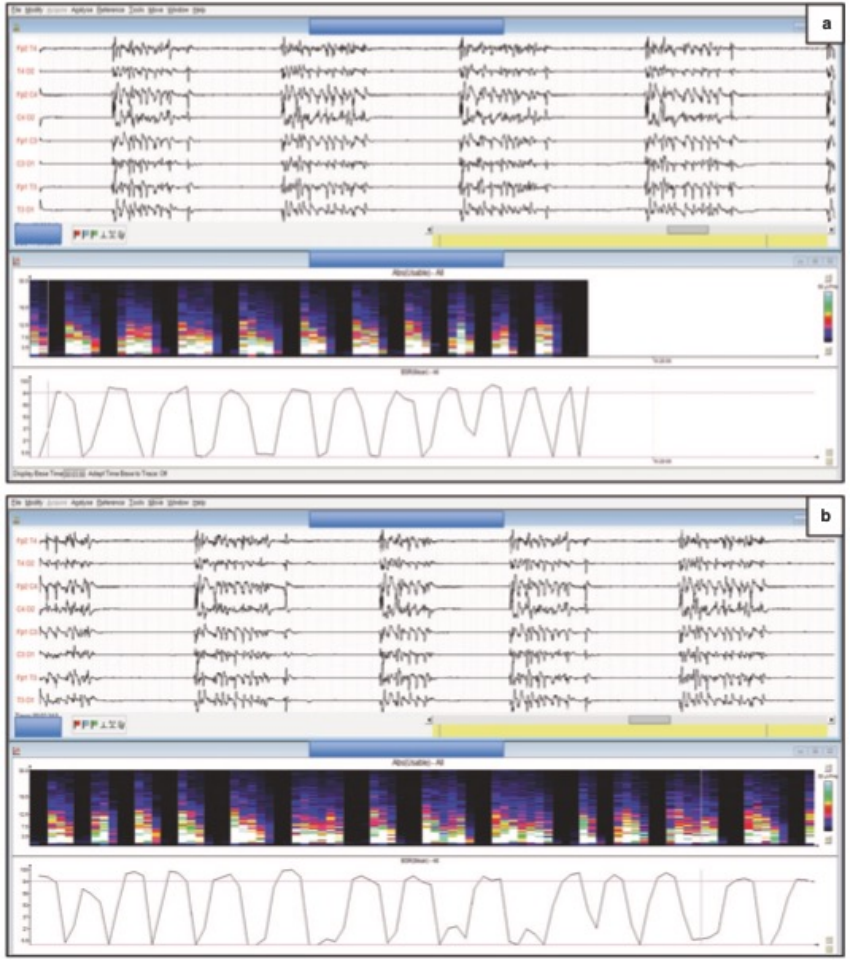


Fig. 46.16 Samples of burst-suppression pattern of identical (**a**) and non-identical (**b**) bursts in two patients with postanoxic encephalopathy. Above, 60 s raw EEG during monitoring; below, Density Spectral Array (DSA) and Burst-Suppression Ratio (BSR). LFF = 0.53, HFF = 70 Hz, ±50 μV/cm

Attenuation - Suppression - Electrocerebral inactivity

Attenuation: period of lower voltage ≥ 10 µV but < 50% of the higher voltage background
Suppression: period of lower voltage are ≤ 10 µV

Burst attenuation/Burst suppression: A pattern of attenuation/ suppression alternating with higher voltage activity, with 50% to 99% of the record consisting of attenuation or suppression (Note: the term "suppression-burst" is synonymous with "burst-suppression")

Electro Cerebral Inactivity *(ECI)*, which is defined as "the absence over all regions of the head of identifiable electrical activity of cerebral origin, whether spontaneous or induced by physiological stimuli (synonyms are electrocerebral silence, flat or isoelectric EEG, but the use of these terms is discouraged)

Electrocerebral inactivity is defined as the absence of nonartifactual electrical activity over 2 µV (peak to peak), at a sensitivity of 2 µV/mm (Kane et al, Clin Neurophysiol Pract, 2017)

Alpha, alpha-theta, and theta coma patterns

The term **alpha coma (AC)** refers to an EEG coma pattern characterised by the presence of diffuse alpha frequency activity; when alpha activity is mixed with theta frequencies, the pattern is named alpha-theta coma (ATC), whereas when the rhythmic diffuse activity falls within the theta band range, the pattern is named theta coma (TC)

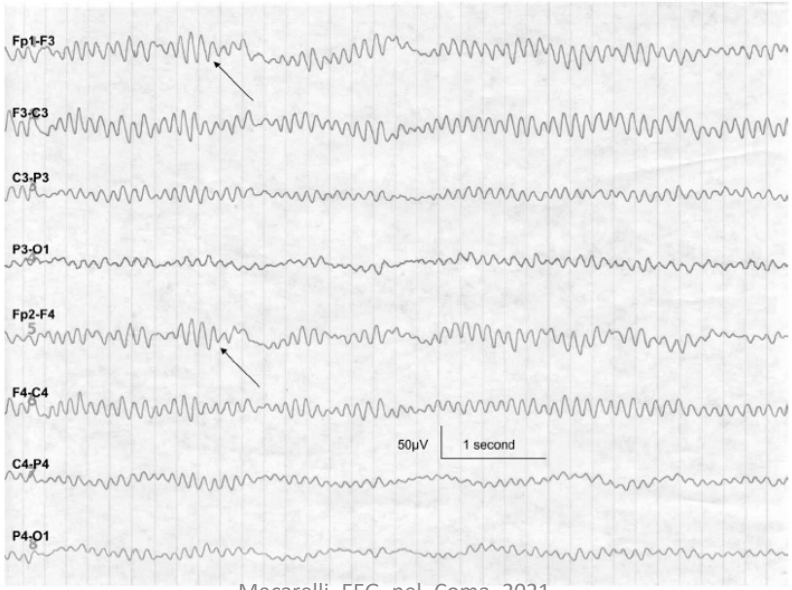


FIGURE 10. Sample EEG demonstrating alpha coma; note the alpha frequency activity anteriorly (arrows)

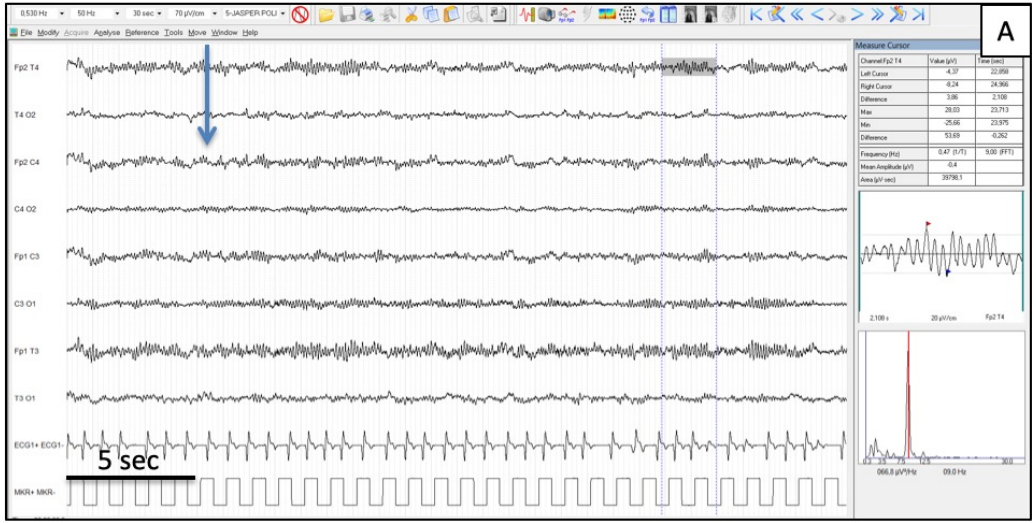
Alpha-Theta Coma **incomplete** or **complete**

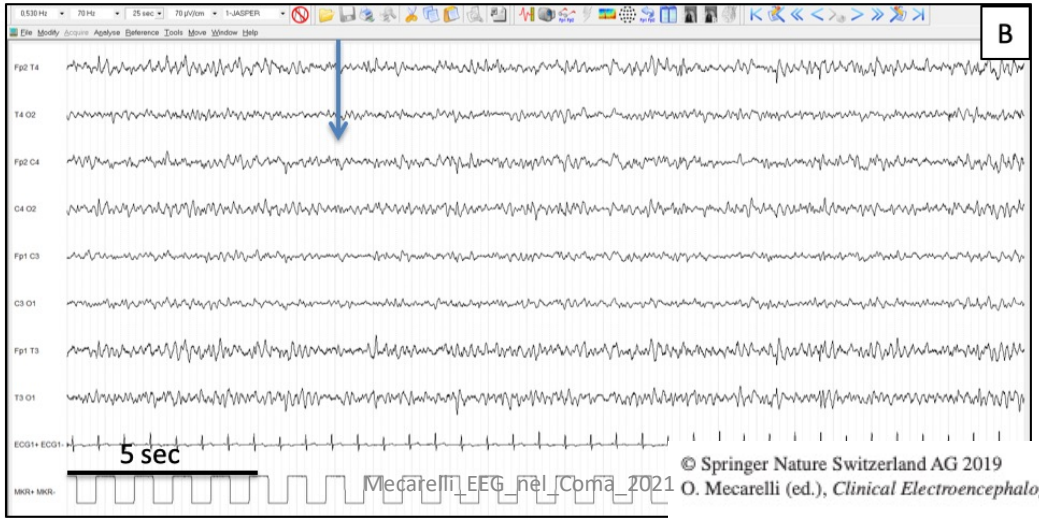
The ***incomplete ATC*** is characterised by: occipital or diffuse, non-monotonous, **hypo-reactive alpha-theta activity**; **SEP usually normal**; and coma, with usually normal brain stem reflexes.

Conversely, the ***complete ATC*** is characterised by: diffuse, frontally predominant, monotonous, **areactive alpha-theta activity**; **SEP usually altered or absent**; and deep coma, with usually absent brainstem reflexes.

(the combination of EEG, SEP, and clinical findings improves the prognostic evaluation of postanoxic ATC)

- full recovery is possible in patients with incomplete ATC
- complete ATC is invariably associated with a poor outcome





O. Mecarelli (ed.), *Clinical Electroencephalography*, https://doi.org/10.1007/978-3-030-04573-9_2

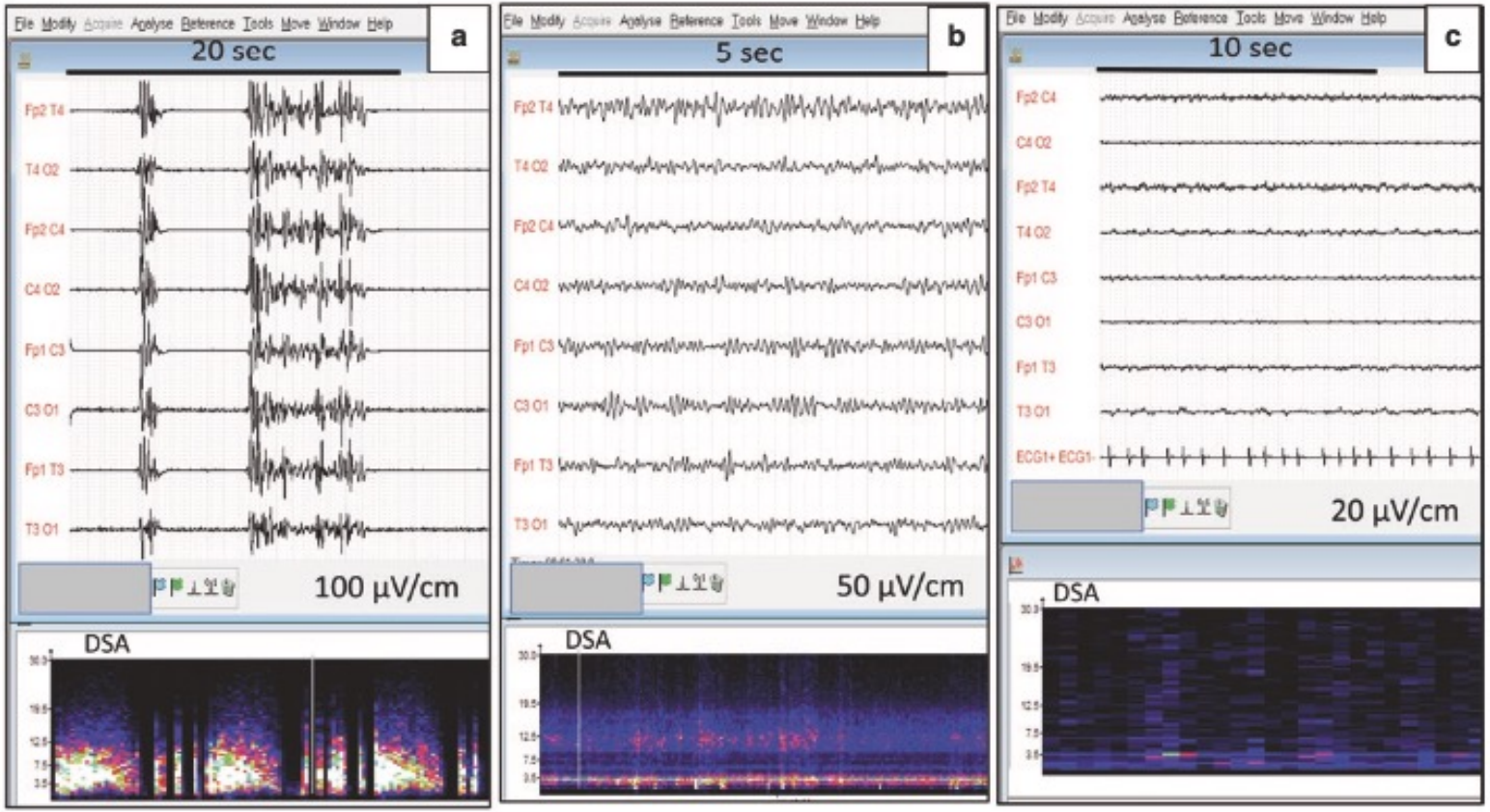


Fig. 48.9 Continuous EEG monitoring in a 56-year-old patient after cardiac arrest: raw EEG and Density Spectral Array (DSA). (**a**) day 1: burst-suppression pattern. (**b**) day 2: areactive alpha-coma of low amplitude. (**c**) day 3: attenuation/suppression of electrocerebral activity. LFF = 1 Hz, HFF = 30 Hz

SPINDLE COMA

Attività fusiforme (“spindles”) a 13-15 Hz spesso associata a onde aguzze al vertice e complessi K, inscritti su rallentamenti diffusi.

N.B.: *è in genere un quadro precoce*

Ipotesi fisiopatogenetiche: interruzione proiezioni ascendenti reticolo-talamo-corticali

Descritto per la prima volta nel 1953 (Van Buren) in un paz. con neoplasia mesencefalica, è stato successivamente segnalato in paz. con trauma cranico , emorragie corticali e troncali, encefalopatie tossico-dismetaboliche, etc.

Valore prognostico?

Dipende dall’etiologia e dalla presenza o meno di reattività

Spindle Coma

FIGURE 9. Sample EEG demonstrating spindle coma pattern; note the spindles (arrows).

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5. Reactivity

Change in cerebral EEG activity to stimulation: This may include change in voltage or frequency, including attenuation of activity. Strength and/or nature of stimulus should be noted, and a standard protocol of testing reactivity with multiple escalating stimuli is strongly encouraged.[20,21] Appearance of muscle activity or eye blink artifacts does not qualify as reactive. Categorize as the following:

a. Reactive.
b. Unreactive.

NOTE: It is suggested that if an EEG is "unreactive" after one round of stimulation, a second round of standardized noxious stimulation should be performed to confirm the finding and should be applied with the patient in their nonstimulated state. If "unreactive" and the patient is on sedatives or paralytics, we suggest including this important caveat in the impression.

c. SIRPIDs-only: when the only reactivity is stimulus-induced rhythmic, periodic, or ictal-appearing discharges (SIRPIDs).[22] This includes SI-RDA, SI-PDs, SI-SW, SI-seizures, SI-bursts, SI-IIC, or SI-BIRDs (see multiple sections below).
d. Unclear (typically used when testing may have not been adequate, there was too much artifact to assess the response, or there was a hint of a change in cerebral activity but not definite).
e. Unknown (typically used when reactivity was not tested or patient was maximally alert throughout the EEG epoch).

EEG BACKGROUND: REACTIVITY

Berger, 1935

- **REACTIVE**
- **UNREACTIVE**
- **SIRPIDs-only**
- **UNCLEAR**
- **UNKNOWN**

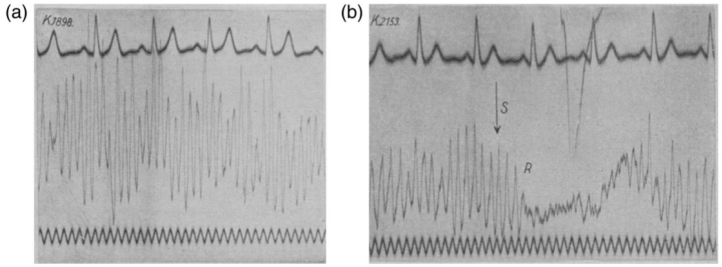


FIGURE 1 Sample recordings by Hans Berger from a family member and a patient. (a) Figure 3 in Berger (1935a): 'J.B., 14 years old'. Typical of his earlier work, the electrocardiogram is depicted in the top trace, and a time trace showing 1/10 s is shown below. The centre trace is the EEG, here recorded using silver chloride needle electrodes in a bipolar montage on forehead and occiput. (b) Figure 4 in Berger (1935a): 'M.M., 33 year old man. Large gap in the skull from the left forehead to the parietal region.' Here, the EEG was recorded epidurally using silver chloride needle electrodes placed 4.5 cm apart inside the gap in the skull. At the time marked with the arrow and S, a needle was briefly inserted into the patient's left index finger. R indicates the subsequent extinction of alpha. [Reprinted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature, Naturwissenschaften (Das Elektrenkephalogramm des Menschen, Hans Berger), Copyright © 1969, Verlag von Julius Springer (1935)]

Eur J Neurosci. 2021;1–11.

Type of stimulation:
- Acoustic
- Nociceptive (> bil synch nipple pinching)

NECESSITA' di STANDARDIZZAZIONE
dei Protocolli di STIMOLAZIONE

EEG Reactions to Exogenous Stimuli

(Rossetti et al, 2009, 2010; Hirsch et al 2013)

Reproducible EEG changes secondary to a stimulus (changes in the background activity)

Morphology and pathophysiology might resemble spontaneous fluctuations in EEG patterns

Reactive background - better prognosis

Tukel & Jasper 1952: **1) blocking type 2) alerting type**

Type of EEG reactions:

- Appearance of delta waves
- Attenuation of Voltage – Low voltage fast activity
- Change from alpha-theta coma to GPDs
- Blocking alpha-theta coma with eyelid artifact
- Blocking osf GPDs whit triphasic morphology
- Change in the repetition rate of GPDs

Reattività del tracciato EEG di Coma

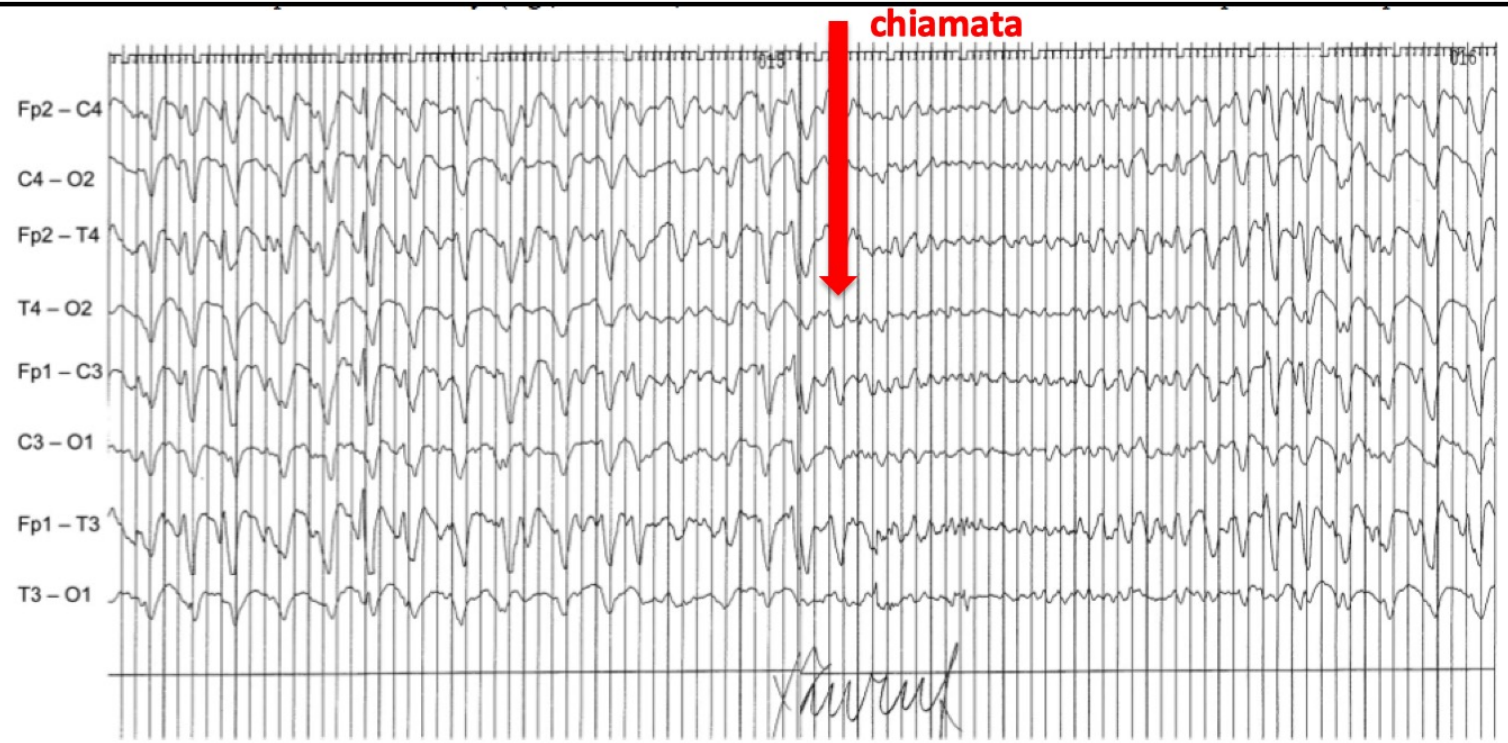
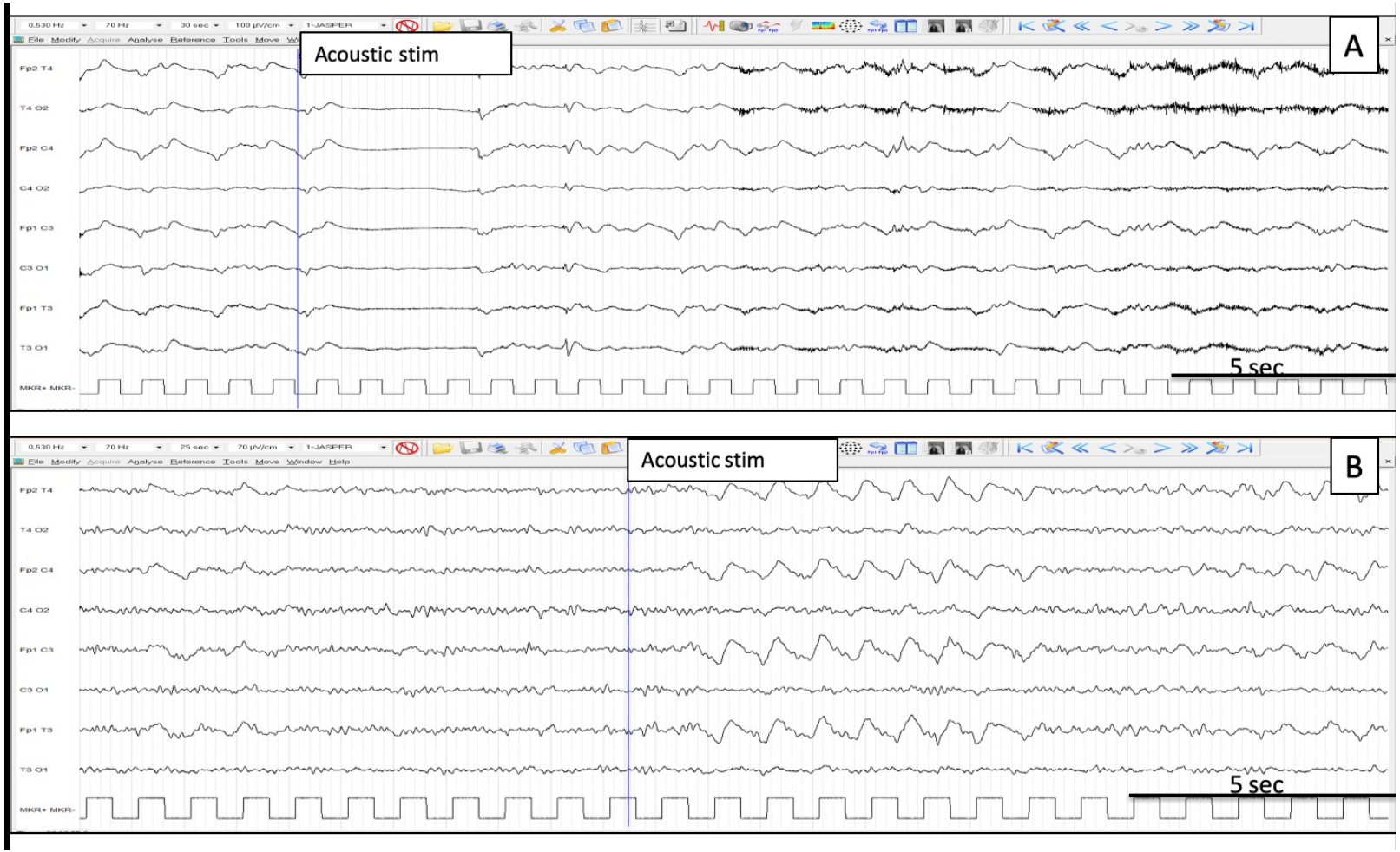
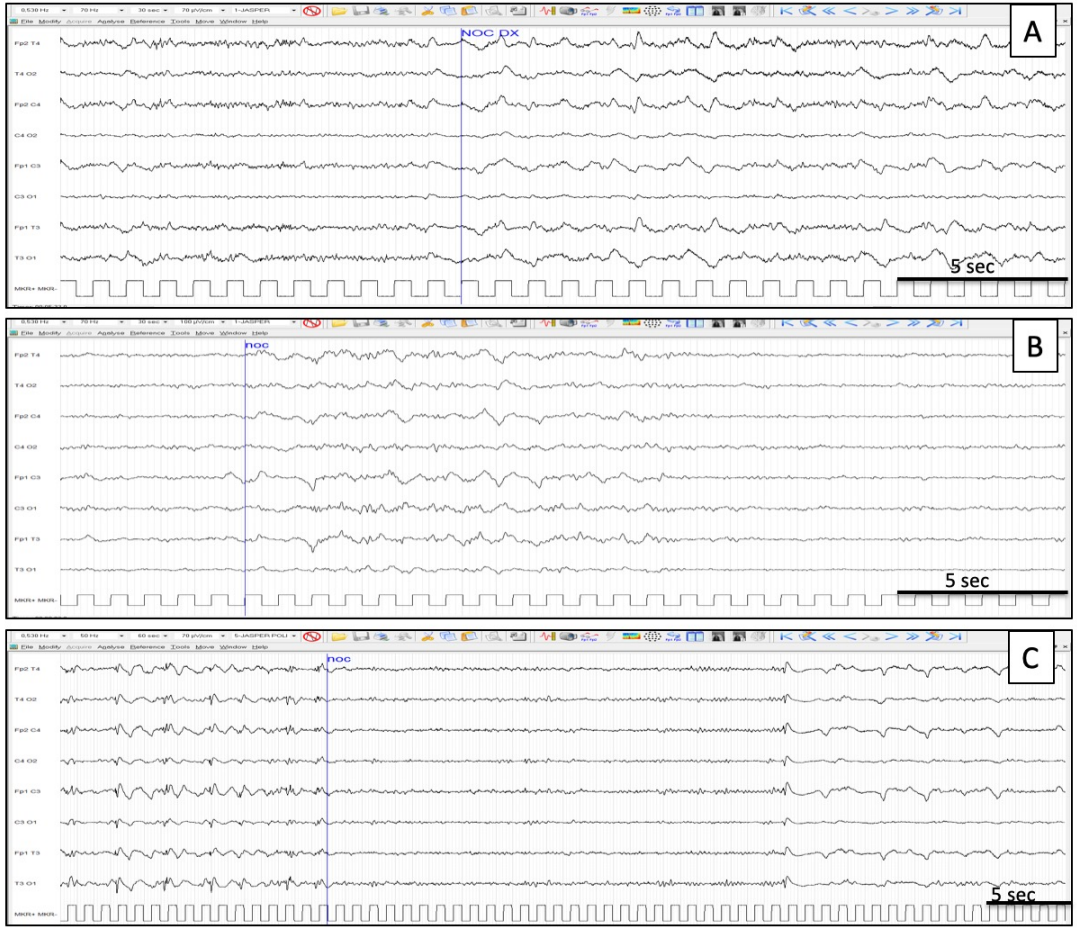


FIG. 13. Woman, 74 years old (time constant 0.3, high-frequency filter of 35 Hz). Comatose after cardiorespiratory arrest. The EEG shows continuous 2 Hz GPDs with triphasic morphology. With exogenous stimulation ("Zuruf"), there is blocking of the GPDs with mixed fast activity over the anterior regions.


Acoustic stim
A
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 C3
C3 O1
Fp1 T3
T3 O1
MKR+ MKR-
5 sec
Acoustic stim
B
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 C3
C3 O1
Fp1 T3
T3 O1
MKR+ MKR-
5 sec

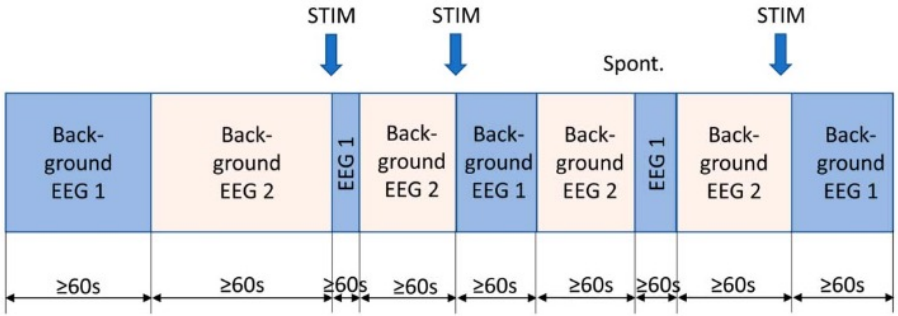

A
NOC DX
5 sec
B
noc
5 sec
C
noc
5 sec

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" (Fig. 8). 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. Categorize state changes as the following:

a. Present with normal stage N2 sleep transients (K-complexes and spindles)
b. Present but with abnormal stage N2 sleep transients
   - Describe both K complexes and spindles separately as the following:
     i. Present and normal.
     ii. Present but abnormal. Specify abnormality (e.g., asymmetry, location, frequency, poorly formed).
     iii. Absent.
c. Present but without stage N2 sleep transients.
d. Absent

VARIAZIONI dell'Attività di Fondo in relazione a cambiamenti del livello di Allerta o alle Stimolazioni



EEG background 1: stimulated/more awake: used for background feature description ("reported background")
EEG background 2: unstimulated/less awake state; commonly lasts minutes to hours (minimum: 60 s)

FIG. 8. State changes. At least 2 sustained types of background EEG, where: 1. The background activity is related to level of alertness or stimulation. 2. Each must persist ≥ 60 seconds to qualify as a "state". 3. Stimulation should be able to transition the patient from the less alert to more alert/more stimulated state. 4. The more alert/more stimulated state is considered the "reported background" EEG. 5. State changes can also occur spontaneously. STIM = stimulation, Spont. = spontaneous.

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) (Fig. 9). A cycle refers to the period of time before the sequence repeats (i.e., includes both states once). Document whether seen in the patient's more awake/stimulated state or less awake state if known. Describe each pattern and typical duration of each pattern. Optional: Describe if this pattern corresponds with cycling of other functions such as respirations, heart rate, blood pressure, movements, muscle artifact, and pupil size.

a. Present.
b. Absent.
c. Unknown/unclear.

NOTE: If each pattern of CAPE lasts >60 seconds, this would qualify as the presence of state changes. If CAPE is always present, cannot be interrupted with stimulation, and at least one of the states lasts <60 seconds, it remains possible for a patient to have CAPE and no state changes.

CAPE:
Cyclic Alternating
Pattern of Encephalopathy

Ogni pattern del CAPE deve durare più di 60 s per identificare un cambiamento di stato

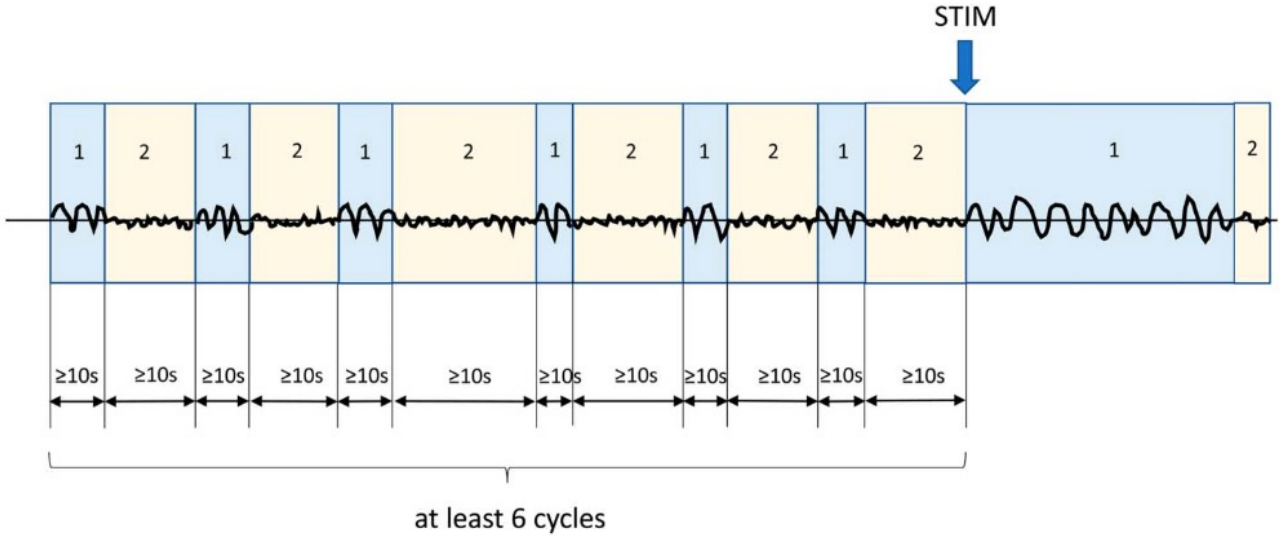


FIG. 9. Cyclic Alternating Pattern of Encephalopathy (CAPE). Changes in EEG background between pattern 1 and pattern 2, where: 1. Each pattern lasts at least 10 seconds, 2. Spontaneously alternates between the two patterns in a regular manner, 3. For at least 6 cycles.

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 (Fig. 10). 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

Breach effect refers to 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.

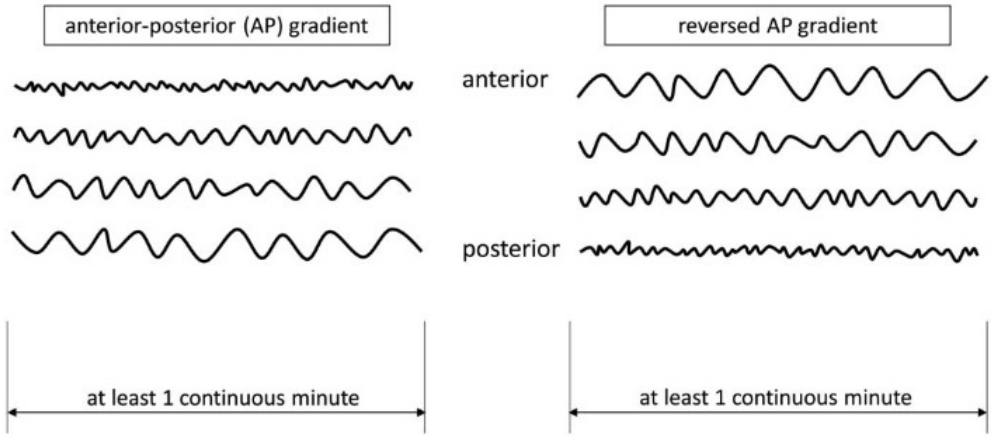


FIG. 10. Anterior-posterior (AP) gradient.

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CONTENTS

EPILEPTIFORM DISCHARGES (EDs):

Non-Rhythmic and Non-Periodic Epileptiform Abnormalities

B. SPORADIC EPILEPTIFORM DISCHARGES

This refers to nonrhythmic and nonperiodic spikes, polyspikes, and sharp waves, as previously defined by Kane et al.[19] in the 2017 revised glossary of terms most commonly used by clinical electroencephalographers. 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 (Fig. 11). A *"sharp wave"* is defined identically, but with a duration of 70 to 200 ms. A spike or sharp wave is usually diphasic or triphasic, apiculate (i.e., pointed peak), asymmetric (typically with a steeper ascending slope than descending, but can be the opposite), and either followed by a slow wave or associated with some other disruption of the background. A *"polyspike"* refers to 2 or more spikes occurring in a row with no interdischarge interval and lasting <0.5 seconds (if ≥ 0.5 seconds, they would either qualify as BIRDs [see section E below, page 24] or, if alternating with suppression or attenuation, a highly epileptiform burst within burst suppression/attenuation [see section A 4d, page 5] [Fig. 12]). The prevalence of epileptiform discharges (combining spikes, polyspikes and sharp waves) should be categorized as follows:

a. Abundant: ≥ 1 per 10 seconds, but not periodic.
NOTE: It can be helpful to record the estimated average and maximum number of spikes per 10-second epoch when abundant epileptiform discharges are seen.
b. Frequent: ≥ 1/minute but less than 1 per 10 seconds
c. Occasional: ≥ 1/hour but less than 1/minute
d. Rare: <1/hour

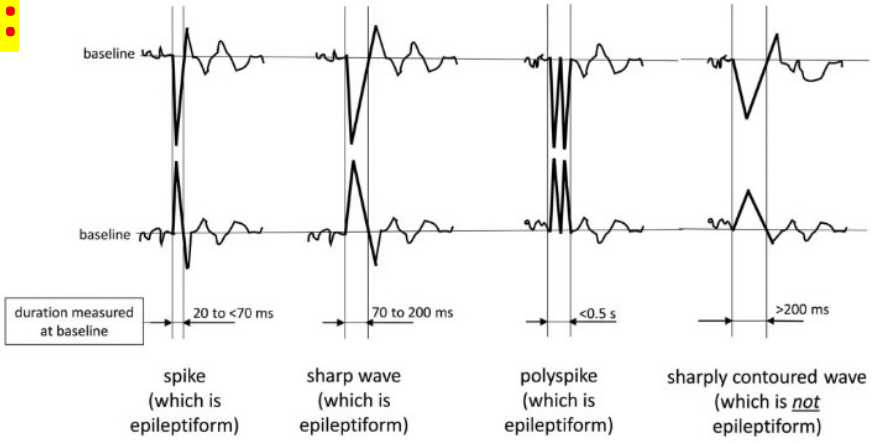

FIG. 11. Sporadic Epileptiform Discharges.

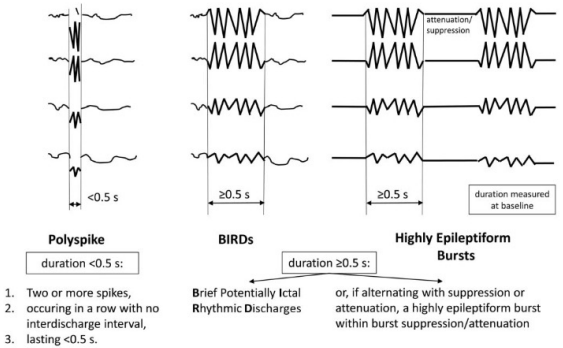

FIG. 12. Polyspike versus BIRDs versus Highly Epileptiform Bursts.

ABUNDANT: ≥ 1 per 10 s
FREQUENT: ≥ 1/min < 1/10s
OCCASIONAL: ≥ 1/h < 1/min
RARE: < 1/h

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CONTENTS

RHYTHMIC and PERIODIC PATTERNS

C. RHYTHMIC AND PERIODIC PATTERNS (RPPs)

All terms consist of two main terms, with modifiers added as appropriate. Main term 1 refers to the localization of the pattern and main term 2 specifies the type of pattern.

LOCALIZATION of PATTERN

1. Main Term 1: G, L, Bl, Ul, or Mf

LATERALIZED (LPDs)

GENERALIZED (GPDs)

UNILATERAL PDs

BILATERAL (asymmetric) PDs

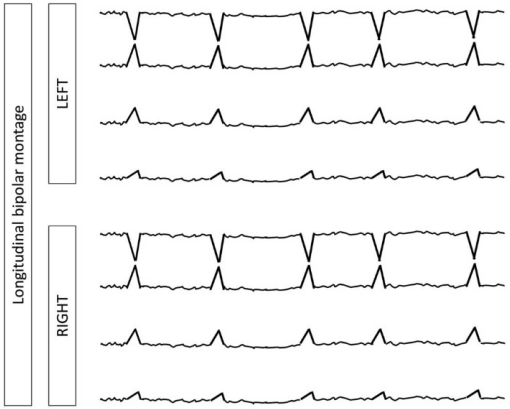


FIG. 13. Generalized Periodic Discharges (GPDs). Generalized: Bilateral synchronous and symmetric periodic discharges. In this case, the pattern is "frontally predominant."

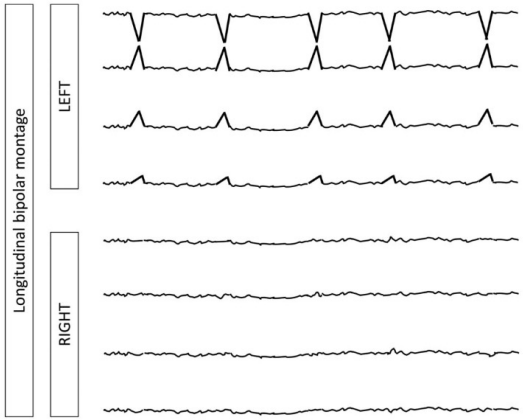


FIG. 14. Lateralized Periodic Discharges (LPDs, unilateral). Unilateral: Periodic discharges only seen in one hemisphere (in this case left).

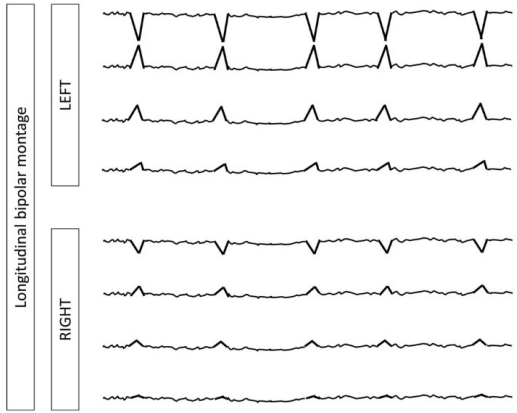


FIG. 15. Lateralized Periodic Discharges (LPDs, bilateral asymmetric). Bilateral asymmetric: Periodic discharges seen bilaterally but clearly and consistently (>80% of the time) higher amplitude over one hemisphere (in this case left).

UNILATERAL INDEPENDENT PDs (UIPDs)

FIG. 18. Unilateral Independent Periodic Discharges (UIPDs). In UIPDs, periodic discharges occur in two independent locations simultaneously with both populations within a single hemisphere (in this case left).

MULTIFOCAL PDs (MfPDs)

FIG. 19. Multifocal Periodic Discharges (MfPDs). In MfPDs, periodic discharges occur in three independent locations simultaneously with at least one in each hemisphere. If all three populations occurred within a single hemisphere this would remain UIPDs.

MORPHOLOGY of PATTERN

2. Main Term 2: PDs, RDA or SW

Discharges of DELTA Waves or SHARP Waves

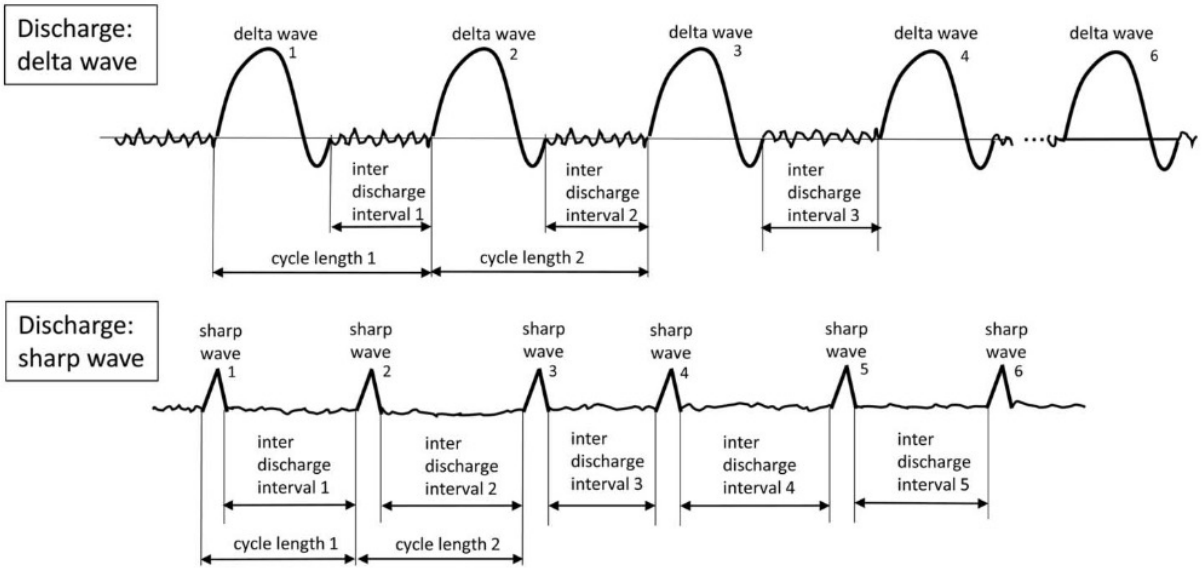


FIG. 20. Periodic Discharges (PDs). 1. Repetition of a waveform with relatively uniform morphology and duration, 2. with a clearly discernable interdischarge interval between consecutive waveforms, and 3. recurrence of the waveform at nearly regular intervals: having a cycle length (i.e., period) varying 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).

Un pattern per qualificarsi come ritmico o periodico deve ripetersi minimo per 6 volte (se a 1 Hz per 6 s, se a 3 Hz per 2 s)

RHYTHMIC DELTA ACTIVITY

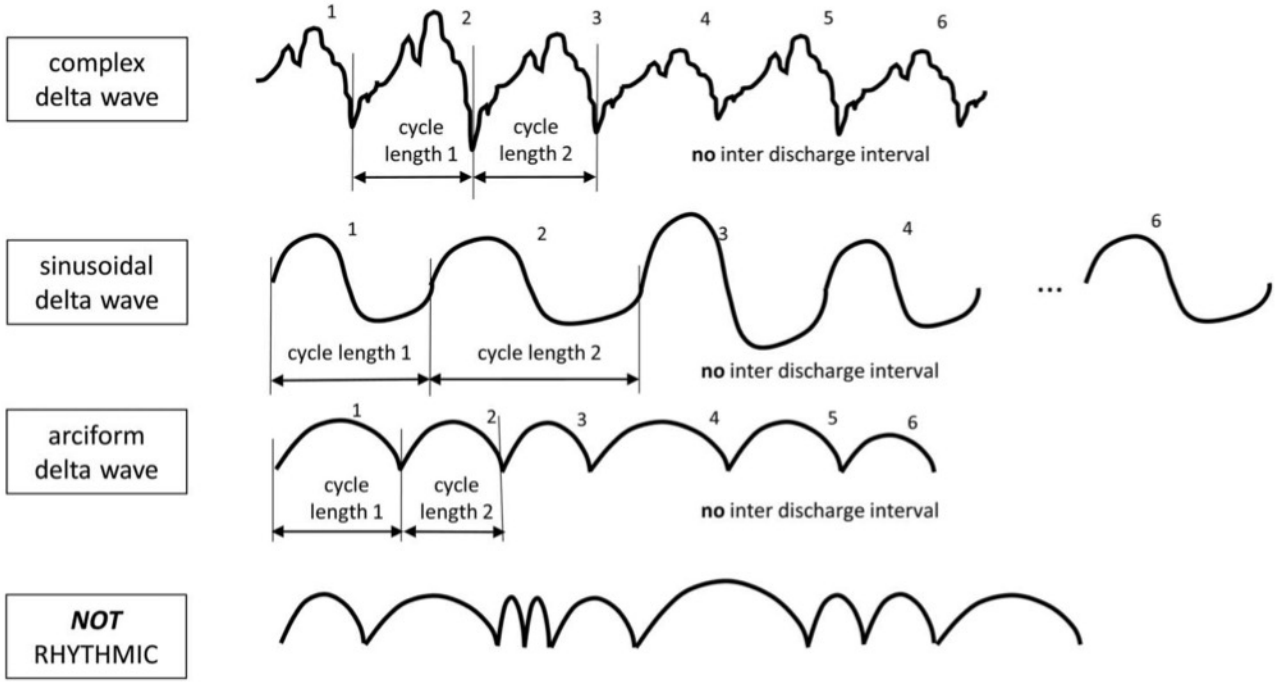


FIG. 21. Rhythmic Delta Activity (RDA). 1. Repetition of a waveform with relatively uniform morphology and duration and 2. without an interval between consecutive waveforms. 3. The duration of one cycle (i.e., the period) of the rhythmic pattern should vary by <50% from the duration of the subsequent 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).

PERIODIC DISCHARGES of EDs

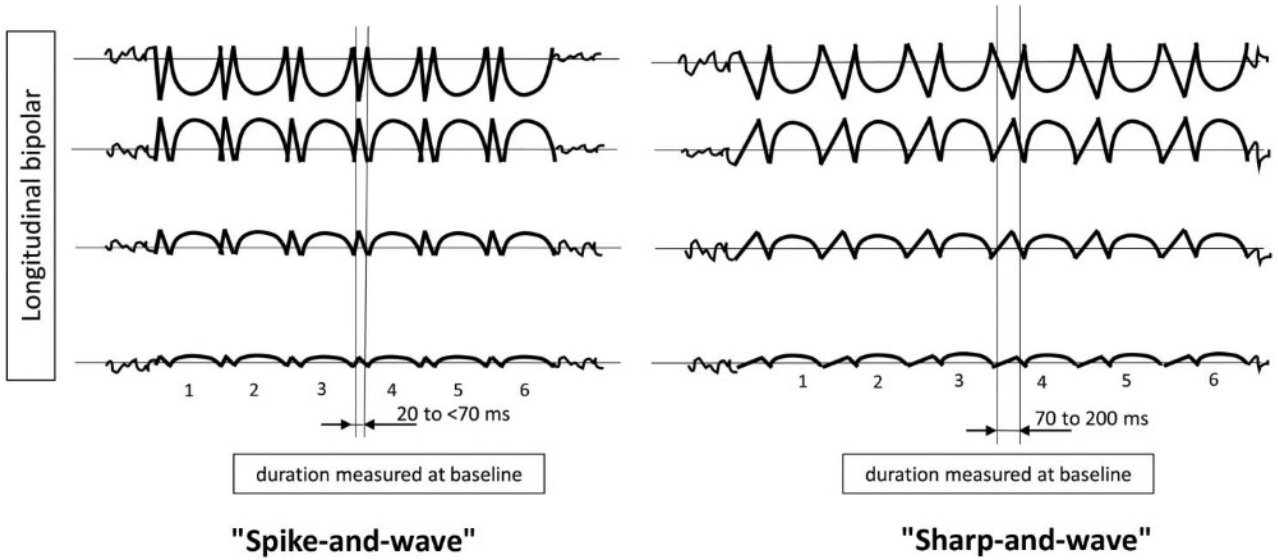


FIG. 22. "Spike-and-wave" or "Sharp-and-wave" (SW). Spike-and-wave or Sharp-and-wave (SW): Polyspike, spike, or sharp wave consistently followed by a slow wave in a regularly repeating and alternating pattern (spike-wave-spike-wave-spike-wave), with a consistent relationship between the spike (or polyspike 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).

Table 13.2 Old and new terms proposed for Periodic or Rhythmic EEG Patterns (adapted from Hirsch et al. J Clin Neurophysiol 2013; 30: 1–27)

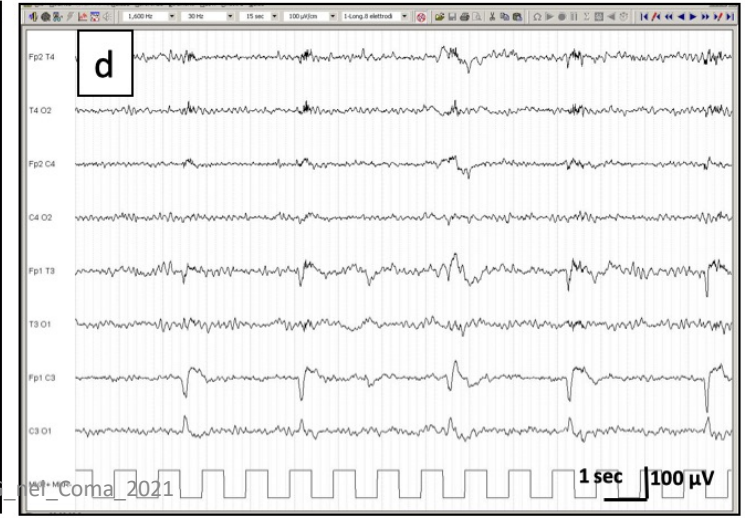
Old term	New term
Periodic Lateralized Epileptiform Discharges (PLEDs)	Lateralized Periodic Discharges (LPDs)
Bilateral Independent Epileptiform Discharges (BIPLEDs)	Bilateral Independent Periodic Discharges (BIPDs)
Generalized Periodic Epileptiform Discharges (GPEDs)	Generalized Periodic Discharges (GPDs)
Triphasic Waves (TW), most of record	GPDs continuous 2/s (with triphasic morphology)
Frontal Intermittent Rhythmic Delta Activity (FIRDA)	occasionally frontally predominant brief 2/s GRDA (fGRDA) (if 1–10% of record)
Stimulus-Induced Rhythmic, Periodic or Ictal Discharges (SIRPIDs)	Stimulus-Induced Generalized Periodic Discharges (SI- GPDs); Stimulus-Induced Lateralized Periodic Discharges (SI-LPDs); Stimulus-Induced Rhythmic Delta Activity (SI-RDA)

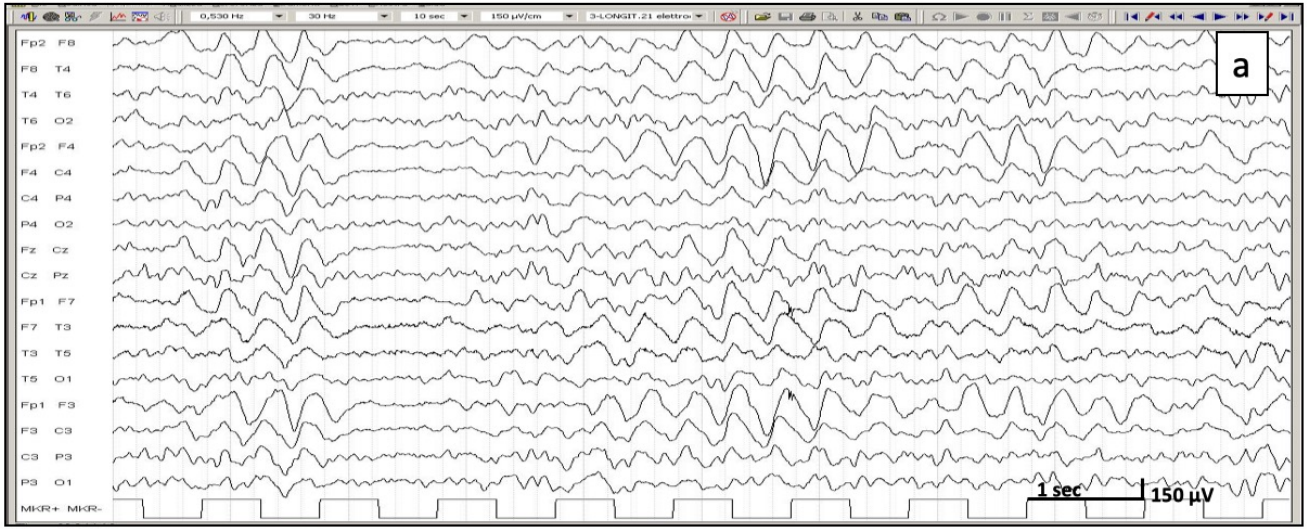
O. Mecarelli (ed.), *Clinical Electroencephalography*, https://doi.org/10.1007/978-3-030-04573-9_2

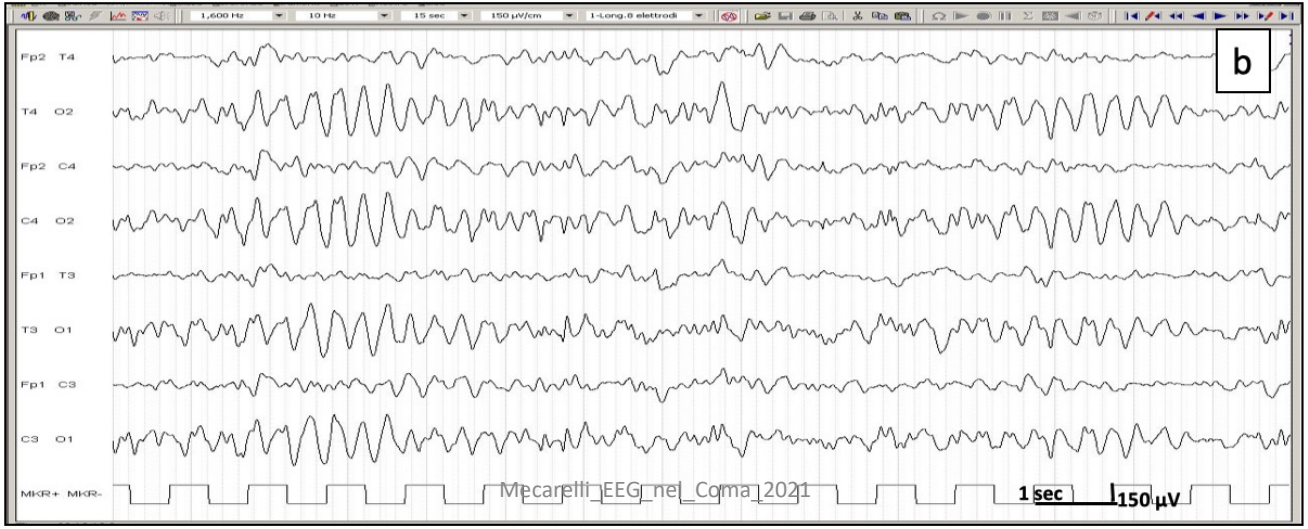

a
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 T3
T3 O1
Fp1 C3
C3 O1
1 sec
100 µV

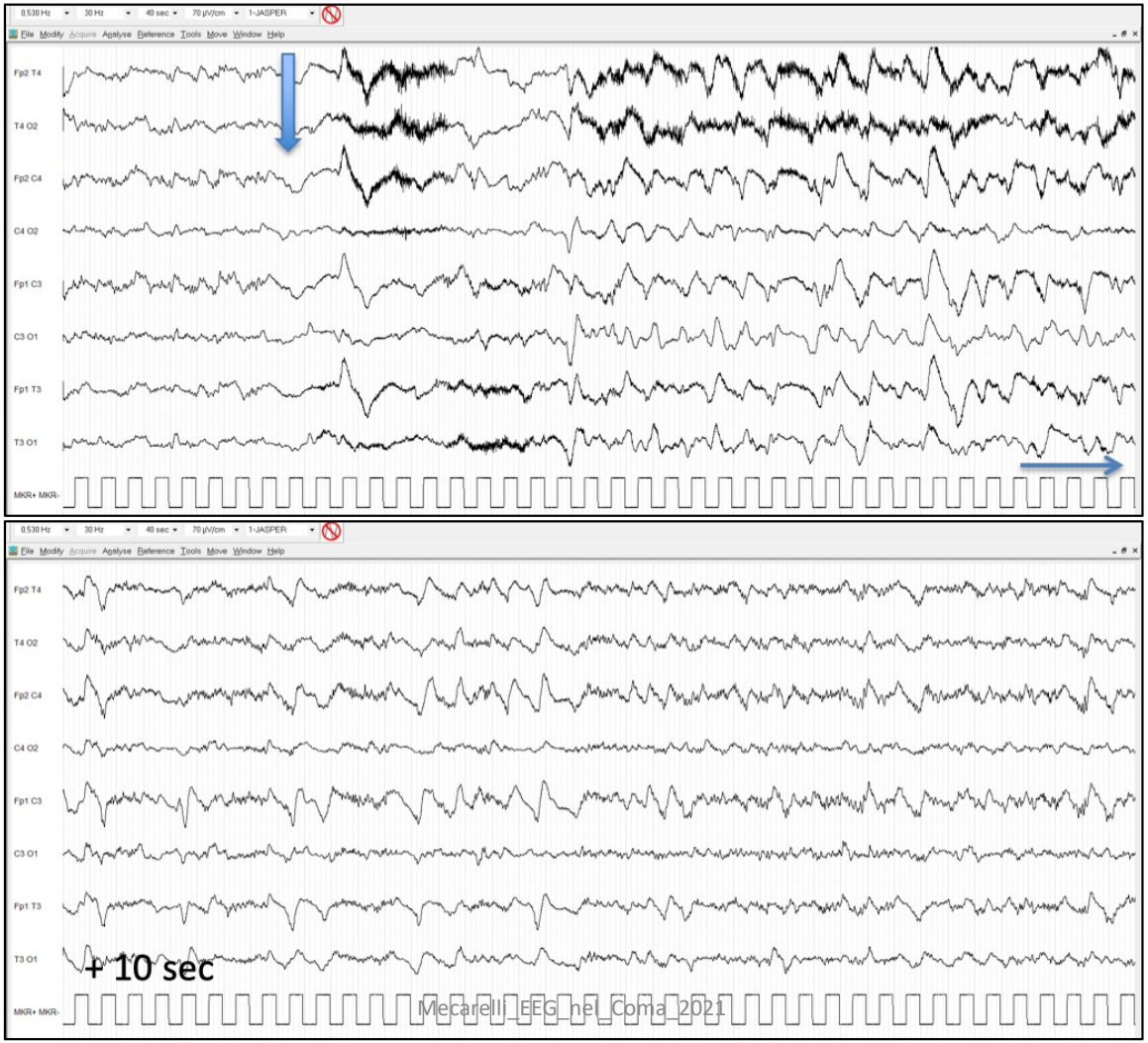

b
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 T3
T3 O1
Fp1 C3
C3 O1
1 sec
100 µV


c
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 T3
T3 O1
Fp1 C3
C3 O1
1 sec
100 µV


d
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 T3
T3 O1
Fp1 C3
C3 O1
1 sec
100 µV


a
Fp2 F8
F8 T4
T4 T6
T6 O2
Fp2 F4
F4 C4
C4 P4
P4 O2
Fz Cz
Cz Pz
Fp1 F7
F7 T3
T3 T5
T5 O1
Fp1 F3
F3 C3
C3 P3
P3 O1
MKR+ MKR-
1 sec
150 µV


b
Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 T3
T3 O1
Fp1 C3
C3 O1
MKR+ MKR-
1 sec
150 µV


Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 C3
C3 O1
Fp1 T3
T3 O1
MKR+ MKR-
+ 10 sec

3. Main Modifiers (Most of the following section can be applied to any EEG phenomenon)

a. *Prevalence*:

i. Continuous: ≥ 90% of record/epoch.
ii. Abundant: 50% to 89% of record/epoch.
iii. Frequent: 10% to 49% of record/epoch.
iv. Occasional: 1% to 9% of record/epoch.
v. Rare: <1% of record/epoch.

b. *Duration*:

i. Very long: ≥ 1 hour.
ii. Long: 10 to 59 minutes.
iii. Intermediate duration: 1 to 9.9 minutes.
iv. Brief: 10 to 59 seconds.
v. Very brief: <10 seconds.

c. *Frequency*

c. *Frequency* = rate per second: Specify typical rate and range for all patterns (e.g., LPDs with typical frequency of 1 Hz and range of 0.5–2 Hz).

d. *Number of phases*

e. *Sharpness*

i. Spiky: duration of that component, measured at the EEG baseline, is <70 ms
ii. Sharp: duration of that component is 70 to 200 ms
iii. Sharply contoured: used for waveforms that have a sharp morphology (steep slope to one side of the wave and/or pointy or apiculate at inflection point[s]) but are too long in duration to qualify as a sharp wave.
iv. Blunt: having smooth or sinusoidal morphology.

g. *Stimulus-Induced (SI-) or Stimulus-Terminated (ST-)*: SI- versus ST- versus spontaneous: Categorize as

h. *Evolution*: Evolving, Fluctuating, or Static: terms refer to changes in frequency, location, or morphology.

EVOLUTION of FREQUENCY

Standardized Critical Care EEG Terminology — L. J. Hirsch, *et al.*

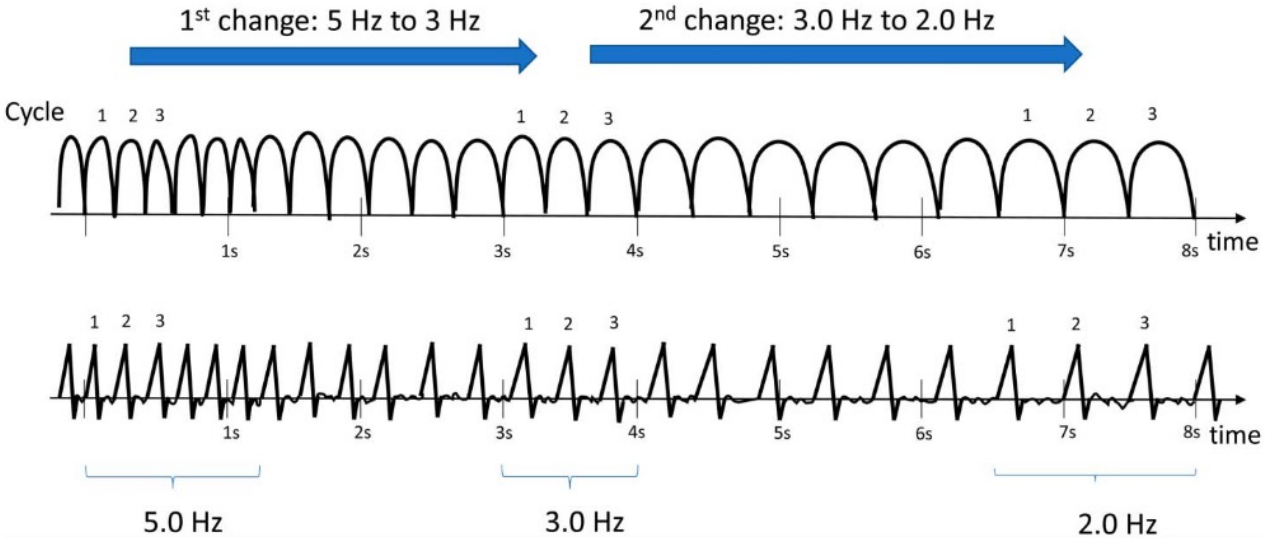


FIG. 24. Evolution of frequency. At least 2 unequivocal, sequential changes in frequency; defined as at least 2 consecutive changes in the same direction by at least 0.5 Hz. To qualify as present, a single frequency must persist for at least 3 cycles. The criteria for evolution must be reached without the evolving feature (frequency) remaining unchanged for 5 or more continuous minutes.

EVOLUTION of MORPHOLOGY

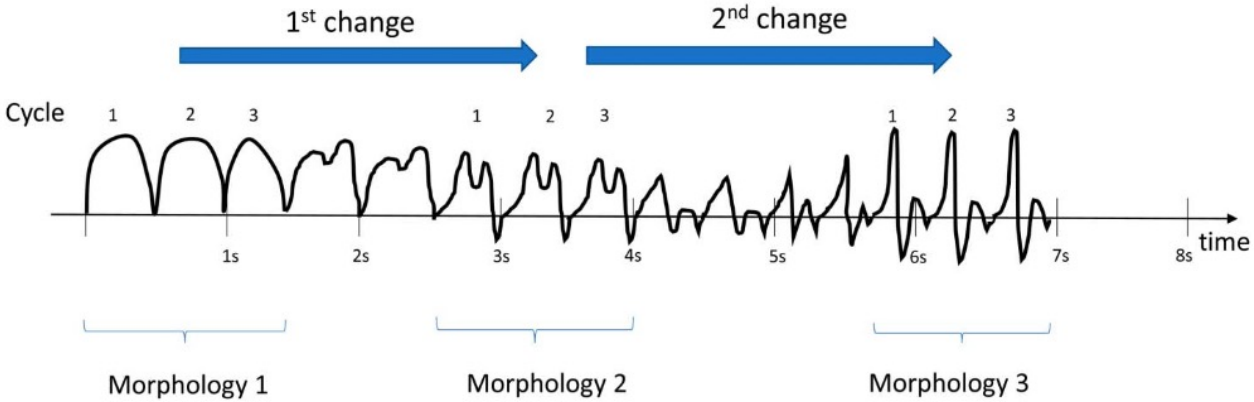


FIG. 25. Evolution of morphology. At least 2 consecutive changes to a novel morphology. Each different morphology or each morphology plus its transitional forms must last at least 3 cycles.

EVOLUTION of LOCATION

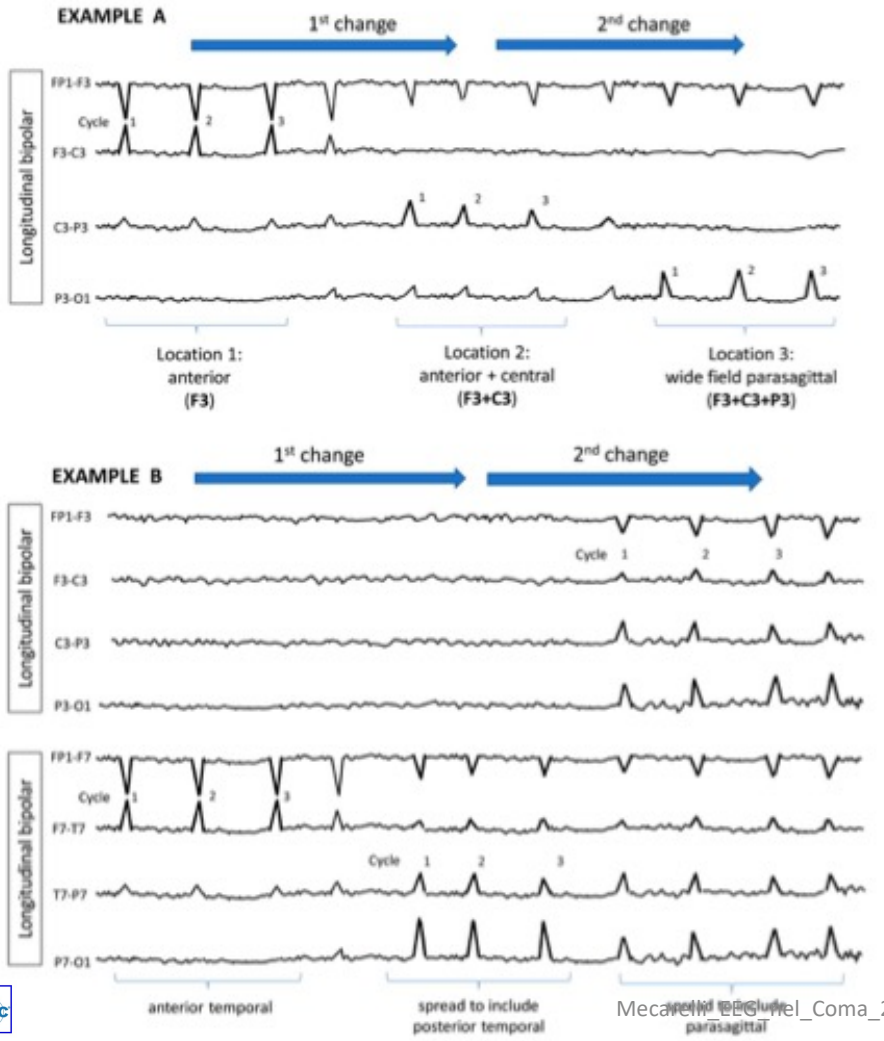


FIG. 26. Evolution of location. Defined as sequentially spreading into or sequentially out of at least two different standard 10–20 electrode locations. To qualify as present, a single location must persist for at least 3 cycles.

FLUCTUATION of FREQUENCY

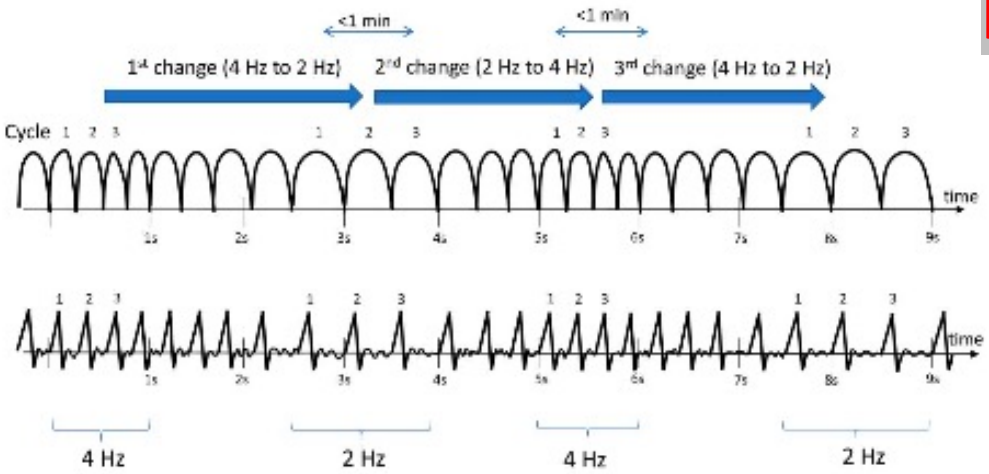


FIG. 27. Fluctuating frequency. ≥ 3 changes, not more than one minute apart, in frequency (by at least 0.5 Hz), but *not qualifying as evolving*. This includes patterns fluctuating from 1 to 1.5 to 1 to 1.5 Hz. To qualify as present, a single frequency must persist at least 3 cycles (e.g. 1 Hz for 3 seconds, or 3 Hz for 1 seconds).

FLUCTUATION of MORPHOLOGY

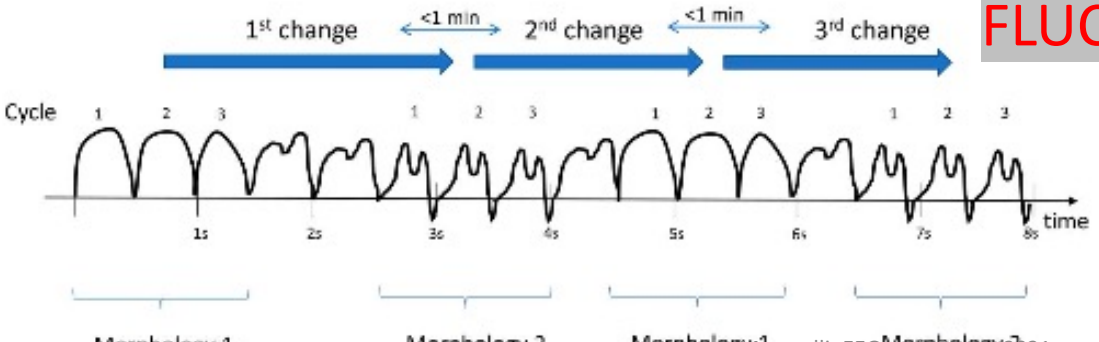
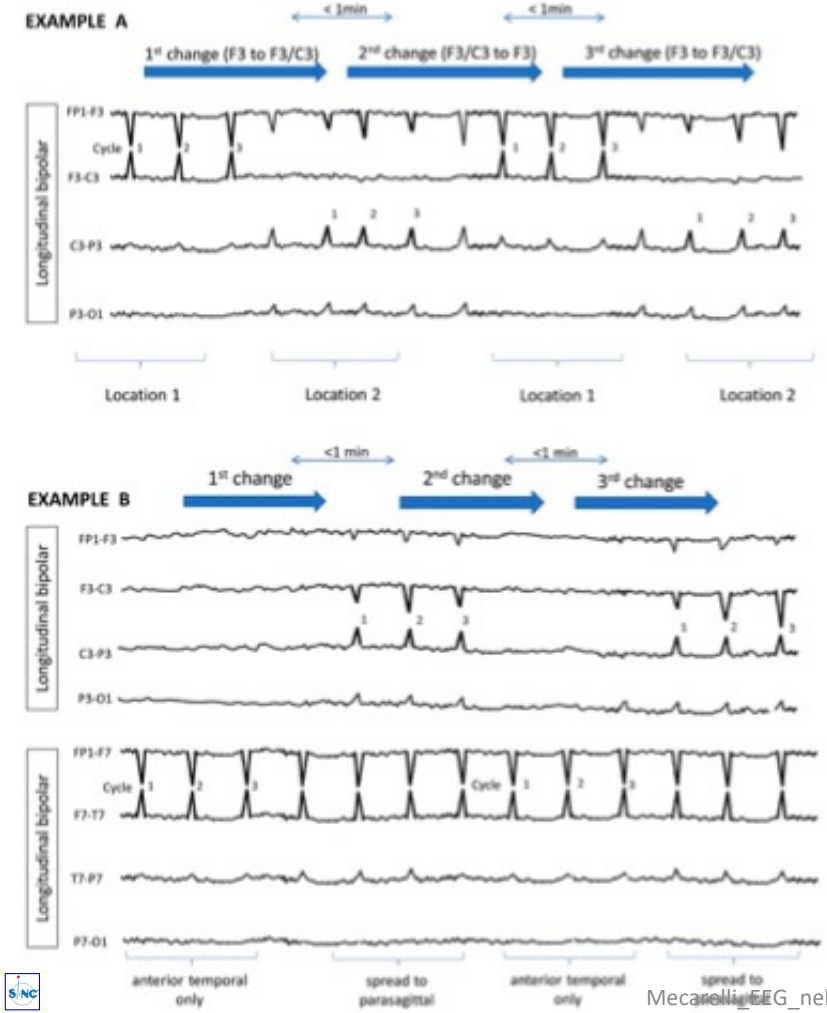


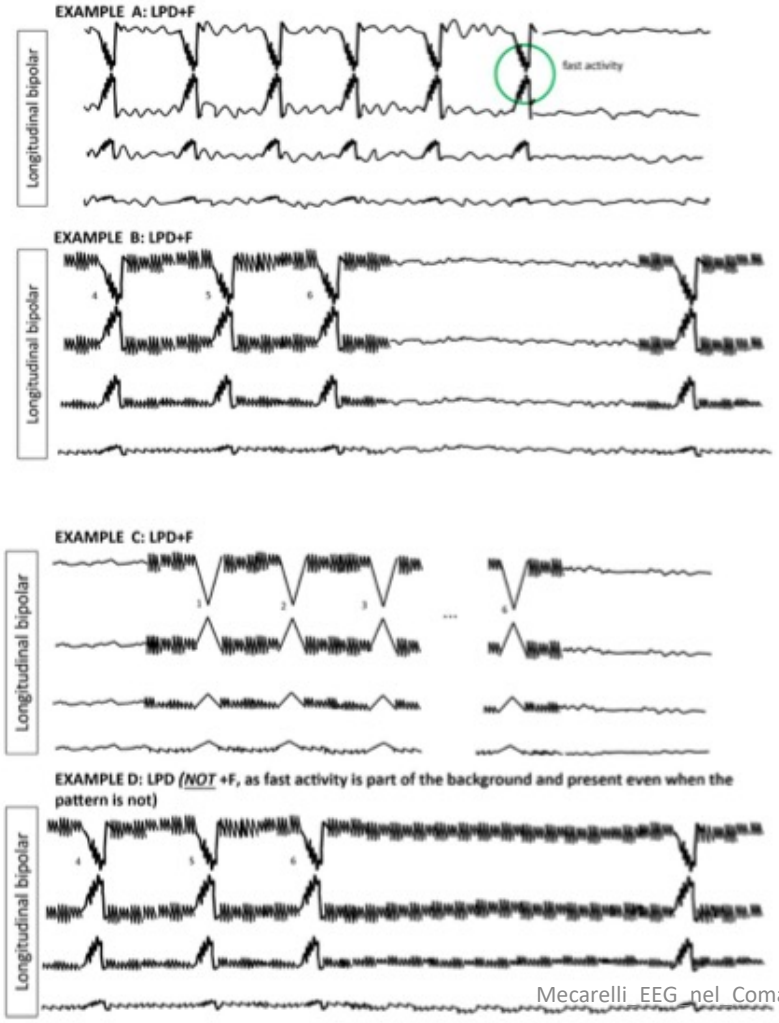
FIG. 28. Fluctuating morphology. ≥ 3 changes, not more than one minute apart, in morphology, but *not qualifying as evolving*. This includes patterns alternating between 2 morphologies repeatedly. To qualify as present, a single morphology must persist at least 3 cycles.



FLUCTUATION of LOCATION

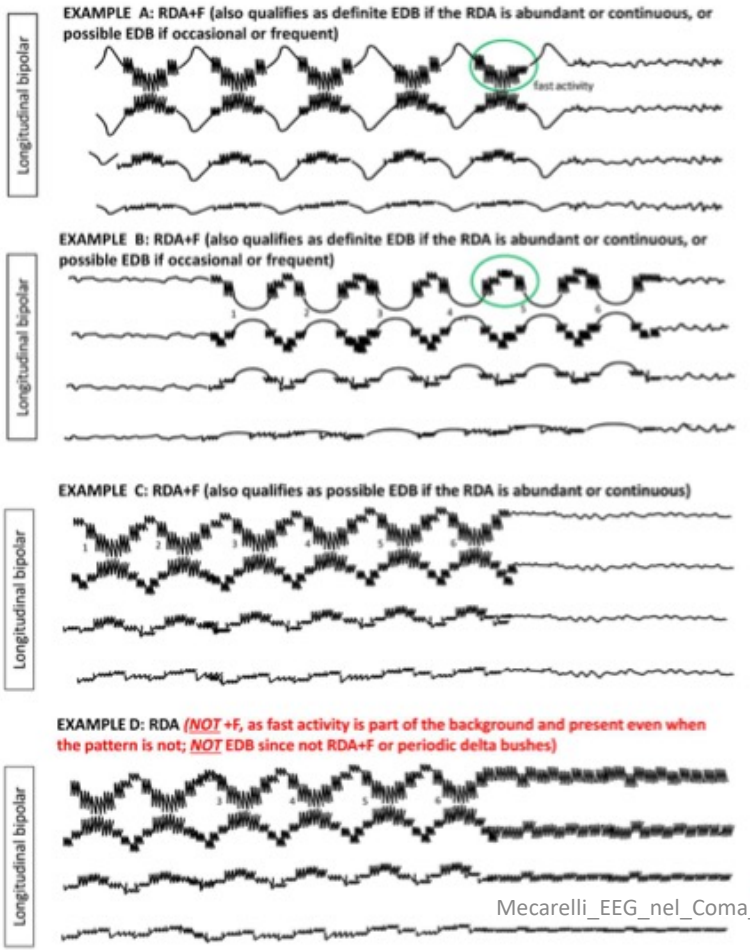
FIG. 29. Fluctuating location. ≥ 3 changes, not more than one minute apart, in location (by at least 1 standard inter-electrode distance), but *not qualifying as evolving*. This includes patterns spreading in and out of a single electrode repeatedly. To qualify as present, a single location must persist at least 3 cycles.

MODIFIERS Plus (*fast activity*)



LPDs + F

FIG. 30. Lateralized Periodic Discharges PLUS *fast* activity (LPDs+F). Code as +F if the fast activity is part of the RDA or PDs pattern and not simply part of the background activity. fast activity cycling with the periodic discharge.



RDA + F

FIG. 31. Rhythmic Delta Activity PLUS *fast* activity (RDA+F). If a pattern qualifying as RDA or PDs has associated continuous fast frequencies (theta or faster), this can and should be coded as +F if the fast activity is not present in the background activity when the RDA or PDs is not present. fast activity cycling with the rhythmic delta and having a stereotyped relationship to the delta wave. EDB = Extreme Delta Brush.

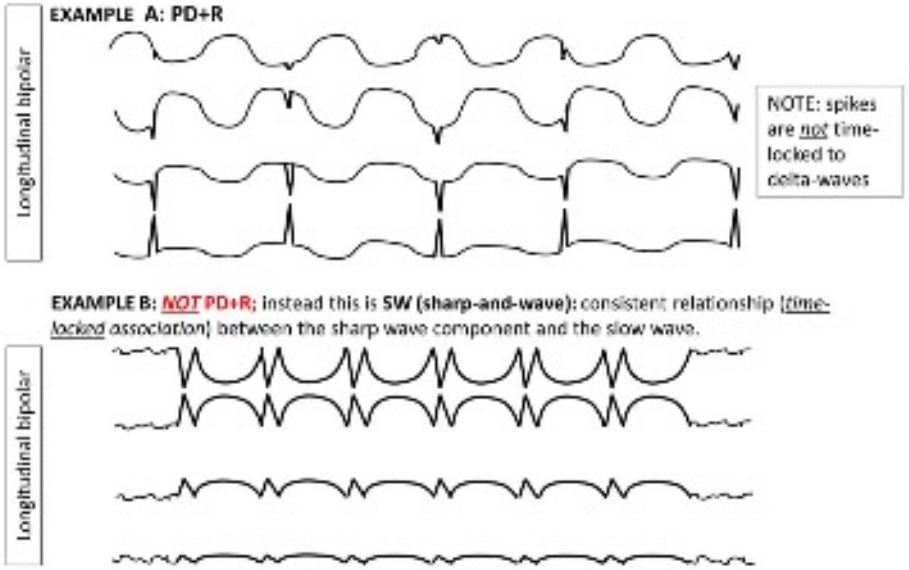


FIG. 32. Periodic Discharges PLUS RDA (PDs+R). RDA occurring at the same time as PDs but *without* time-locked association with the PDs would qualify as PDs+R.

FIG. 34. Bilateral Independent Periodic Discharges PLUS *fast* activity (BIPDs+F). BIPDs with *fast* activity in one hemisphere only (PD on one side, and PD +F on the other) would qualify for BIPDs+F.

EXTREME DELTA BRUSH (EDB)

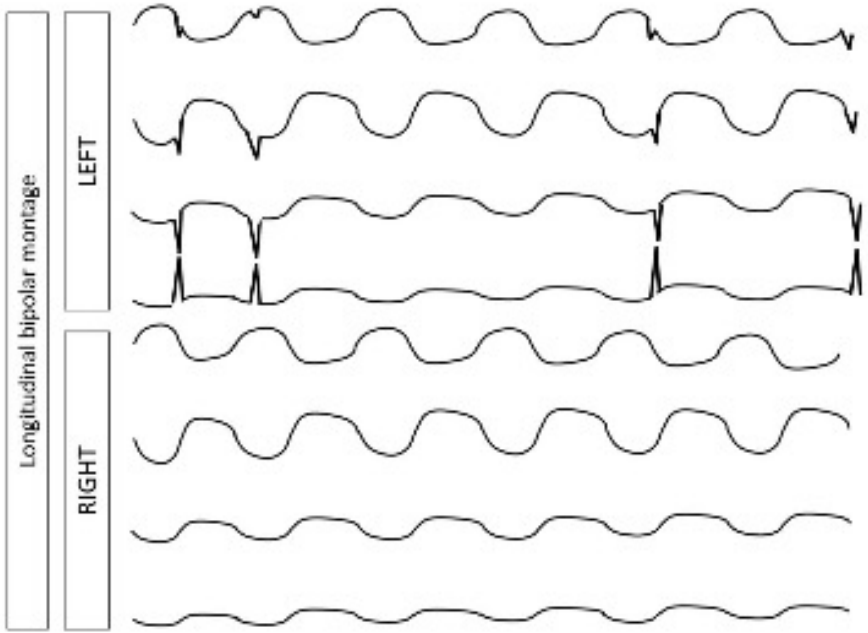


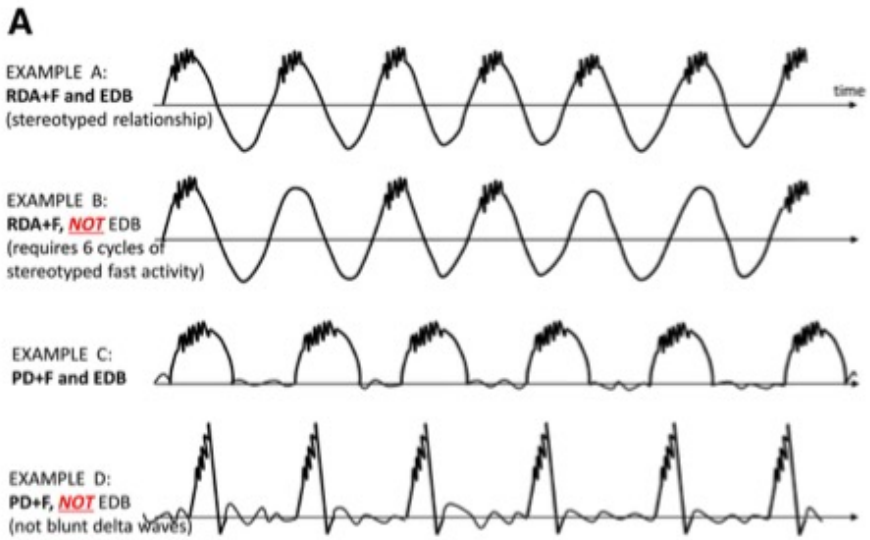
FIG. 33. Generalized Rhythmic Delta Activity PLUS Spikes (GRDA+S). Generalized rhythmic delta activity with associated spikes in one hemisphere only (RDA on one side and synchronous RDA +S on the other) would still qualify as GRDA+S.

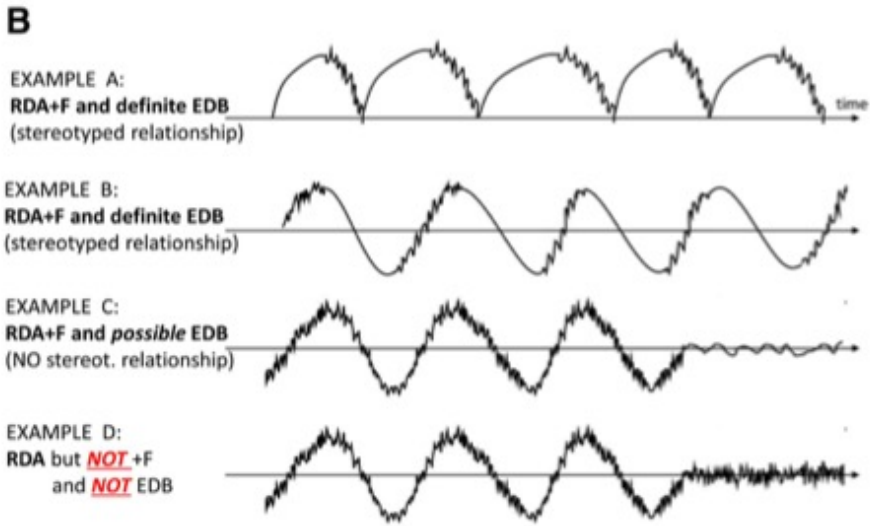
TABLE 2. Relationship between RDA+F, PDs+F and Extreme Delta Brush (EDB)

	RDA+F; or PDs+F if (and only if) the PDs are blunt delta waves	
	Continuous/ Abundant (≥50% of record/epoch)	**Frequent/ Occasional (≥1 to 49% of record/epoch)**
Fast activity WITH stereotyped relationship to delta wave	Definite EDB	Possible EDB
Fast activity WITHOUT stereotyped relationship to delta wave	Possible EDB	RDA+F or PDs+F, but NOT EDB

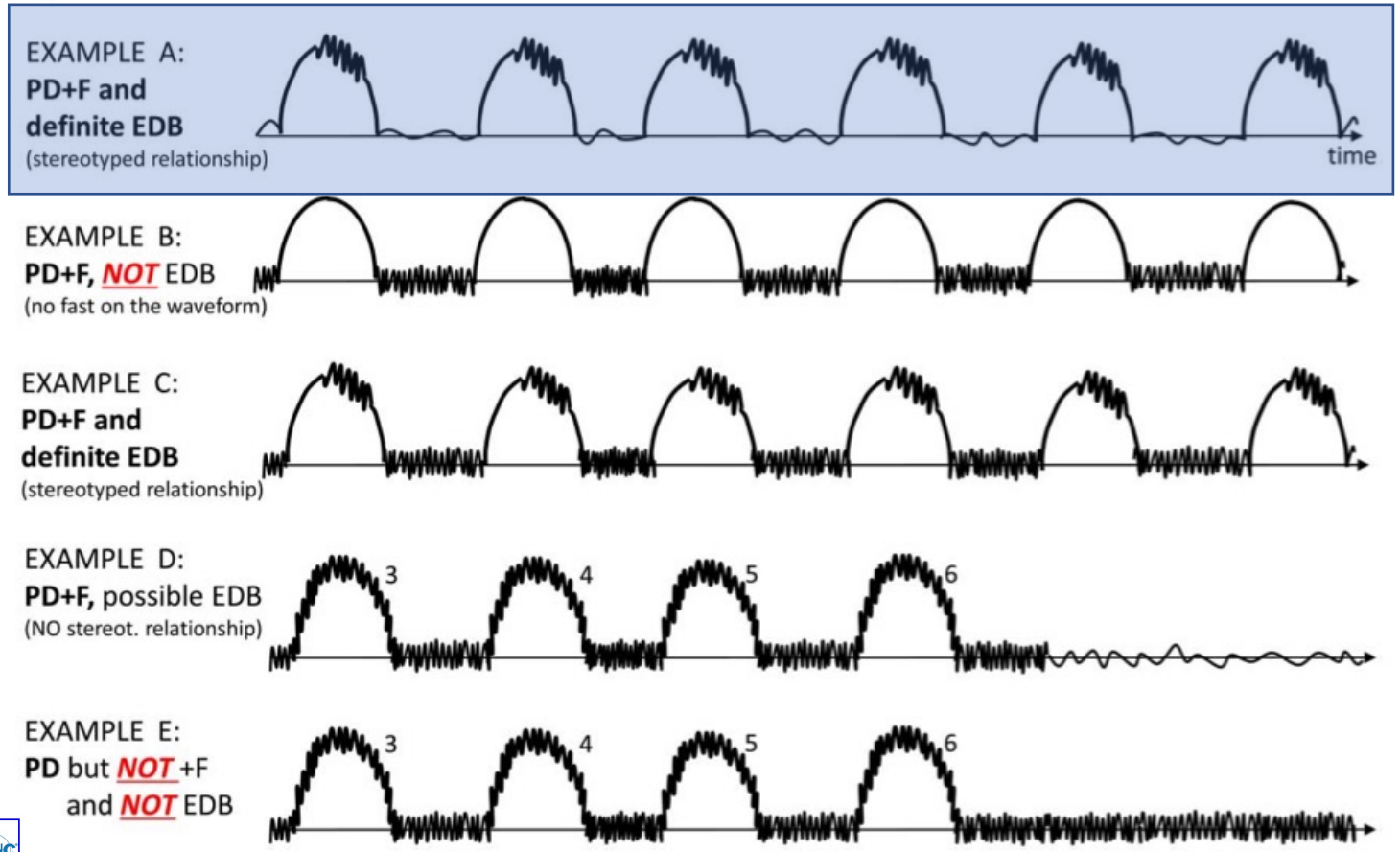
EXTREME DELTA BRUSH (EDB)

DEFINITE EDB: RDA + F or PDs + F. :
Abundant or Continuos Fast Activity with STEREOTYPED relationship with RDA or PDs
POSSIBLE EDB: Occasional or Frequent Fast Activity without Stereotyped Relationship





C


EXAMPLE A:
PD+F and
definite EDB
(stereotyped relationship)
time
EXAMPLE B:
PD+F, NOT EDB
(no fast on the waveform)
EXAMPLE C:
PD+F and
definite EDB
(stereotyped relationship)
EXAMPLE D:
PD+F, possible EDB
(NO stereot. relationship)
3
4
5
6
EXAMPLE E:
PD but NOT +F
and NOT EDB
3
4
5
6

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CONTENTS

D. ELECTROGRAPHIC AND ELECTROCLINICAL SEIZURES

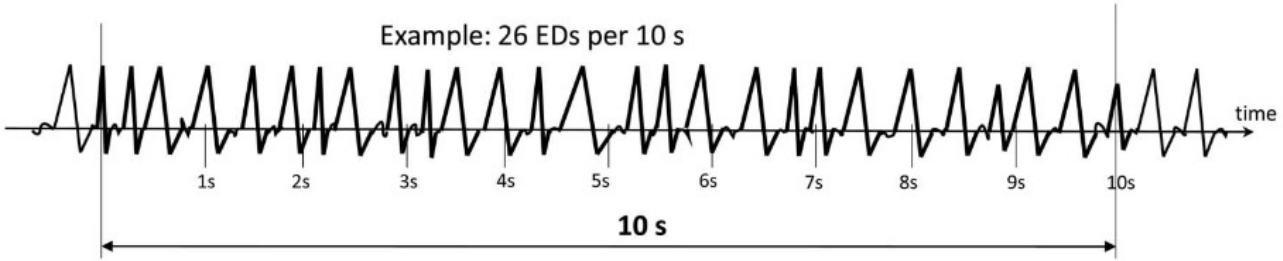
1. Electrographic Seizures (ESz)

ESz (largely based on the Salzburg criteria)[11,12] is defined as either:

a. Epileptiform discharges* averaging >2.5 Hz for ≥ 10 seconds (>25 discharges in 10 seconds), OR

b. Any pattern with definite evolution as defined above and lasting ≥ 10 seconds (see Supp EEG 24a, b, and c, Supplemental Digital Content 1, http://links.lww.com/JCNP/A134) (Fig. 38).

Epileptiform discharges averaging **>2.5 Hz** for **≥10 s** (>25 discharges in 10 s)



2. Electrographic Status Epilepticus (ESE)

ESE is defined as an ESz for ≥ *10 continuous minutes or for a total duration of* ≥ *20% of any 60-minute period* of recording. The 10 minute cutoff matches the definition of focal status epilepticus with impaired consciousness by the International League Against Epilepsy.[17] The 20% cutoff, lowered

FIG. 38. Electrographic seizure (ESz).

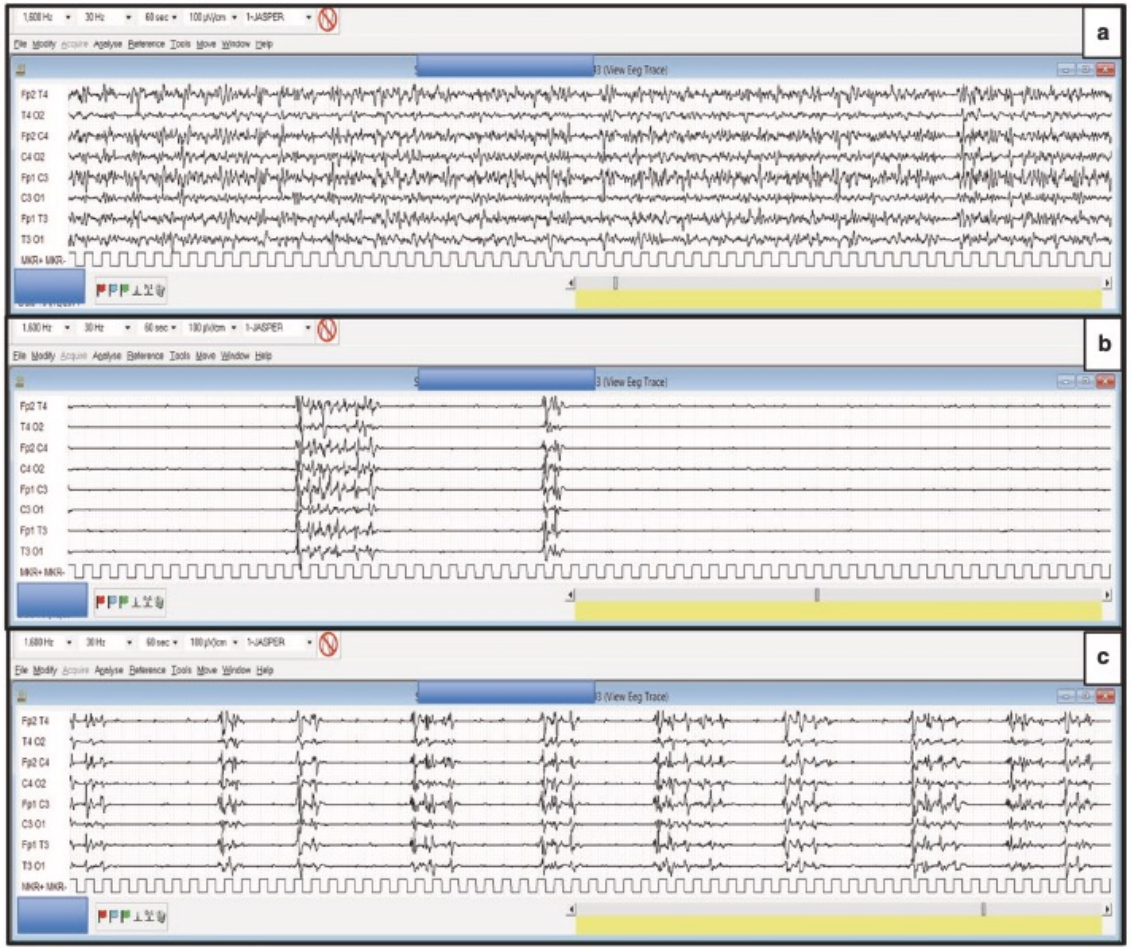


Fig. 48.8 Continuous EEG (cEEG) monitoring in a 76-year-old patient with traumatic brain injury. (**a**) Continuous diffuse epileptiform activity. (**b**) After a bolus of propofol (1 mg/kg) followed by an infusion of 20 mg/kg/h for 35 min, the cEEG showed a pattern of burst suppression with suppression periods >70% of the trace. (**c**) Few minutes after the interruption of propofol infusion, the periods progressively shorter

O. Mecarelli (ed.), *Clinical Electroencephalography*, https://doi.org/10.1007/978-3-030-04573-9_2

3. Electroclinical Seizure (ECSz)

ECSz is defined as any EEG pattern with either:

a. Definite clinical correlate* time-locked to the pattern (of any duration) (see Supp EEG 25, Supplemental Digital Content 1, http://links.lww.com/JCNP/A134) (Fig. 39), OR

b. EEG *AND* clinical improvement with a parenteral (typically IV) antiseizure medication (see Supp EEG 26a and b, Supplemental Digital Content 1, http://links.lww.com/JCNP/A134) (Fig. 39).

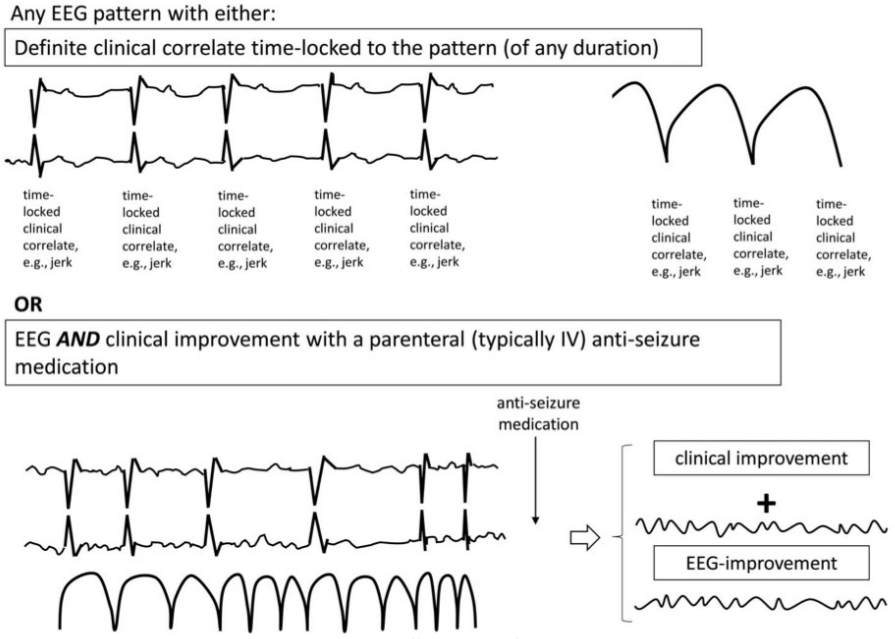


FIG. 39. Electroclinical seizure (ECSz).

4. Electroclinical Status Epilepticus (ECSE)

ECSE is defined as an electroclinical seizure for ≥ 10 *continuous minutes or for a total duration of* $\geq 20\%$ *of any 60-minute period* of recording. An ongoing seizure with bilateral tonic-clonic (BTC) motor activity only needs to be present for ≥ 5 continuous minutes to qualify as ECSE. This is also referred to as "convulsive SE," a subset of "SE with prominent motor activity."[17] In any other clinical situation, the minimum duration to qualify as SE is ≥ 10 minutes.

EEG per il Monitoraggio dello Stato Epilettico

Stato Epilettico Convulsivo: la diagnosi è clinica ma il Monitoraggio EEG è importante per quanto riguarda lo studio del suo follow-up

Stato Epilettico Non Convulsivo: impossibile il suo inquadramento senza EEG

A definition and classification of status epilepticus – Report of the ILAE Task Force on Classification of Status Epilepticus

*†‡Eugen Trinka, §Hannah Cock, ¶Dale Hesdorffer, #Andrea O. Rossetti, **Ingrid E. Scheffer, ††Shlomo Shinnar, ‡‡Simon Shorvon, and §§Daniel H. Lowenstein

Epilepsia, 56(10):1515–1523, 2015
doi: 10.1111/epi.13121

Axis 3. Electroencephalographic (EEG) Correlates

1. None of the ictal EEG patterns of any type of SE is specific.
2. Epileptiform discharges are regarded as the hallmark, but with increasing duration of SE, the EEG changes and rhythmic nonepileptiform patterns may prevail.
3. EEG is of limited clinical value in convulsive form of SE (overloaded with movement and muscle artifact)
4. EEG is indispensable in the diagnosis of NCSE, as the clinical signs are often subtle and nonspecific

Axis-3 EEG correlates

Axis 3: Electroencephalographic correlates

1 *Location:* generalized (including bilateral synchronous patterns), lateralized, bilateral independent, multifocal.
2 *Name of the pattern:* Periodic discharges, rhythmic delta activity or spike-and-wave/sharp-and-wave plus subtypes.
3 *Morphology:* sharpness, number of phases (e.g., triphasic morphology), absolute and relative amplitude, polarity.
4 *Time-related features*: prevalence, frequency, duration, daily pattern duration and index, onset (sudden vs. gradual), and dynamics (evolving, fluctuating, or static).
5 *Modulation:* stimulus-induced vs. spontaneous.
6 *Effect of intervention (medication) on EEG.*

Localizzazione

Generalizzata
Lateralizzata
Bilaterale indipendente
Multifocale

Tipo di Pattern

Scariche periodiche
Attività delta ritmica o P-O/SW plus

Morfologia

Aguzzi
Numero di fasi
Ampiezza assoluta e relativa
Polarità

Evoluzione temporale

Prevalenza
Frequenza
Durata
Esordio
(improvviso/graduale)
Dinamica

Modulazione

Spontaneo
Stimolo-indotto

Effetto della terapia sull'EEG

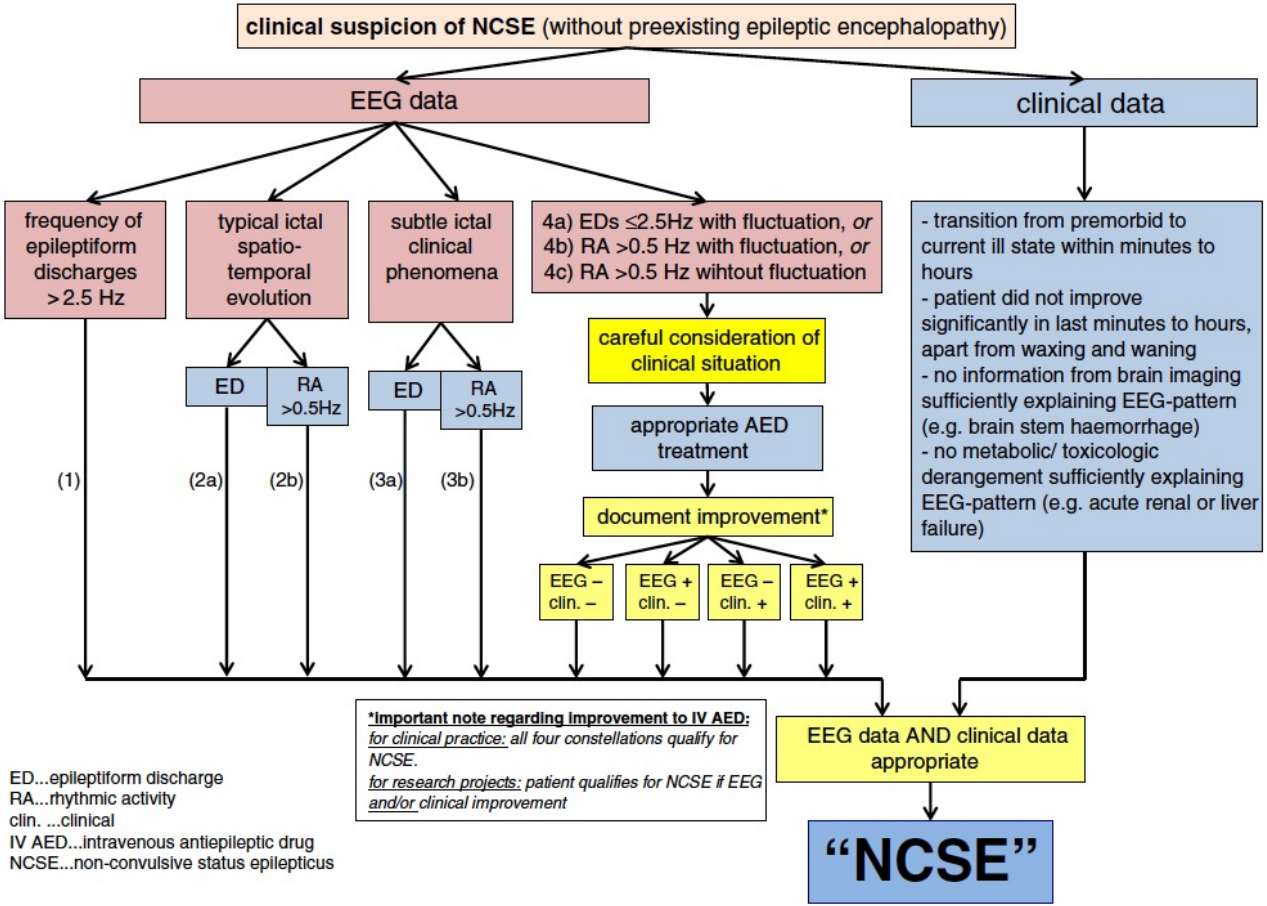


Fig. 12. Algorithm for diagnosis of nonconvulsive status epilepticus with the modified Salzburg Consensus Criteria for NCSE (mSCNC) (see text for further details) [152].

Diagnostic accuracy of the Salzburg EEG criteria for non-convulsive status epilepticus: a retrospective study

Lancet Neurol 2016; 15: 1054–62

Markus Leitinger, Eugen Trinka, Elena Gardella, Alexandra Rohracher, Gudrun Kalss, Erisela Qerama, Julia Höfler, Alexander Hess, Georg Zimmermann, Giorgi Kuchukhidze, Judith Dobesberger, Patrick B Langthaler, Sándor Beniczky

Criteri Primari

Criteri Secondari

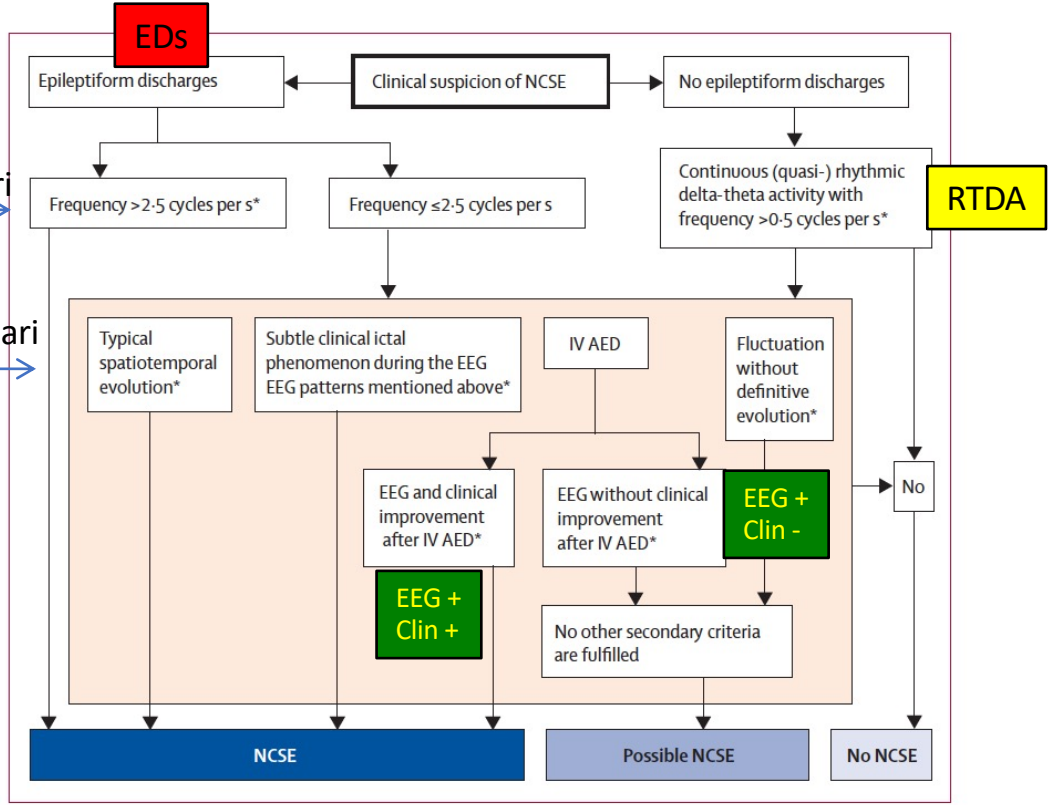


***Figure 1*: Salzburg EEG criteria for the diagnosis of NCSE**

Evoluzione Spazio-Temporale

- Almeno due inequivocabili modificazioni sequenziali in **FREQUENZA, MORFOLOGIA o LOCALIZZAZIONE**
  (incremento iniziale e decremento finale)

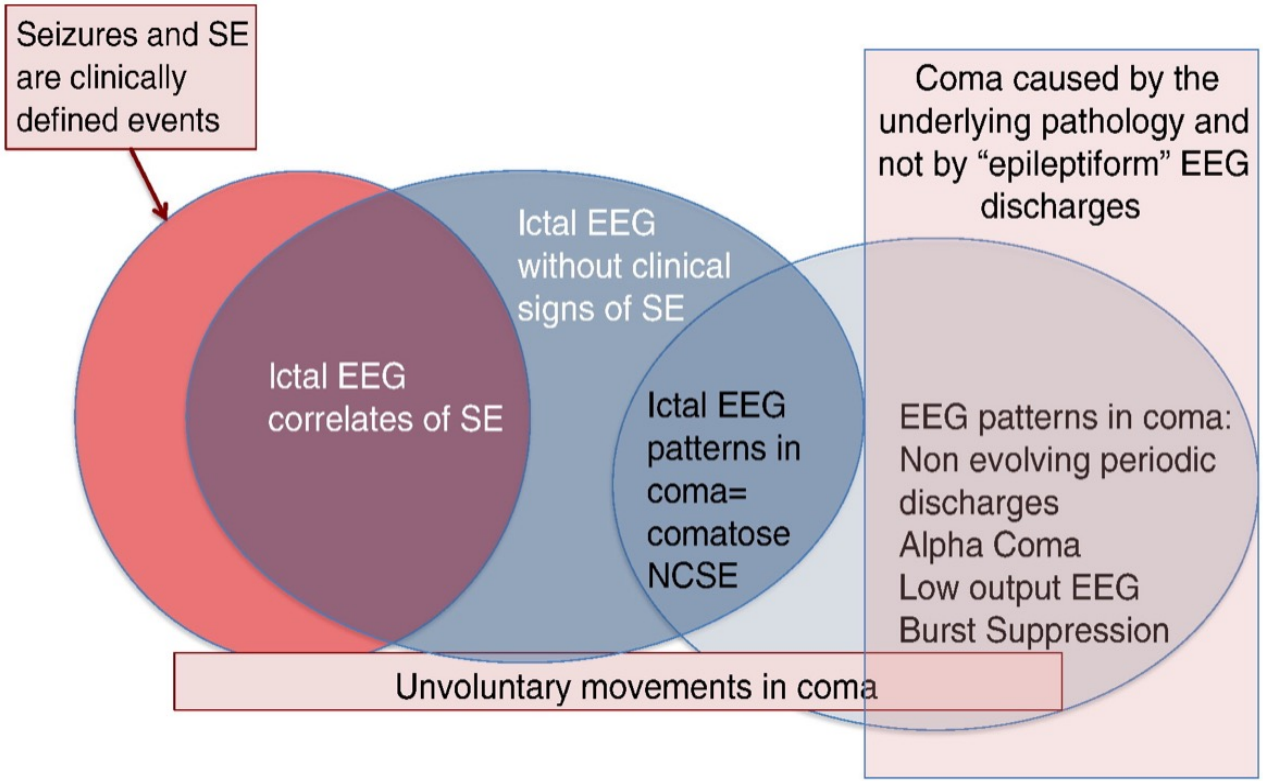
L' **Evoluzione in FREQUENZA** è definita come almeno 2 cambiamenti consecutivi in frequenza, di almeno 0.5 Hz, nella stessa direzione (es: 2 Hz 2.5 Hz 3 Hz; oppure 3 Hz 2.5 Hz 2 Hz) Ciascuna frequenza deve rimanere presente per almeno 3 cicli e non deve restare invariata per > 5 min.

L'**Evoluzione in MORFOLOGIA** è definita come almeno 2 cambiamenti consecutivi ad una nuova morfologia

L'**Evoluzione in LOCALIZZAZIONE** è definita come coinvolgimento sequenziale di almeno Elettrodi del SI 10-20, per almeno 3 cicli e senza restare invariata per > 5 min

L'Evoluzione Spazio-temporale deve essere distinta dalla FLUTTUAZIONE.
Per FLUTTUAZIONE si intende > 3 modificazioni, a non più di 1 minuto l'uno dall'altro in:

- **frequenza: di almeno 0.5 Hz ma non nella stessa direzione (es: 2 Hz 1.5 Hz 2 Hz)**
- **Morfologia: tra 2 morfologie ripetutamente**
- **Localizzazione: diffusione verso o lontano un singolo elettrodo ripetutamente**



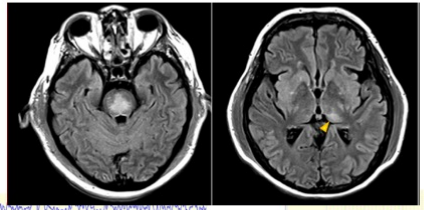
Epilepsy & Behavior 49 (2015) 203–222

Not everything that shakes is a seizure... Role of continuous EEG in the intensive care unit

Thomas Ritzenthaler[a,d,*], Chloé Laurencin[b], Nathalie André Obadia[c], Carole Bodonian[a], Frédéric Dailler[a]

Neurophysiologie Clinique/Clinical Neurophysiology (2017) **47**, 13—18

Summary Treatment of status epilepticus often requires highly sedative drugs with risk of side effects. Correct diagnosis is mandatory in order to prevent introduction of usefulness treatments. We report a case of suspected myoclonic status epilepticus. A thalamic lesion secondary to an osmotic demyelination syndrome was found to be the likely etiology of the myoclonus. Electrophysiological data (electroencephalography and electromyography) provided evidence for a subcortical origin of myoclonus and use of continuous EEG allowed monitoring of drug withdrawal.



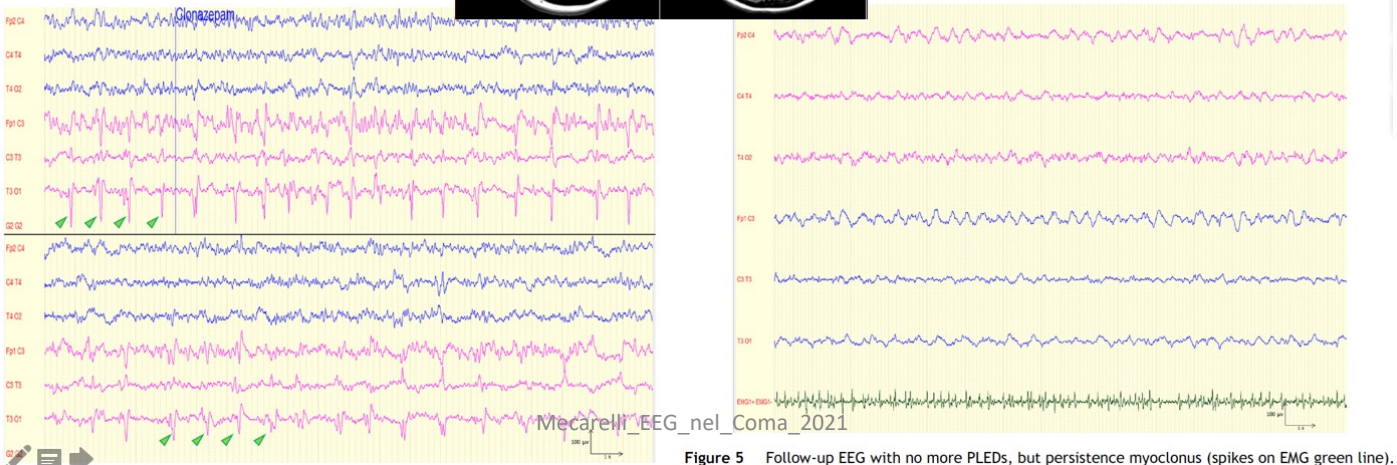
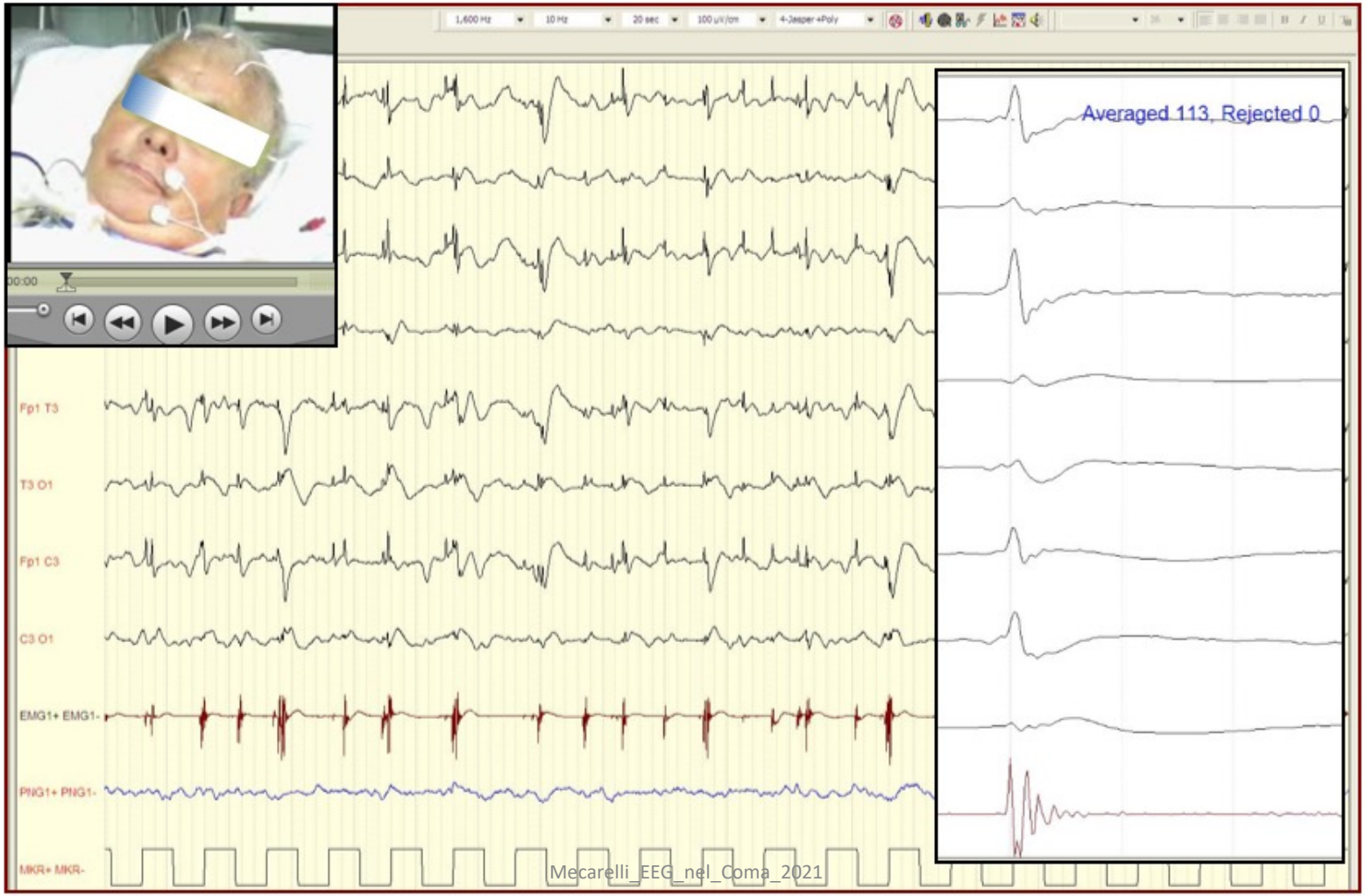


Figure 5 Follow-up EEG with no more PLEDs, but persistence myoclonus (spikes on EMG green line).


Averaged 113, Rejected 0
Fp1 T3
T3 O1
Fp1 C3
C3 O1
EMG1+ EMG1-
PNG1+ PNG1-
MKR+ MKR-


Fp2 T4
T4 O2
Fp2 C4
C4 O2
Fp1 T3
T3 O1
Fp1 C3
C3 O1
ECG1+ ECG1-
EMG1+ EMG1-
EMG orb
PNG1+ PNG1-
EOG
MKR+ MKR-

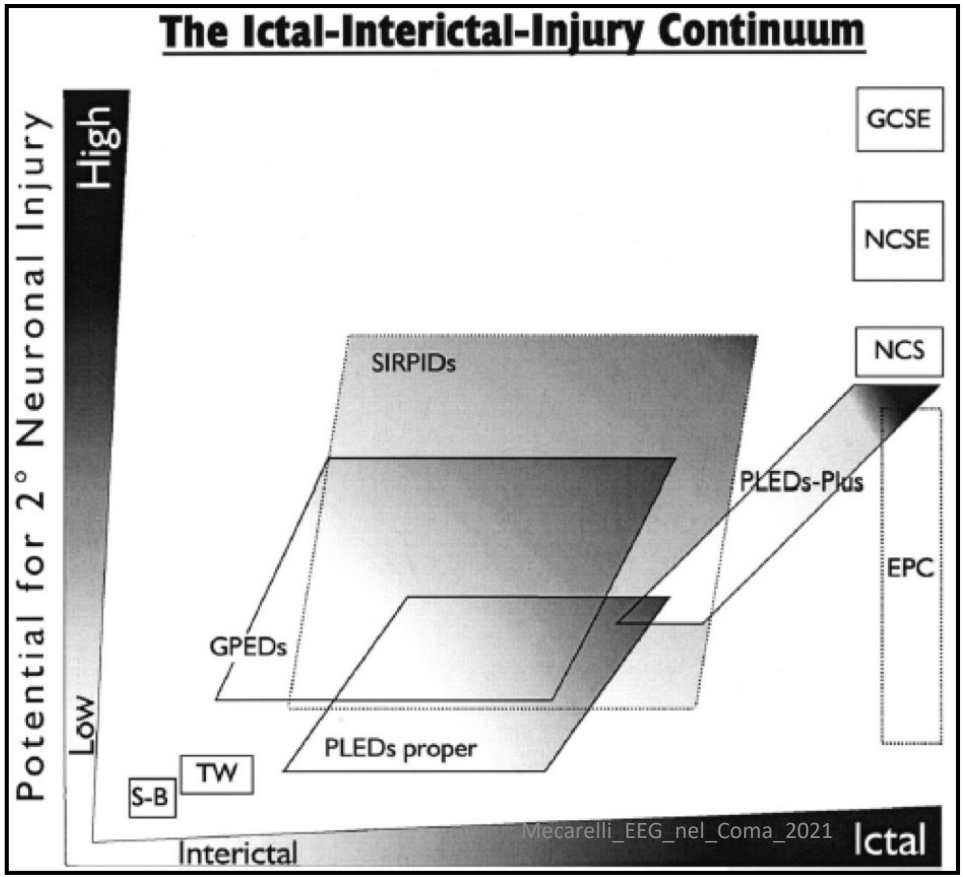
2021 ACNS CRITICAL CARE EEG TERMINOLOGY

CONTENTS

Which EEG Patterns Warrant Treatment in the Critically Ill? Reviewing the Evidence for Treatment of Periodic Epileptiform Discharges and Related Patterns

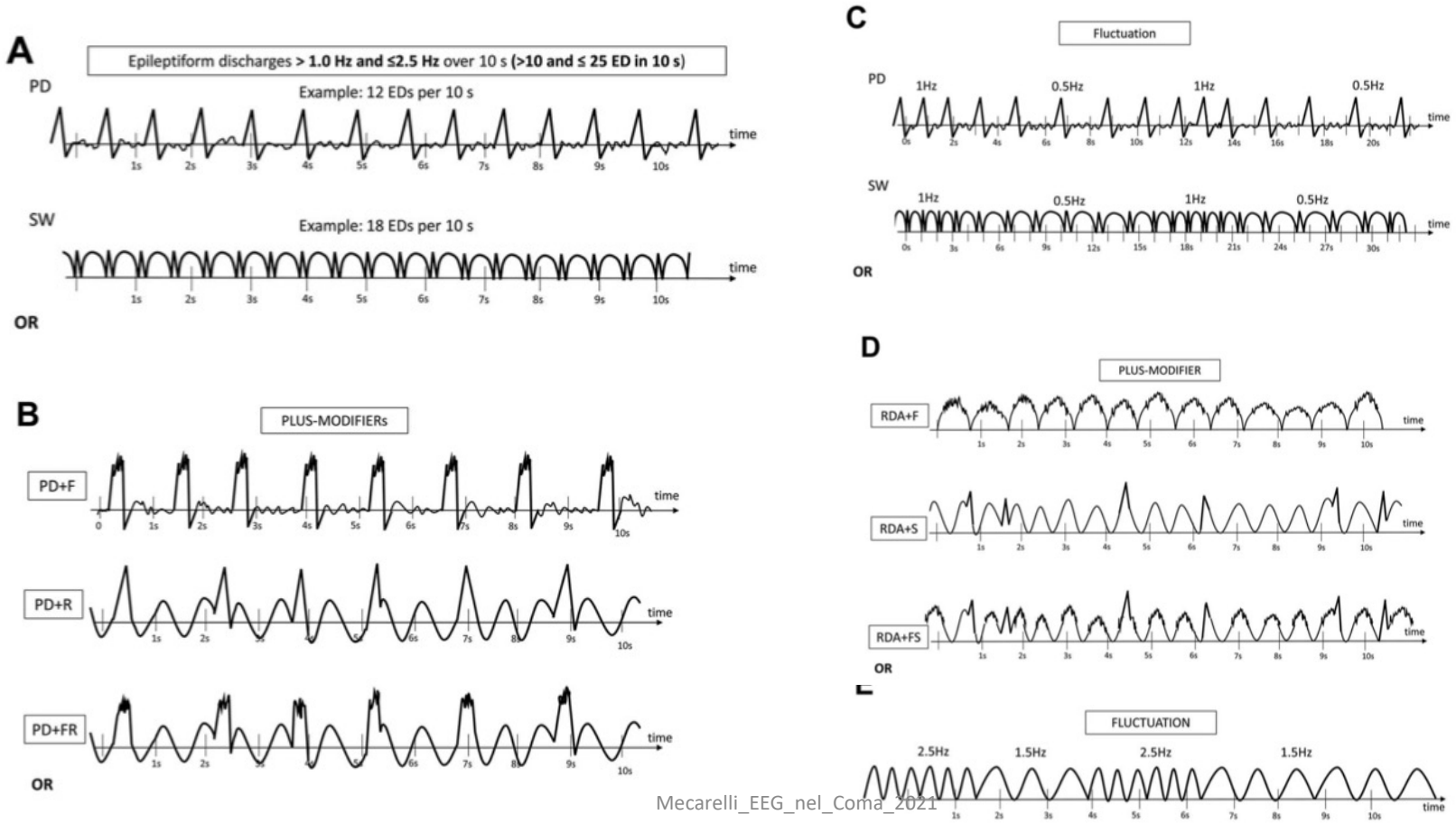
Derek J. Chong and Lawrence J. Hirsch

Journal of Clinical Neurophysiology • Volume 22, Number 2, April 2005 *Which EEG Patterns Warrant Treatment?*



This plot demonstrates various clinical-EEG diagnoses depicted on the ictal-interictal continuum.
The potential for secondary neuronal injury should be a more important indicator of whether treatment should be aggressive

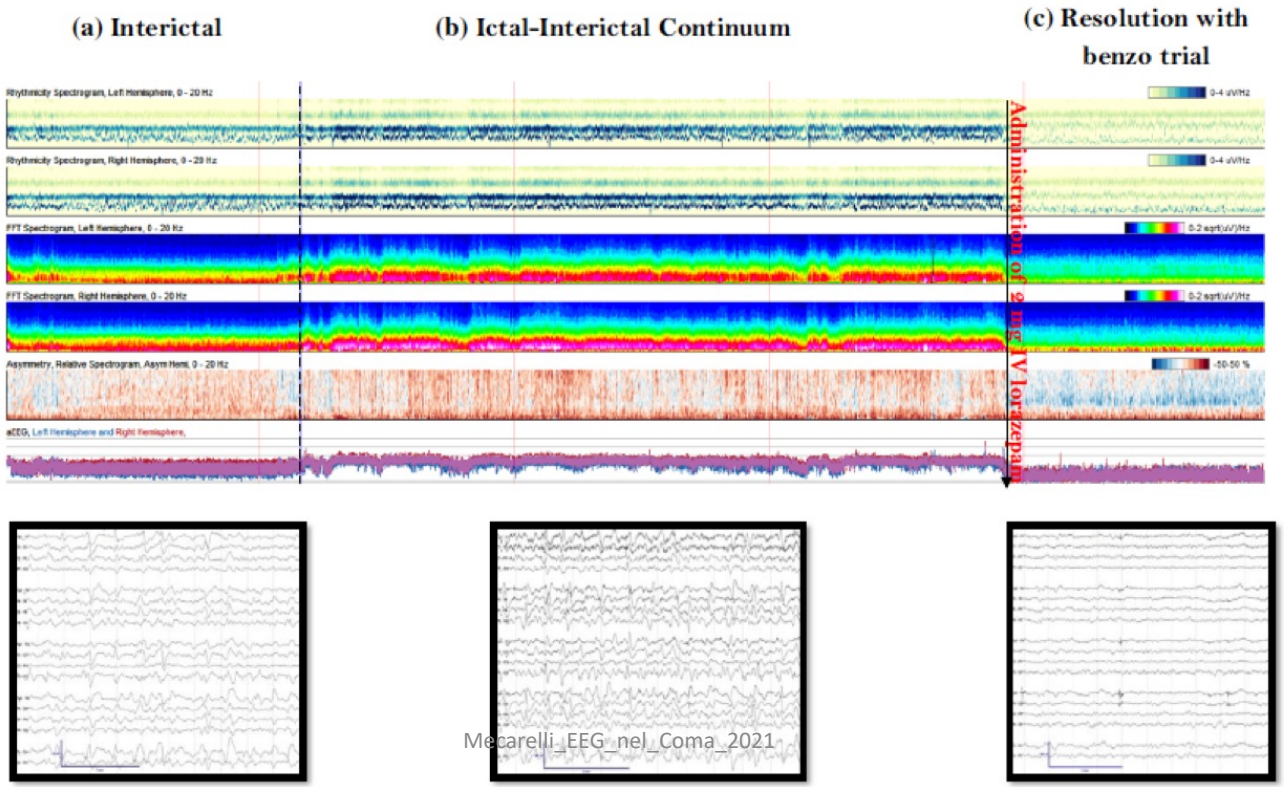
F. THE ICTAL-INTERICTAL CONTINUUM (IIC)



Understanding and Managing the Ictal-Interictal Continuum in Neurocritical Care

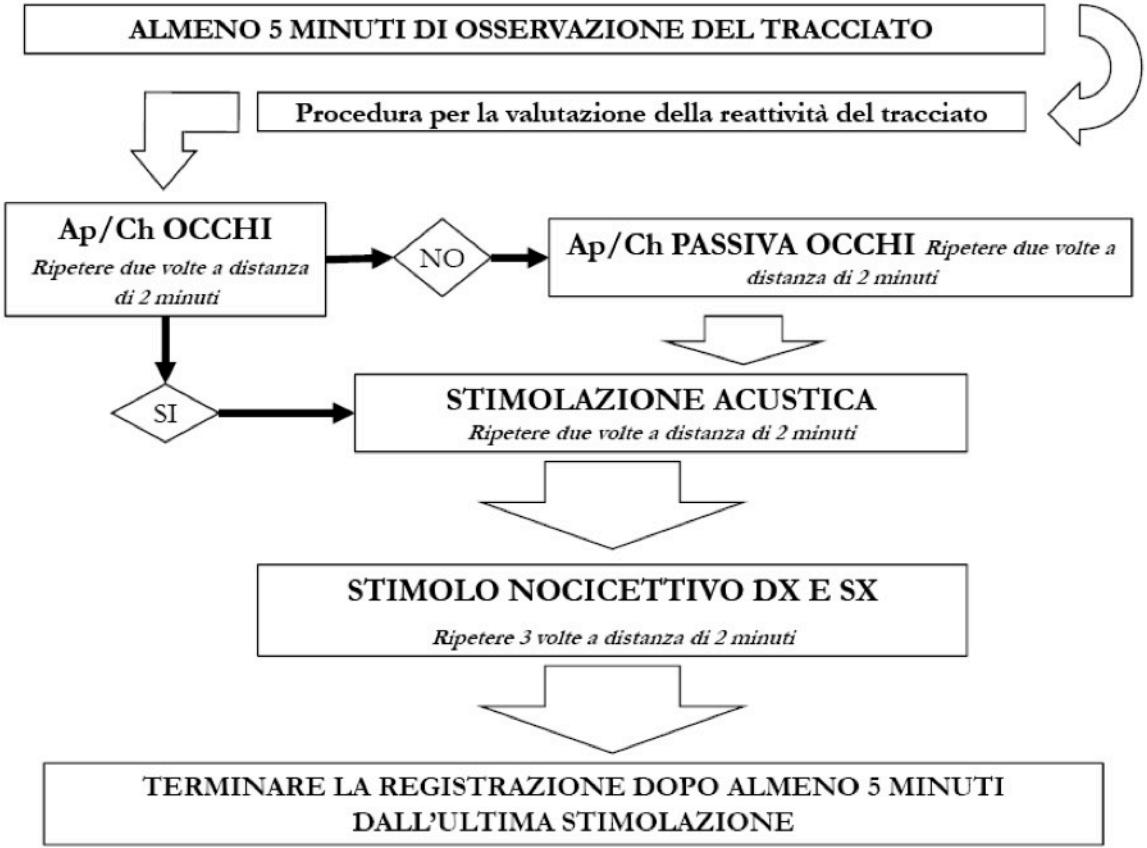
Curr Treat Options Neurol (2016) 18: 8
DOI 10.1007/s11940-015-0391-0

Adithya Sivaraju, MD, MHA[1]
Emily J. Gilmore, MD, MS[2,*]

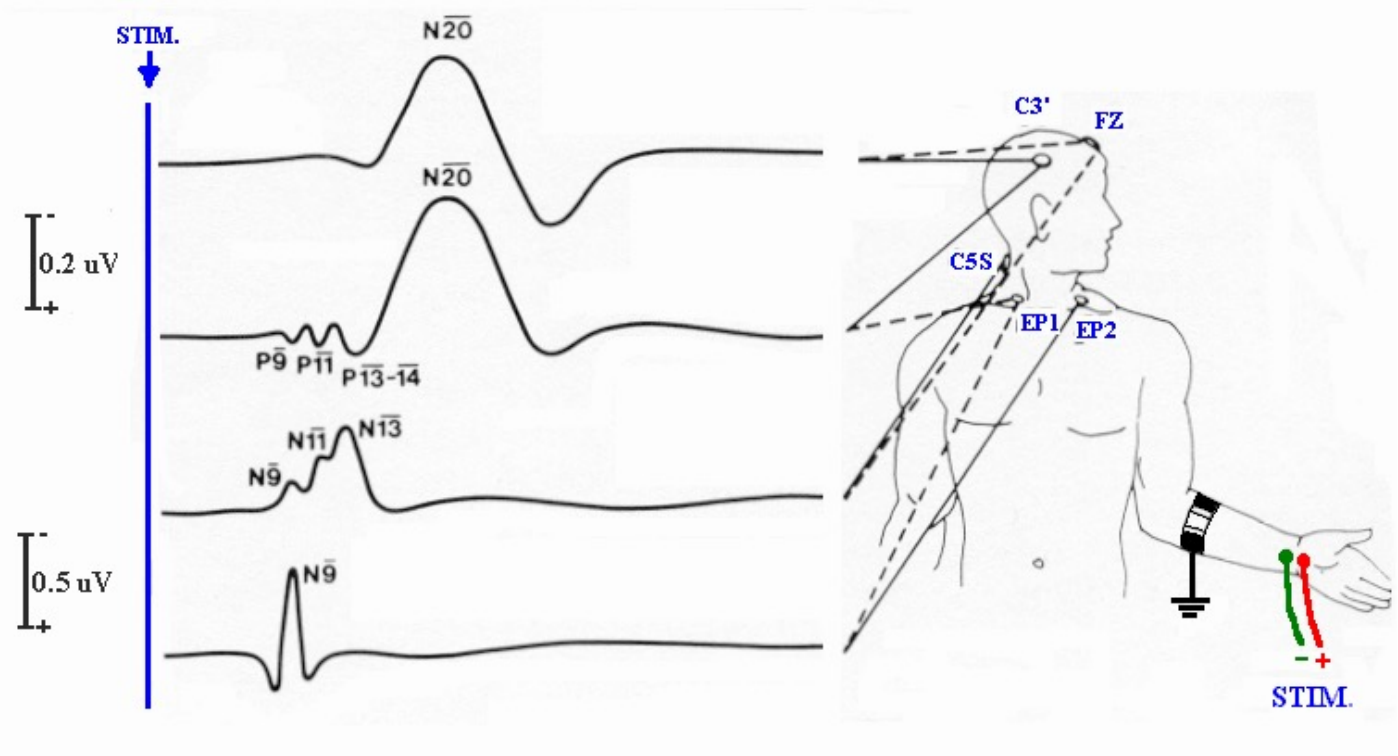


Neuromonitoraggio in ICU

EEG



Potenziali Evocati Somatosensoriali (PES) AA Superiori:



EEG versus PES

Sensibilità alla neurosedazione	Resistenza alla neurosedazione
Sensibilità danno metabolico	Resistenza danno metabolico
Specificità diagnosi NCS e SENC	----------
Sensibilità danno strutturale ipossi/ischemico	Sensibilità danno strutturale ipossi/ischemico
Interpretazione esperta	Interpretazione semplificata

Table 48.2 Characteristics of various instrumental techniques for the evaluation of cerebral functions in comatose patients

	Practicality	Spatial resolution	Temporal resolution	Specificity	Interpretation
cEEG	++++	+++	++++	++++	+
Evoked potentials	+++	++	++	++	+
Transcranial Doppler	+++	++	++	++	+
Neuroimaging (CT-MR)	+	++++	+	+++	++
IBP monitoring	++++	+	+++	++	+++

cEEG continuous EEG, *CT* computed tomography, *MR* magnetic resonance, *IBP* intracranial blood pressure

O. Mecarelli (ed.), *Clinical Electroencephalography*, https://doi.org/10.1007/978-3-030-04573-9_2

Pattern EEG di COMA esemplificativi

LPDs “sharply contoured” (unilateral)

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

LPDs “sharply contoured” (bilateral asymmetric)

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

Spiky LPDs

FIG. 5. LPDs: 0.5-1 per second spiky lateralized periodic discharges. Despite their spike-and-wave morphology, the discharges are periodic (as there is a quantifiable inter-discharge interval between consecutive waveforms and recurrence of the waveform at nearly regular intervals).

LPDs + F = spiky LPDs with superimposed FAST activity

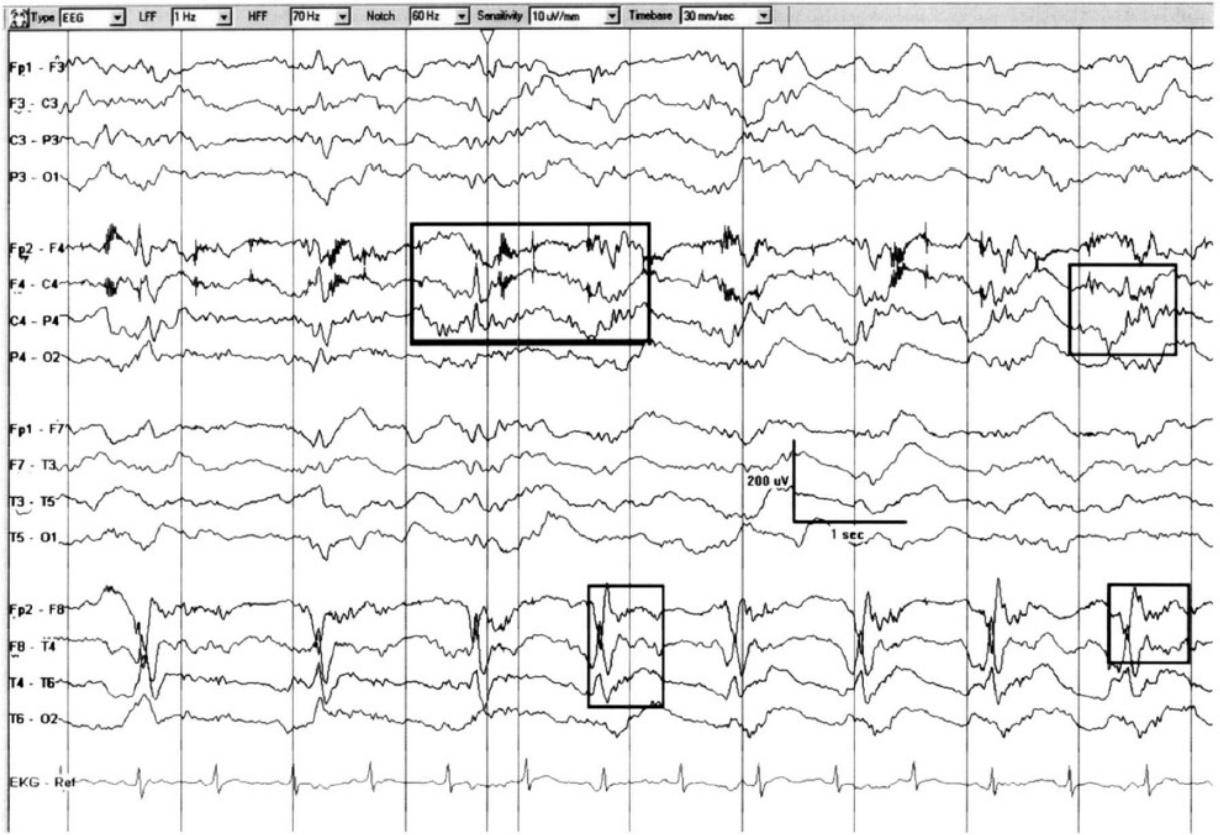


FIG. 6. LPDs+F: 0.5 to 1 per second spiky LPDs with superimposed burst of low amplitude fast activity (highlighted in boxes).

LPDs + R = LPDs with superimposed quasi-rhythmic Delta Activity

FIG. 7. LPDs+R: Irregular (in morphology and repetition rate) 0.5-1 per second quasi-periodic discharges with superimposed quasi-rhythmic delta activity in the right hemisphere with occasional spread to the left. Less "stable" pattern and more ictal-appearing than LPDs alone; compare with Figure 1.

“FLUCTUATING” LPDs

FIG. 8. Fluctuating LPDs: Lateralized periodic discharges that fluctuate in frequency between 0.5 and 1 per second.

BIPDs + F = Bilateral Independent PDs with Fast Activity

FIG. 13. BIPDs+F: Bilateral independent periodic discharges at 0.5-1 per second, most prominent centroparietally on both sides. The periodic discharges have a sharp morphology and are associated with low amplitude sharply contoured quasi-rhythmic fast activity, especially posteriorly, and more prominent on the right where the fast activity is nearly continuous.

GPDs = Generalized Periodic Discharges

FIG. 9. GPDs: One per second sharp generalized periodic discharges.

GPDs with Triphasic Morphology and A-P lag

FIG. 10. GPDs with triphasic morphology and A-P lag: Generalized periodic discharges at just under 1.5 per second. In this case there is also a triphasic morphology and an anterior-posterior lag, highlighted with the diagonal line in the upper right of the figure.

GPDs + F

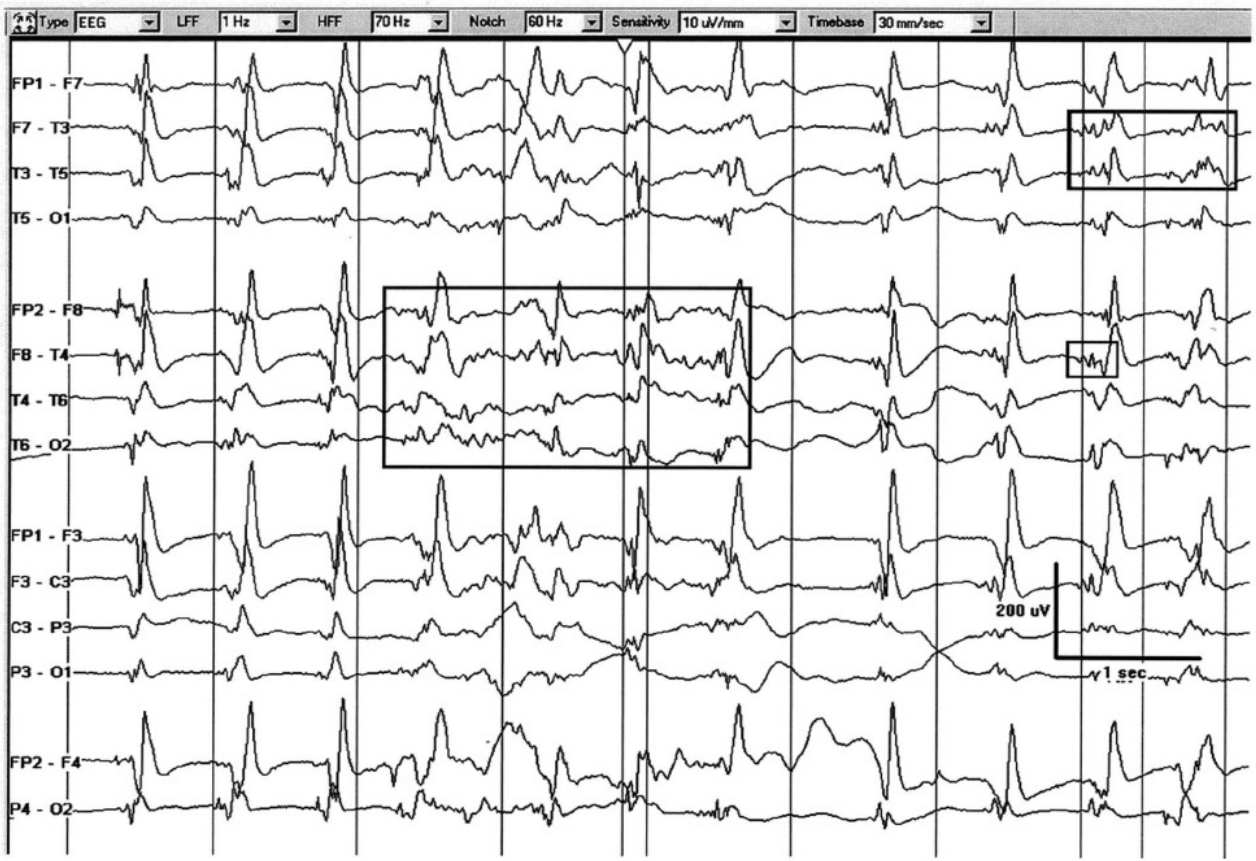


FIG. 11. GPDs+F: 1-1.25 per second sharp GPDs with superimposed low amplitude quasi-rhythmic sharp activity (highlighted in boxes).

GPDs with frontal predominance

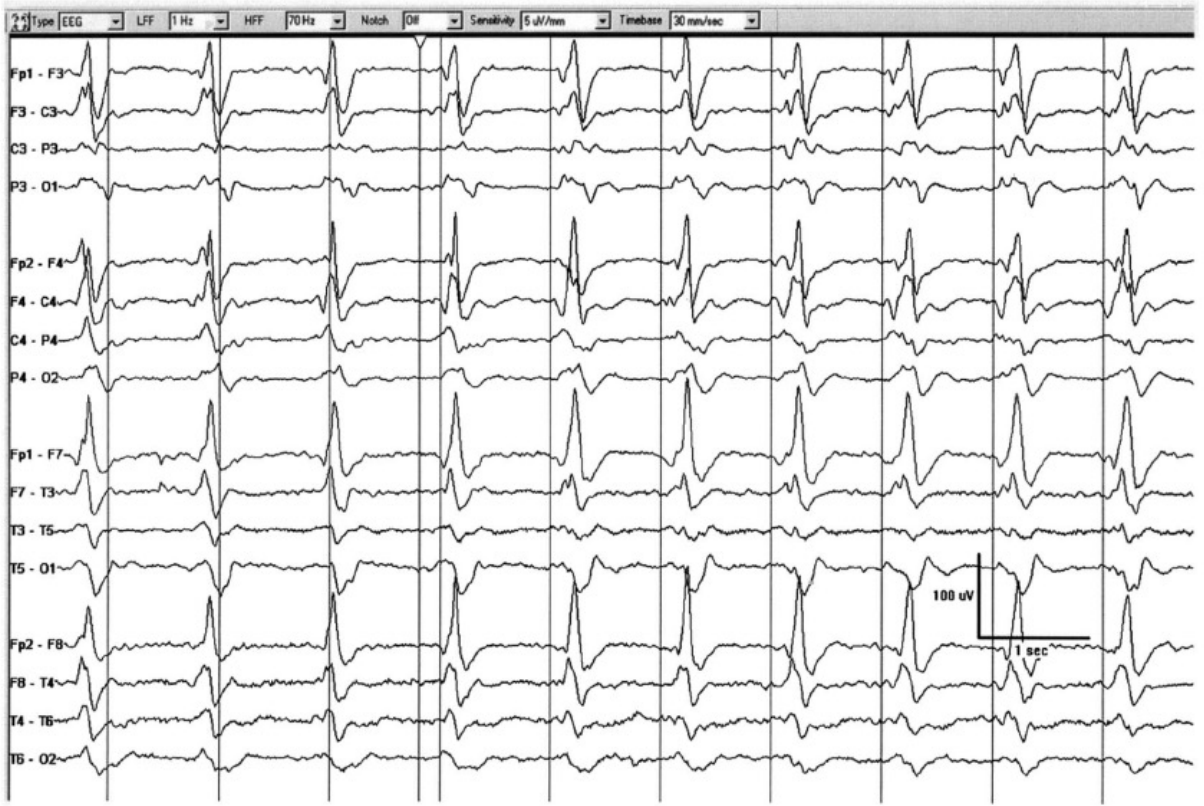


FIG. 12. GPDs: One per second generalized periodic discharges, characterized by a marked frontal predominance and a sharp morphology. Despite background attenuation, the discharges last less than 500ms and thus do not qualify as bursts.

GRDA = Generalized Rhythmic DELTA Activity, frontally predominant

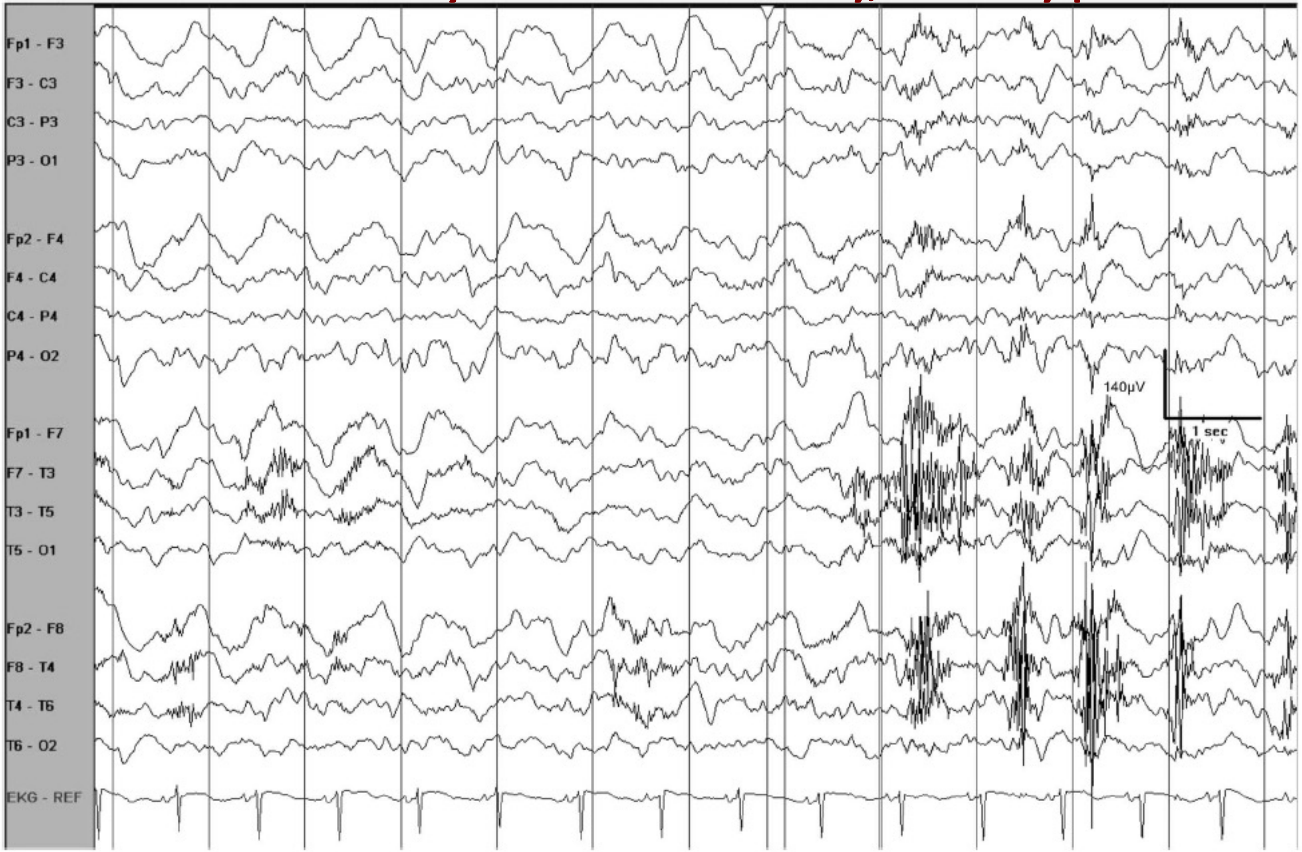


FIG. 14. GRDA: Generalized rhythmic delta activity, frontally predominant. If the lower amplitude faster (α range) frequencies are not present in the background when the GRDA is not present, then this would qualify as GRDA+F.

SI-GRDA = Stimulus-Induced GRA

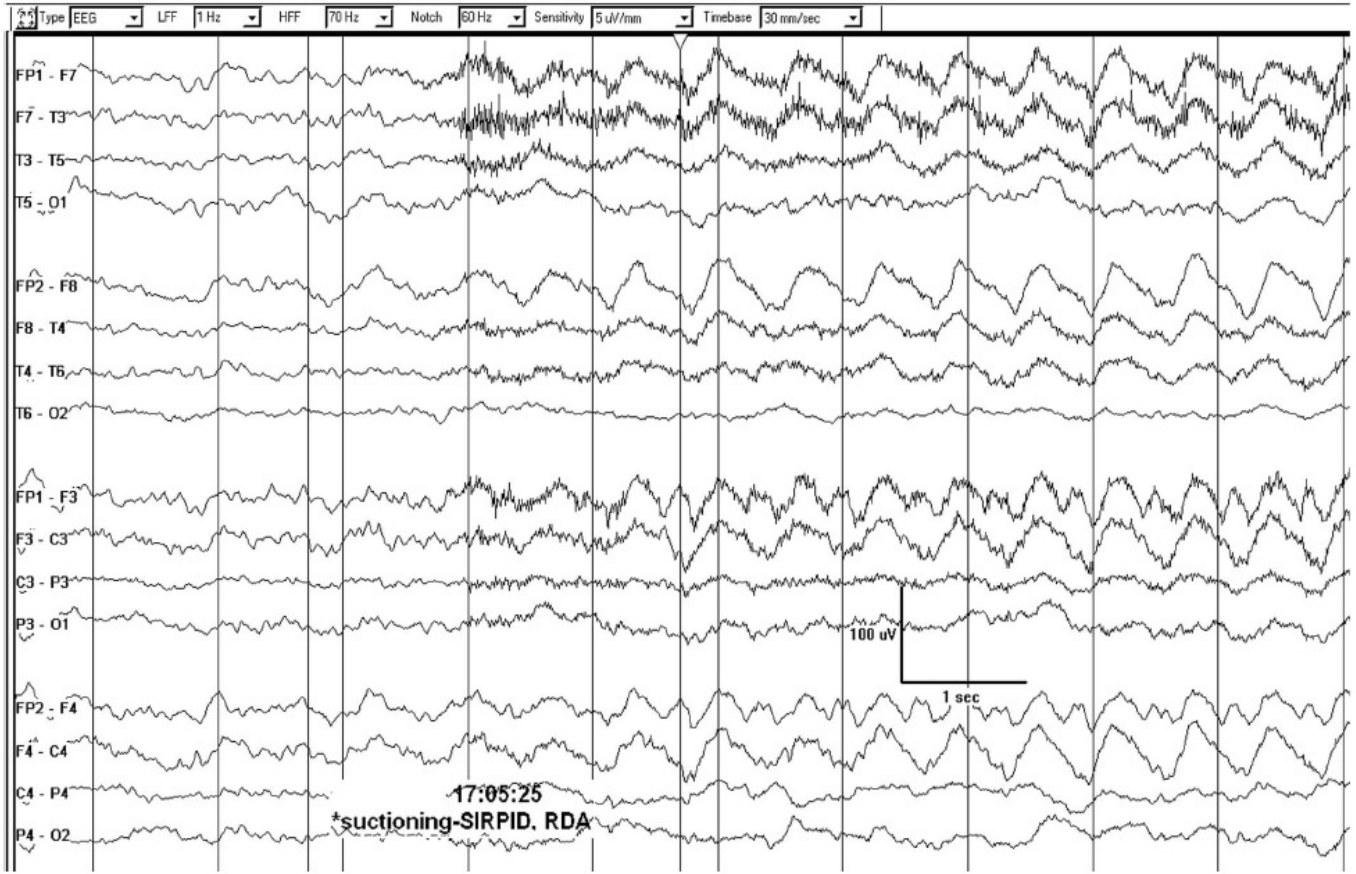


FIG. 15. SI-GRDA: Stimulus-induced generalized rhythmic delta activity, frontally predominant. In this case, the pattern was elicited by suctioning the patient.

EVOLVING LRDA (in morphology and frequency)

FIG. 16. Evolving LRDA: Lateralized rhythmic delta activity that evolves in morphology and frequency. It begins as low voltage sharply contoured 1.5 Hz delta in the left parasagittal region, evolves to 3 Hz rhythmic delta, then again slows.

EVOLVING LRDA (from 4 Hz to 2.5 Hz)

FIG. 17. Evolving LRDA: Lateralized rhythmic delta activity that evolves in frequency and morphology from a 4 per second blunt RDA to a 2.5 per second sharply contoured RDA.Mecarelli_EEG_nel_Coma_2021

LRDA + S = RDA with superimposed repetitive Sharp Waves

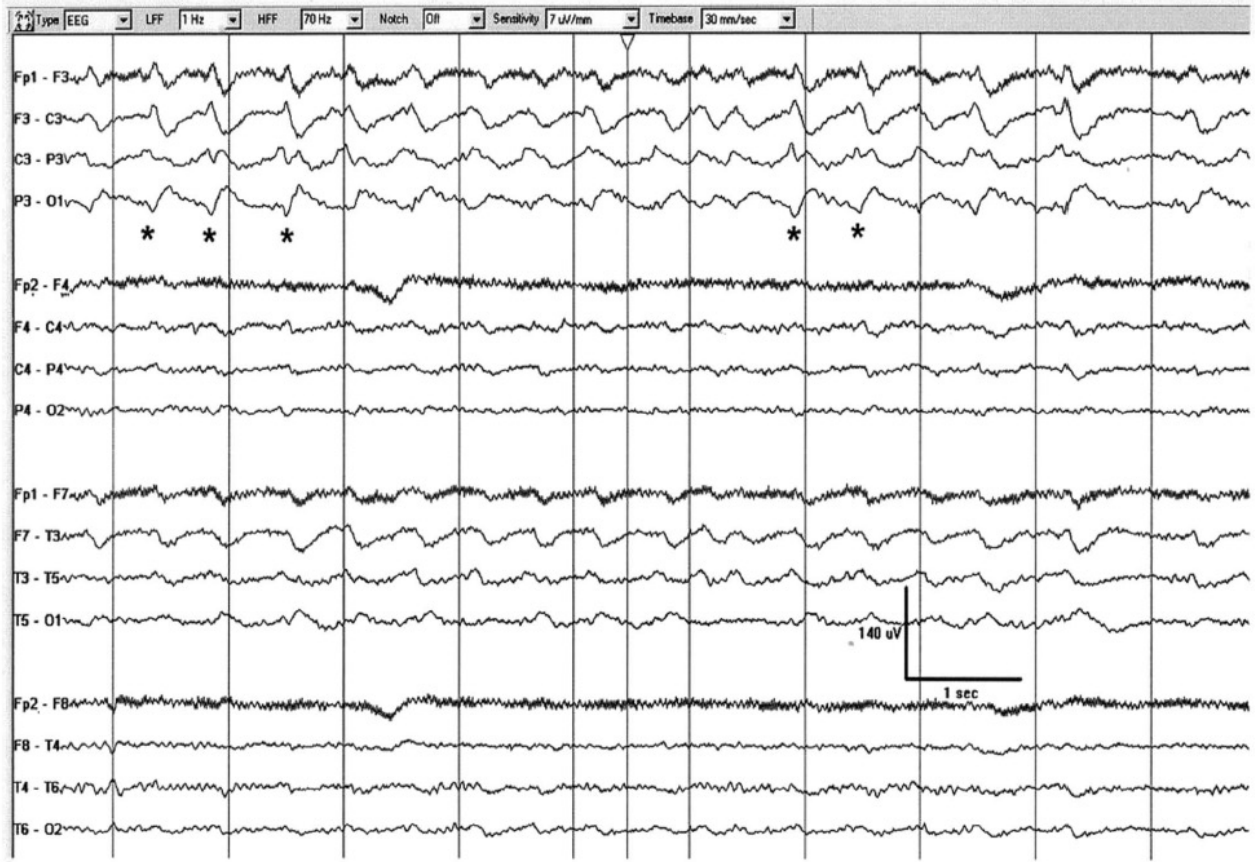


FIG. 18. LRDA+S: Two per second lateralized rhythmic delta activity with superimposed repetitive sharp waves (several marked with asterisks). The superimposed low amplitude fast activity is also present on the right hemisphere and should not be recorded as +F.

LRDA + S = RDA with superimposed repetitive Sharp Waves

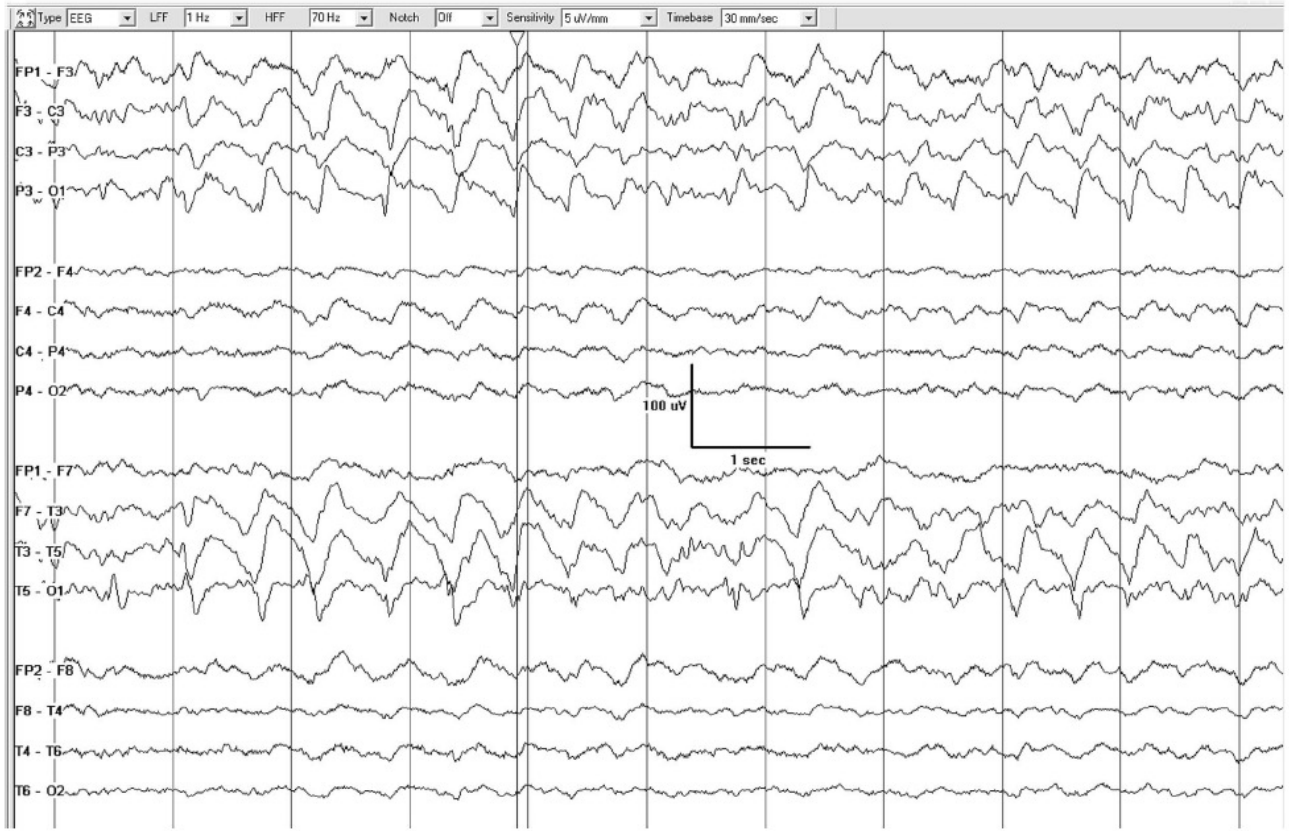


FIG. 19. LRDA+S: Two per second lateralized rhythmic delta activity with superimposed sharp waves most prominent in the left parasagittal region. The superimposed low amplitude fast activity is also present on the right hemisphere and could be recorded as +F if not present in the background (i.e., in the absence of the rhythmic delta activity).

GSW = Generalized Spike-and-Wave 1.5 Hz

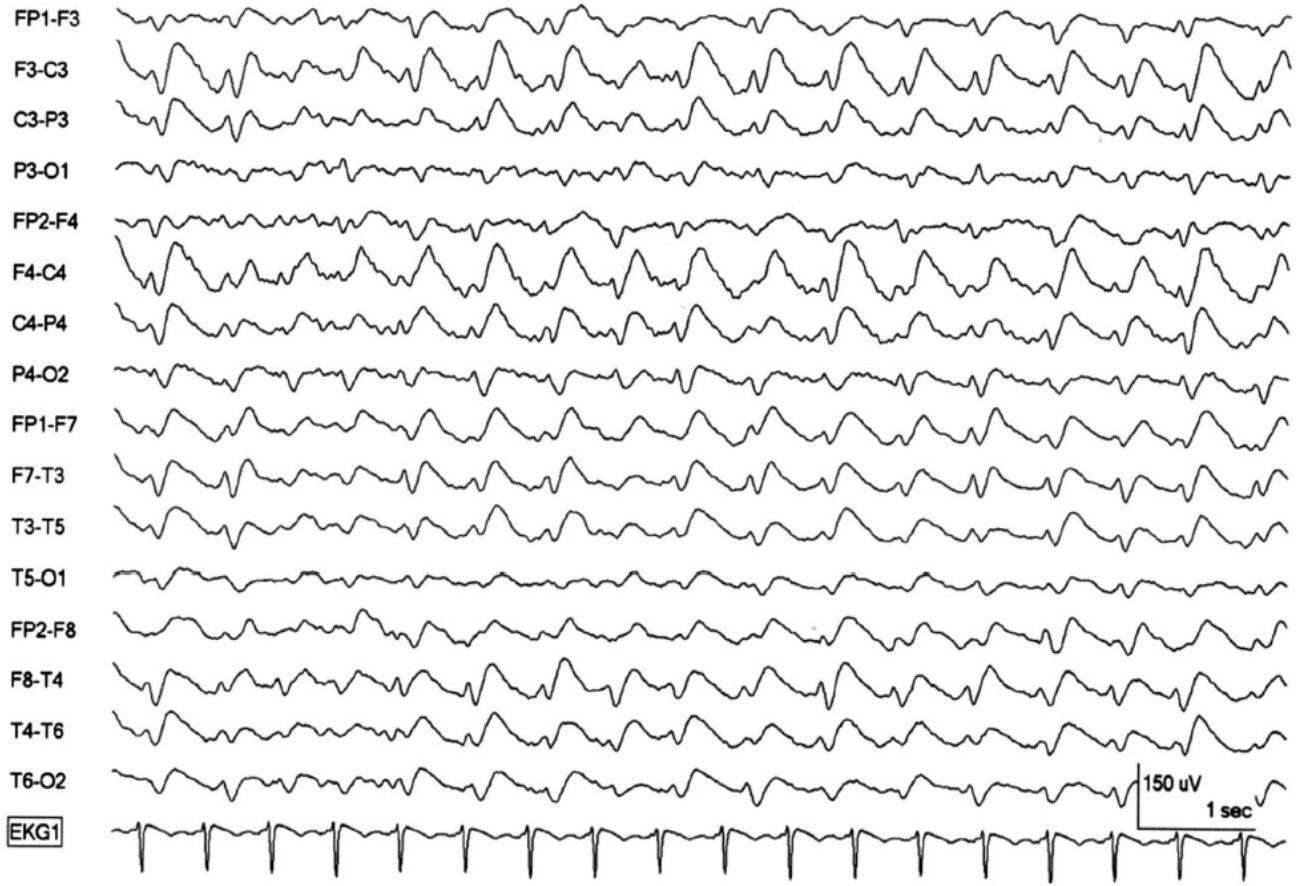


FIG. 21. GSW: 1.5 per second generalized spike-and-wave.

GSW = Generalized Polyspike-and-Wave, frontally predominant

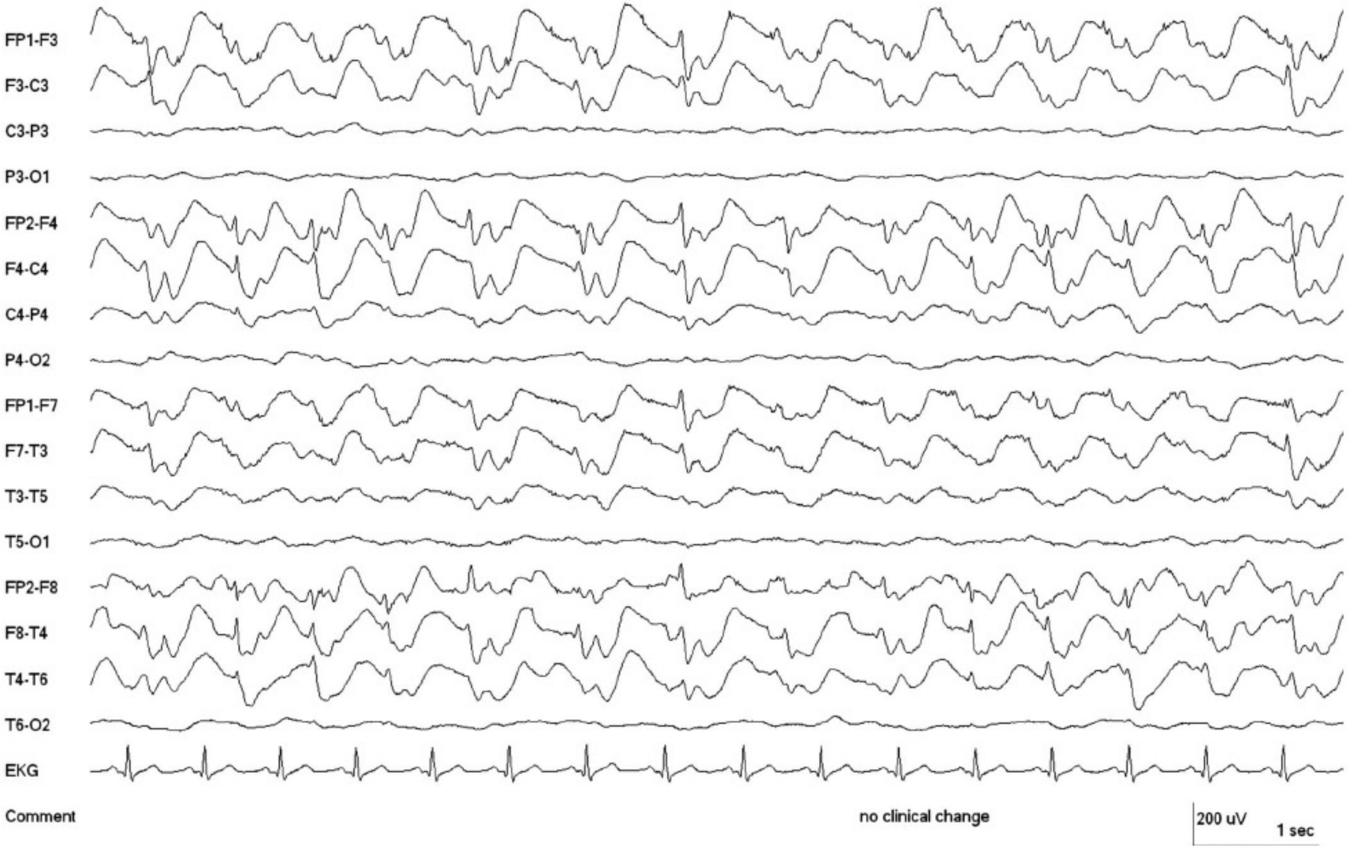


FIG. 20. GSW: 1.5 per second generalized polyspike-and-wave, frontally predominant. A polyspike precedes every slow wave and there is no inter-discharge interval; thus this pattern does not qualify for GRDA+S or GPDs+R.

BURST-SUPPRESSION PATTERN: Bursts of generalized activity (> 500 ms and > 3 phases) on a suppressed background (< 10 uV)

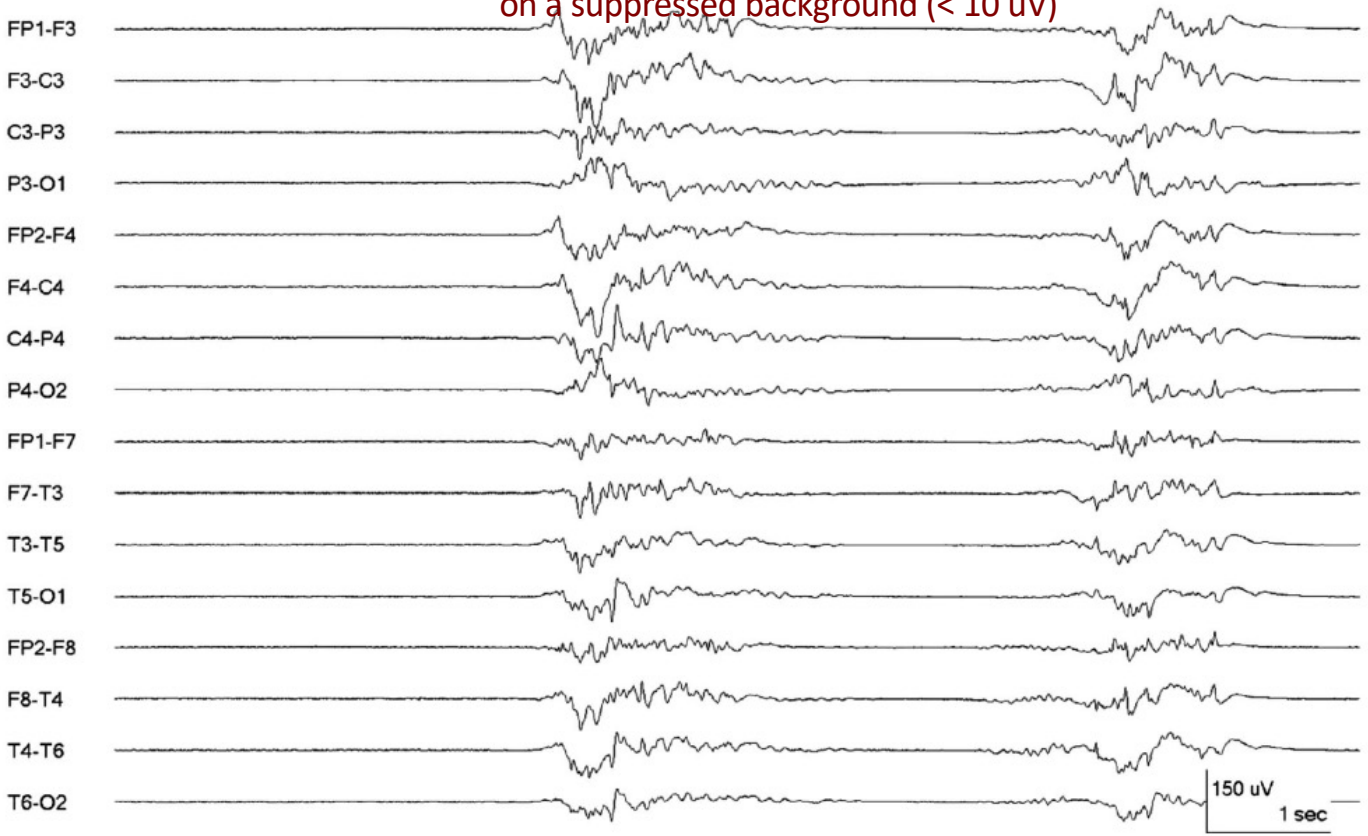


FIG. 22. Burst-suppression pattern: Bursts (>500ms AND >3phases) of generalized activity on a suppressed (<10 μV) background.

BURST-ATTENUATION PATTERN: Bursts of generalized activity (> 500 ms and > 3 phases) on a low amplitude background activity (< 50% of the background/bursts, but > 10 uV)

FIG. 23. Burst-attenuation pattern: In between bursts of generalized activity, there is low amplitude background activity (<50% of the background/bursts, but >10 μV).