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

Hirsch LJ, Fong MWK, Leitinger M, LaRoche SM, Beniczky S, Abend NS, Lee JW, Wusthoff CJ, Hahn CD, Westover MB, Gerard EE, Herman ST, Haider HA, Osman G, Rodriguez-Ruiz A, Maciel CB, Gilmore EJ, Fernandez A, Rosenthal ES, Claassen J, Husain AM, Yoo JY, So E, Kaplan PW, Nuwer MR, van Putten M, Sutter R, Drislane FW, Trinka E, Gaspard N.

Introduction:

In the early 2000s, a subcommittee of the American Clinical Neurophysiology Society (ACNS) set out to "standardize terminology of periodic and rhythmic EEG patterns in the critically ill to aid in future research involving such patterns". The initial proposed terminology was published in 2005[1]. This was presented at many meetings on several continents, subjected to multiple rounds of testing of inter-rater reliability, underwent many revisions, and was then published as an ACNS guideline in 2013[2]. Inter-rater agreement of the 2012 version (published in early 2013) was very good, with almost perfect agreement for seizures, main terms 1 and 2, the +S modifier, sharpness, absolute amplitude, frequency, and number of phases[3]. Agreement was substantial for the +F and +R modifiers (66% and 67%), but was only moderate for triphasic morphology (58%), and fair for evolution (21%, likely at least partly due to the short EEG samples provided)[3]. The authors concluded that inter-rater agreement for most terms in the ACNS critical care EEG terminology was high, and that these terms were suitable for multicenter research on the clinical significance of these critical care EEG patterns.

With the help of infrastructure funding from the American Epilepsy Society and administrative and website support from the ACNS, a database that incorporated the ACNS terminology was developed for clinical and research purposes, tested during routine clinical care in multiple centers[4], and made available at no cost on the ACNS website (https://www.acns.org/research/critical-care-eeg-monitoring-research-consortium-ccemrc/ccemrc-public-database). This greatly enhanced the ability to complete multicenter investigations.

After establishment of the standardized terminology and free access to a database incorporating these terms, there have been many investigations into the clinical significance of rhythmic and periodic patterns (RPPs) in critically ill patients. Patterns such as lateralized rhythmic delta activity (LRDA) were found to be highly associated with acute seizures[5,6], equivalent to the association found with lateralized periodic discharges (LPDs) in one study[5]. The association of all the main patterns in the nomenclature with seizures was defined in a multicenter cohort of almost 5000 patients, with seizure rates highest for LPDs, intermediate for LRDA and generalized periodic discharges (GPDs), and lowest for generalized rhythmic delta activity (GRDA)[6]. This and other studies have shown that several of the modifiers within the nomenclature do indeed have clinically relevant meaning. For example, studies have shown that higher frequency (especially >1.5 Hz), higher prevalence, longer duration, and having a "plus" modifier are all associated with a higher chance of acute seizures[6,7]. On the other hand, whether a pattern was spontaneous or "stimulus-induced" did not seem to have a significant effect on its association with seizures[6]. In other investigations, the "triphasic morphology" modifier was investigated blindly with multiple expert reviewers, calling into question its relationship with metabolic encephalopathy, as well as its lack of a relationship with seizures[8,9]. For patients with refractory status epilepticus treated with anesthetic-induced coma, the presence of "highly-epileptiform" bursts suggested that an attempted wean off of anesthetics at that time was much more likely to lead to seizure recurrence than if the bursts were not highly epileptiform[10]. Even long-term outcome seemed to be associated with some modifiers, with a higher risk of later epilepsy found if LPDs were more prevalent, longer duration or had a "plus" modifier[7].

Changes in the 2021 version of The Terminology:

Although the prior version of the terminology was easy to use, reliable, and valuable for both research and clinical care, new terms and concepts have emerged. In this version, we incorporate recent research findings, add definitions of several new terms, and clarify a few definitions of old terms. Most of the old terms remain unchanged, but there have been some important clarifications and corrections (such as the calculation of the number of phases) and multiple additions. One new main term was added (Unilateral Independent). Electrographic seizures (ESz), electrographic *status epilepticus* (ESE), electroclinical seizures (ECSz), and

electroclinical *status epilepticus* (ECSE) have now been defined, largely based on the "Salzburg criteria"[11,12]. Brief potentially ictal rhythmic discharges (BIRDs) have been added based on recent publications[13,14]; and a consensus definition of the ictal-interictal continuum (IIC) has been proposed. We also added definitions of identical bursts, state changes, cyclic alternating pattern of encephalopathy (CAPE), and extreme delta brush (EDB). Lastly, for educational purposes and conceptual clarity, we provided extensive cartoons (diagrams) of most patterns to quickly demonstrate the core features and principles.

ACNS Standardized Critical Care EEG Terminology

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

Major changes

EEG background

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

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

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

Electrographic and Electroclinical Seizure Activity

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

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

Brief Potentially Ictal Rhythmic Discharges (BIRDs) (new term: Section E)
Ictal-Interictal Continuum (IIC) (new term: Section F)

Minor Changes

EEG background

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

Rhythmic and Periodic Patterns

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

Methods:

All the definitions are based on extensive discussions not only among the authors of this document, but among many others, both live and via email and questionnaires. There was not always complete consensus on some issues; electronic voting (with each voter blinded to the

opinion of others for the first round) was utilized for most of these issues. We considered additional changes from prior versions or from the literature such as eliminating the 10-second cutoff for defining electrographic seizures, but as no clear consensus was reached (it was close to a split decision), this was not changed.

2021 ACNS Critical Care EEG TERMINOLOGY

CONTENTS

General notes:

NOTE: This terminology is intended to be used at all ages, excluding neonates, though some terms may not be ideal for infants. For the neonatal version of the terminology, please see https://www.acns.org/UserFiles/file/The_American_Clinical_Neurophysiology_Society_s.12.pdf [16].

NOTE: This terminology is intended for use in the critically ill, although it can be applied in other settings as well. It is mostly compatible with the 2017 multinational revised glossary of terms most commonly used by clinical electroencephalographers[17].

NOTE: Although any finding on EEG can be focal, regional or hemispheric, such as an asymmetry or slowing, and this is a very important distinction in some circumstances such as epilepsy surgery, all of these are combined within the terms “lateralized” or “asymmetric” in this nomenclature. However, additional localizing information (e.g., where the pattern is maximal and which lobes are involved) can be provided and can also be applied to several modifiers and sporadic epileptiform discharges. This additional localizing information was built into the freely available Critical Care EEG Monitoring Research Consortium (CCEMRC) database that

incorporated the prior version of this nomenclature (https://www.acns.org/research/critical-care-eeg-monitoring-research-consortium-ccemrc/ccemrc-public-database)[4]. This database will be updated with this 2021 nomenclature fully incorporated.

NOTE: In this section and throughout the document, the term "ictal" is used to refer to an EEG pattern seen during an epileptic seizure, whether clinical or electrographic-only, as it is commonly used in EEG literature.

NOTE: "Hz" is used as an abbreviation for "per second" for all types of periodic or rhythmic patterns, even when referring to non-continuous waveforms.

NOTE: All voltage measurement in this document are based on peak to trough (not peak to baseline) measurements in a standard 10-20 longitudinal bipolar recording. However, for assessing voltage symmetry, an appropriate referential recording is preferred.

A. EEG BACKGROUND

1. Symmetry:

a. Symmetric.
b. Mild asymmetry (consistent asymmetry in voltage [Diagram 1a] on an appropriate referential recording of <50%, or consistent asymmetry in frequency of 0.5-1 Hz [Diag. 1b]).
c. Marked asymmetry (≥50% voltage or >1 Hz frequency asymmetry [Diag. 1c]).

NOTE: When any of the following features (A.2 – A.10) are asymmetric, they should be described separately for each hemisphere.

2. Predominant background frequency when most awake or after stimulation:

a. Alpha or faster.
b. Theta.
c. Delta.

NOTE: If 2 or 3 frequency bands are equally prominent, report each one.

3. Posterior dominant ("alpha") rhythm: (Must be demonstrated to attenuate with eye opening; wait >1 s after eye closure to determine frequency to avoid "alpha squeak")

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

4. Continuity:

a. ***Continuous*** (Diag. 2).
b. ***Nearly Continuous***: continuous, but with occasional (**1-9%** of the record) periods of attenuation or suppression lasting at ≥1 s. 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 suppressions/attenuations 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[16].
c. ***Discontinuous***: A pattern of attenuation/suppression alternating with higher voltage activity, with **10-49%** of the record consisting of attenuation or suppression.
d. ***Burst-attenuation/Burst-suppression***: A pattern of attenuation/suppression alternating with higher voltage activity, with **50-99%** of the record consisting of attenuation (EEG 1) or suppression (EEG 2).

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

NOTE: **Bursts** must average ≥0.5 s and have at least 4 phases (i.e., at least 3 baseline crossings; see section A 3.d for definition of number of phases); if shorter or fewer phases, they should be considered **discharges** (as defined under Rhythmic and Periodic Patterns, main term 2 below) (Diag. 3). Bursts within burst-suppression or burst-attenuation can last up to 30 s.

NOTE: For nearly continuous, discontinuous and burst attenuation/burst suppression patterns, specify:

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

NOTE: For burst attenuation/burst suppression patterns only, also specify:

i. Typical duration of bursts and interburst intervals.

ii. Sharpest component of a typical burst using the sharpness categories defined above under modifier 5 below.

iii. Presence or absence of **Highly Epileptiform Bursts**: 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)* (EEG 3) (Diag 5a); record typical frequency and location (G, L, BI, UI or Mf, as defined in Rhythmic and Periodic Pattern section below). Also present if a rhythmic, potentially ictal-appearing pattern occurs within the majority (>50%) of bursts; record maximum frequency and location if this occurs (Diag. 5b).

iv. Presence or absence of **Identical Bursts**: Present if the first 0.5 s or longer of each burst (Diag. 6a), or of each stereotyped cluster of 2 or more bursts (Diag. 6b), appears visually similar in all channels in the vast majority (>90%) of bursts (EEG 4).

e. ***Suppression/attenuation***: entirety or near-entirety (>99%) of the record consists of either suppression (all <10 μV, as defined above) or low voltage activity (all <20 μV but not qualifying as suppression). Specify whether attenuated or suppressed.

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[18,19]. Appearance of muscle activity or eye blink artifacts does not qualify as reactive. Categorize as:

a. Reactive.
b. Unreactive.

    NOTE: "Unreactive" should only be reported when it was clearly and adequately tested with good quality EEG; otherwise use "unclear" or "unknown". If unreactive and the patient is on sedatives or paralytics, we suggest including this important caveat in the impression.

c. SIRPID**s**-only: when the only reactivity is stimulus-induced rhythmic, periodic or ictal-appearing discharges (SIRPIDs)[20]. 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 either 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).

6. State changes: Present if there are at least 2 sustained types of background EEG related to level of alertness or stimulation; each must persist at least 60 seconds to qualify as a "state" (Diag. 7). 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:

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:
        i. Present and normal.

ii. Present but abnormal. Specify abnormality (asymmetry, location, frequency, poorly formed).

iii. Absent.

c. Present but without stage N2 sleep transients.

d. Absent

NOTE: Presence of state changes virtually always indicates presence of reactivity; however, presence of reactivity does not necessarily indicate presence of state changes as the reactivity may last <60 seconds.

*7. **Cyclic Alternating Pattern of Encephalopathy (CAPE):*** This refers to changes in background patterns, each lasting at least 10 s, and spontaneously alternating between the two patterns in a regular manner for at least 6 cycles (but often lasts minutes to hours) (Diag. 8). A cycle refers to the period of time before the sequence repeats (i.e., includes both states once). State 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 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.

8. Voltage:

a. Normal.

b. Low (most or all activity <20 μV in longitudinal bipolar with standard 10-20 electrodes [measured from peak to trough], but not qualifying as suppressed).

c. Suppressed (all activity <10 μV).

NOTE: If the background is nearly continuous or discontinuous, EEG background voltage refers to the higher voltage portion.

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 (Diag. 9). 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 to the rest of the brain, especially compared to the homologous region on the opposite side of the head.

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

B. SPORADIC EPILEPTIFORM DISCHARGES: This refers to non-rhythmic and non-periodic **spikes, polyspikes and sharp waves**, as previously defined by Kane N et al in the 2017 revised glossary of terms most commonly used by clinical electroencephalographers[17]. 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 (Diag. 10). A **sharp wave** is defined identically, but with a duration of 70-200 ms. A spike or sharp wave is usually di- 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 s (if ≥0.5 s, they would either qualify as BIRDs [see section E below] or, if alternating with suppression or attenuation, a highly epileptiform burst within burst suppression/attenuation [see section A 4e iv] [Diag 11]). The prevalence of epileptiform discharges (combining spikes, polyspikes and sharp waves) should be categorized as follows:

a. ***Abundant*:** ≥1 per 10 s, but not periodic.
   NOTE 17: 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/min but less than 1 per 10 s
c. ***Occasional*:** ≥1/h but less than 1/min
d. ***Rare*:** <1/h

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.

1. *Main Term 1: G, L, BI, UI, or Mf:*

a. **Generalized** (**G**): any bilaterally synchronous and symmetric pattern (EEG 5 and 6), even if it has a restricted field (e.g. bifrontal).

   NOTE: Some suggested that a more accurate term would be "bilateral synchronous" but this was rejected for several reasons: 1. many lateralized patterns are also bilateral synchronous (see definition of "lateralized" immediately below); 2. this is more difficult to abbreviate (2 letters); and 3, the word "generalized" has been used widely to refer to patterns, discharges, seizures and epilepsies that are not truly generalized. "Generalized" in this sense has also been used in many studies in the literature related to critical care EEG, and in the prior version of this nomenclature. Thus, it was not changed. See subcategories below.

   NOTE: A pattern that is bilateral with shifting predominance (i.e., sometimes higher amplitude on left, sometimes right) but is not consistently lateralized to one side would be considered "Generalized".

b. **Lateralized** (**L)**: unilateral, or bilaterally synchronous but clearly and consistently more prominent in one hemisphere (EEG 7); includes focal, regional and hemispheric patterns (Diag. 12).

c. **Bilateral Independent** (**BI**): two independent (and therefore asynchronous) lateralized patterns with one in each hemisphere occurring simultaneously (EEG 8) (Diag. 13), i.e. two independent patterns occurring at the same time (overlapping in time) rather than sequentially (one starting after the other stops).

NOTE: If there are two independent lateralized patterns at different times (e.g., on the left for an hour, and then later in the record on the right for an hour), these would be LPDs from the left and LPDs from the right, but not BIPDs since they are not simultaneous.

NOTE: The "I" in "BI" is capitalized as it stands for its own word, "Independent".

d. **Unilateral Independent (UI)**: two independent (and therefore asynchronous) periodic (EEG 9) or rhythmic patterns (EEG 10) in the same hemisphere occurring simultaneously (Diag. 14), i.e. two independent patterns occurring at the same time (overlapping in time) rather than sequentially (one starting after the other stops).

NOTE: If there are two independent lateralized patterns at different times (e.g., in the left frontal region for an hour, and then later in the record the left temporal region for an hour), these would be two populations of LPDs on the left, but not UIPDs since they are not simultaneous.

NOTE: Focal midline patterns may be deemed in the same hemisphere (unilateral) as an independent pattern in either the left or right hemisphere. E.g. PDs of 1 Hz in the left hemisphere occurring simultaneously with independent focal midline PDs at 0.5 Hz, would still classify as UIPDs.

e. **Multifocal** (**Mf**): at least three independent lateralized patterns, with at least one in each hemisphere, all occurring simultaneously (EEG 11) (Diag. 15).
NOTE: Additional localizing information:

- For Generalized patterns**:**
  i. *"Frontally predominant":* Voltage in anterior derivations is at least 50% greater than that in posterior derivations on a common average, transverse bipolar, ipsilateral ear or non-cephalic referential recording (EEG 12).
  ii. *"Occipitally predominant":* Voltage in posterior derivations is at least 50% greater than in anterior derivations on an ipsilateral ear, common average, or non-cephalic referential recording.
  iii. *"Midline predominant":* Voltage in midline derivations is at least 50% greater than in parasagittal derivations on a common average or non-cephalic referential recording.
  iv. *"Generalized, not otherwise specified":* Similar voltage in all regions and not qualifying as any one of the above 3 categories.
- For Lateralized patterns:
  i. Specify unilateral vs. bilateral asymmetric:
    a. *"Unilateral":* seen in only one hemisphere. Side should be specified.
    b. *"Bilateral asymmetric":* seen bilaterally but clearly and consistently more prominent in one hemisphere. Referred to as "Lateralized, bilateral asymmetric". For example, PDs seen bilaterally and synchronously, but consistently greater on the left would be referred to as "Left LPDs, bilateral asymmetric" (EEG 13).
  ii. Specify the most involved lobe(s) (F, P, T, O, or hemispheric if more specific localization is not possible).

  NOTE: For unilateral independent patterns, the above should be specified for each pattern separately.
- For Bilateral Independent and Multifocal patterns:
  i. Specify symmetric vs. asymmetric
    - "Symmetric": Approximately equal in both hemispheres or with no consistent asymmetry. Patterns that are bilateral,

asynchronous and symmetric would be called "Bilateral Independent, symmetric", or "Multifocal, symmetric".

- "Asymmetric": Clearly and consistently more prominent on one side. Patterns that are bilateral and asynchronous but clearly more prominent on one side would be called "Bilateral Independent, asymmetric", or "Multifocal, asymmetric", followed by "L>R" or "R>L".

ii. Specify lobes most involved in both hemispheres (F, P, T, O, or "hemispheric" if more specific localization is not possible).

2. ***Main Term 2: PDs, RDA or SW:***

a. **Periodic Discharges (PDs):**

- **Periodic:** Repetition of a waveform with relatively uniform morphology and duration with a clearly discernable inter-discharge interval between consecutive waveforms and recurrence of the waveform at nearly regular intervals (Diag. 16). "Nearly regular intervals" is defined as having a cycle length (i.e., period) varying by <50% from one cycle to the next in the majority (>50%) of cycle pairs.
- **Discharges**: Waveforms lasting <0.5 s, regardless of number of phases, or waveforms ≥0.5 s with no more than 3 phases. This is as opposed to **Bursts**, defined as waveforms lasting ≥0.5 s *and* having at least 4 phases. Discharges and bursts must clearly stand out from the background activity.

b. **Rhythmic Delta Activity (RDA):**

- **Rhythmic:** Repetition of a waveform with relatively uniform morphology and duration, and without an interval between consecutive waveforms (Diag. 17). 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. An example of a rhythmic pattern would be a sinusoidal waveform, although there are other examples; a pattern can be sharp at the top and/or the bottom of the waveform and still be rhythmic (but would no

longer be sinusoidal). Irregular or polymorphic delta should not be reported as RDA.

- **RDA**: Rhythmic activity 0.5 to ≤4.0 Hz.

c. **Spike-and-wave or Sharp-and-wave (SW):** Spike, polyspike or sharp wave consistently followed by a slow wave in a regularly repeating and alternating pattern (spike-wave-spike-wave-spike-wave), with a consistent relationship between the spike (or polyspike or sharp wave) component and the slow wave for at least 6 cycles; and with no interval between one spike-wave complex and the next (EEG 14) (Diag. 18) (if there is an interval, this would qualify as PDs, where each discharge is a spike-and-wave).

NOTE: 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).

NOTE: If a pattern qualifies as both PDs and RDA simultaneously, it should be coded as PDs+R rather than RDA+S (see "plus" modifier below).

Most of the following sections can be applied to any EEG phenomenon.

3. *Main Modifiers*:

a. **Prevalence:** Specify percent of record or epoch that includes the pattern. This should be based on the proportion of an epoch that includes or is within the pattern. The time between widely spaced PDs counts as part of the pattern duration. For example, 2-Hz PDs present for 1 min every 10 mins is 10% prevalence, and 0.25-Hz PDs present for 1 min every 10 mins is also 10% prevalence. When categorizing or using qualitative terms, follow the cutoffs listed below for each term. Suggested clinical terms are given as well. If 2 or more patterns are present, record the presence and prevalence of each one (e.g. ~20% GRDA, 20% GPDs, and 30% BIPDs).

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

v. Rare: <1% of record/epoch.

b. **Duration**: Specify typical duration of pattern if not continuous. When categorizing or using qualitative terms, follow the cutoffs listed below for each term. Also record the longest continuous duration.

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

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).

Record typical, minimum and maximum frequency using the following categories: <0.5, 0.5, 1, 1.5, 2, 2.5; and if very brief duration: 3, 3.5 and 4 Hz.

NOTE: 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.

NOTE: No RPP in this terminology can have a typical frequency of >4 Hz; if an RPP is >4 Hz and ≥0.5 s, it would always meet criteria for either BIRDs (if <10 s) or 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.

d. **Number of phases** = 1 + number of baseline crossings of the typical discharge as assessed in longitudinal bipolar and in the channel in which it is most readily appreciated. A phase is that part of the signal that is on one side of (above or below) the imaginary baseline (Diag. 19). The start and endpoints do not count as baseline crossings. Applies to PDs and the entire spike-and-wave or sharp-and-wave complex of SW (including the slow wave). This does not apply to RDA. Categorize as: 1, 2, 3 or >3.

e. **Sharpness**: Specify for both the dominant phase (phase with greatest voltage) and the sharpest phase if different. For both phases, describe the *typical* discharge. Applies only to PDs and the spike/sharp component of SW, not RDA. Categorize as:

i. Spiky: duration of that component, measured at the EEG baseline, is <70 ms
ii. Sharp: duration of that component is 70-200 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.

f. **Voltage** (amplitude) [of PDs, SW or RDA; not background EEG, which is in section A8 above]:

i. Absolute: Typical voltage measured in standard longitudinal bipolar 10-20 recording in the channel in which the pattern is most readily appreciated. For PDs, this refers to the highest voltage component. For SW, this refers to the spike/sharp wave. Voltage should be measured from peak to trough (not peak to baseline). Specify for RDA as well.

   Categorize as:

   a. Very low: <20 μV
   b. Low: 20-49 μV
   c. Medium: 50-149 μV
   d. High: ≥150 μV

ii. Relative: For PDs *only* (PDs require 2 voltages, absolute and relative). Typical ratio of voltage of the highest voltage component of the discharge to the voltage of the typical background between discharges, measured in the same channel and montage as absolute voltage. Categorize as: ≤2 or >2.

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

a. Stimulus-Induced (SI-): reproducibly brought about or exacerbated by an alerting stimulus, with or without clinical alerting, when a patient is in their less-stimulated state; an SI- pattern may also be seen spontaneously at other times (due to spontaneous alerting or arousal) (EEG 15). Even if most instances of the pattern are spontaneous, it can still qualify as "SI-" if it can be reproducibly brought about by an alerting stimulus.
b. Stimulus-Terminated (ST-): reproducibly terminated or attenuated by an alerting stimulus, with or without clinical alerting, when a patient is in their less-stimulated state; an ST- pattern may also self-terminate at other times. Even if most instances of the pattern resolve or attenuate spontaneously, it can still qualify as "ST-" if it can be reproducibly terminated or attenuated by an alerting stimulus.
c. Spontaneous: never clearly induced, exacerbated, improved or terminated by stimulation.
d. Unknown: includes unclear or untested.

NOTE: Specify type of stimulus (auditory; light tactile; patient care and other non-noxious stimulations; or noxious: suction, sternal rub, nailbed pressure, nostril tickle, trapezius squeeze, or other).

NOTE: The term **"**SIRPIDs**"** refers to stimulus-induced (or stimulus-exacerbated) rhythmic, periodic or ictal-appearing discharges, and is a term that includes all SI- patterns together (SI-RDA, SI-PDs, SI-SW, SI-IIC, SI-BIRDs or SI-seizures). In general, one should refer to the specific "SI–" pattern rather than using the general term "SIRPIDs", especially for a given patient.

h. **Evolution:** Evolving, Fluctuating, or Static: terms refer to changes in frequency, location or morphology.
    i. **<u>Evolving:</u>** At least 2 unequivocal, sequential changes in frequency, morphology or location defined as follows: Evolution in *frequency* is defined as at least 2 consecutive changes in the same direction by at least 0.5 Hz, e.g. from 2 to 2.5 to 3 Hz, or from 3 to 2 to 1.5 Hz (Diag. 20); Evolution in *morphology* is defined as at least 2 consecutive changes to a novel

morphology (Diag. 21); Evolution in *location* is defined as sequentially spreading into or sequentially out of at least two different standard 10-20 electrode locations (Diag. 22a and b). The two consecutive changes must be in the same category (frequency, morphology or location) to qualify.

- To qualify as evolution in frequency, a single frequency must persist for at least 3 cycles (e.g. 1 Hz for 3 s, or 3 Hz for 1 s). Thus, the following pattern would qualify as evolving: 3 Hz for ≥ 1 s, then 2 Hz for ≥ 1.5 s (the first change), then 1.5 Hz for ≥ 2 s (the 2nd change) (EEG 16).
- To qualify as evolution in morphology, each different morphology or each morphology plus its transitional forms must last at least 3 cycles. Thus, the following examples would both qualify: Spiky 4-phase PDs for 3 cycles then sharp 2-3 phase PDs for 3 cycles then blunt diphasic PDs for 3 cycles.
- To qualify as evolution in location, the pattern must spread into or out of two standard 10-20 electrode locations and the involvement of each additional electrode must be present for at least 3 cycles e.g. 1-Hz LPDs only at T7, spreading to include F7 for 3 s then F7, T7 and P7 for 3 s.
- The criteria for evolution must be reached without the evolving feature (frequency, morphology or location) remaining unchanged for 5 or more continuous minutes. Thus, the following pattern would *not* qualify as evolving: 3 Hz for 1 min, then 2 Hz for 7 mins, then 1.5 Hz for 2 mins.
- Evolution in voltage (amplitude) alone does not qualify as evolving and does not qualify as a different morphology.

NOTE: 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 definite BIRDs (see Section E). Any RPP with evolution lasting ≥10 s meets criterion B of an electrographic seizure and should be coded as such.

ii. **Fluctuating**: ≥3 changes, not more than one minute apart, in frequency (by at least 0.5 Hz) (Diag. 23), morphology (Diag. 24), or location (by at least 1 standard inter-electrode distance) (Diag. 25a and b), but *not qualifying as evolving* (EEG 17). This includes patterns fluctuating from 1 to 1.5 to 1 to 1.5

Hz; alternating between 2 morphologies repeatedly; or spreading in and out of a single additional electrode location repeatedly. To qualify as present, a single frequency, morphology or location must persist at least 3 cycles (e.g. 1 Hz for 3 s, or 3 Hz for 1 s).

- The following would *not* qualify as fluctuating: 2 Hz for 30 s, then 1.5 Hz for 30 s, then 2 Hz for 3 mins, then 1.5 Hz for 30 s, then 2 Hz for 5 mins. The changes are too far apart (>1 minute).
- The following *would* qualify as fluctuating: 2 Hz for 10 s, then 2.5 Hz for 30 s, then 2 Hz for 5 s, then 2.5 Hz for 5 s.

iii. **Static:** Not qualifying as evolving or fluctuating.

NOTE: Change in voltage (amplitude) alone would not qualify as evolving or fluctuating.

NOTE: If evolving or fluctuating in frequency, a minimum and maximum frequency should be specified under the "frequency" modifier above. For non-generalized patterns, specify degree of spread (none, unilateral, or bilateral).

i. **Plus (+)** = additional feature which renders the pattern more ictal-appearing (i.e., more closely resembling an EEG pattern seen during seizures) than the usual term without the plus. This modifier applies only to PDs and RDA, not SW.

i. **Subtyping of "+":** all cases with "+" should be categorized as follows into +F, +R, +FS, or +FR:

a. "+F": with superimposed (some prefer the synonyms of admixed or associated) *fast* activity, defined as theta or faster, whether rhythmic or not. "+F" can be applied to PDs (EEG 18 and 19) (Diag. 26a and b) or RDA (Diag. 27a and b).

b. "+R": with superimposed *rhythmic* or quasi-rhythmic delta activity; can be applied to PDs only (Diag. 28).

c. "+S": with associated *sharp waves* or *spikes, or sharply contoured*; can be applied to RDA only (EEG 20). The sharp contour, sharp waves, or spikes need to occur at least once every 10 s, but not as part of an SW pattern (Diag. 29).

NOTE: It is possible to have "+FR" for PDs, or "+FS" for RDA.

NOTE: The wave within periodic spike-wave discharges (spike-wave-interval-spike-wave-interval-spike-wave-interval…) does not qualify a pattern as PD+R as the wave is simply part of the spike-wave complex (which is the periodic discharge itself). However, RDA occurring at the same time as PDs but without time-locked association with the PDs would qualify as PD+R.

NOTE: If a pattern qualifies as both PDs and RDA simultaneously with approximately equal prominence, it should be coded as PDs+R rather than RDA+S.

NOTE: Re: Bilateral "+" vs. unilateral: If a pattern is bilateral and qualifies as plus on one side, but not on the other, the overall main term should include the plus (even though one side does not warrant a plus). For example, bilateral independent periodic discharges with fast activity in one hemisphere only (PDs on one side, and independent PDs+F on the other) would qualify for BIPDs+F (EEG 21) (Diag. 30). Similarly, generalized rhythmic delta activity with associated spikes in one hemisphere only (RDA on one side and synchronous RDA+S on the other) would qualify for GRDA+S.

NOTE: Re: +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. In other words, code as +F if the fast activity is part of the RDA or PD pattern and not simply part of the background activity (Diag. 26b and Diag. 27b). When referring to PD+F, the fast activity can either be continuous (as long as the fast activity was not present when the PDs were not present) or can occur with each discharge in a regular fashion (regardless of background).

NOTE: **Extreme Delta Brush** (EDB): A specific subtype of +F (Table 1):

- ***Definite EDB:*** Consists of either abundant or continuous:
    A. RDA+F, in which the fast activity has a stereotyped relationship to the delta wave (e.g., always maximal on the upstroke, crest, or downstroke of the wave) (Diag. 31a and b); OR

B. PD+F, in which each PD contains a single blunt delta wave with superimposed fast activity, and in which the fast activity has a stereotyped relationship to the delta wave (i.e., periodic delta brushes) (EEG 22) (Diag. 31 a and c)

- ***Possible EDB***:

A. Satisfying criterion A) or B) above EXCEPT either:

i. only occasional or frequent (rather than abundant or continuous) OR

ii. the superimposed fast activity lacks a stereotyped relationship to the delta wave; continuous, invariant fast activity during RDA would fall into this category (Diag. 31b and c).

NOTE: EDB is a subtype of +F, therefore it must qualify as +F for it to also be considered as EDB. RDA with fast activity in the background and not associated with the pattern does not qualify as +F and therefore cannot qualify as EDB.

NOTE: The only periodic pattern that can qualify for EDB is periodic delta brushes. Any other periodic pattern with superimposed fast activity remains PD+F only. By similar notion PD+F with the fast in between periodic delta waves would also not qualify as EDB. This is because the fast activity is not associated with the wave (i.e., it is not periodic delta brushes).

NOTE: EDB can be in any location as any other form of RDA or PDs (i.e., generalized [Diag. 32a], lateralized [Diag. 32b], bilateral independent [Diag. 32c], unilateral independent or multifocal).

NOTE: There are multiple other features that may make a pattern more "ictal-appearing", such as increased sharpness, higher voltage (amplitude) and fluctuation, but these are already accounted for in the other modifiers.

4. *Minor Modifiers*:

a. "**Sudden onset**" versus "**gradual onset**" ("sudden onset" preferred over "paroxysmal"). Sudden onset is defined as progressing from absent to well developed within 3 seconds.

b. **"Triphasic morphology"**: Three phases, negative-positive-negative, with each phase longer than the previous, and the second (positive) phase of highest voltage (EEG 23); or the same but with the first (negative) phase of sufficiently low voltage to be obscured by background activity, leaving a biphasic waveform, positive-negative in polarity. Note that a biphasic waveform may be categorized as "triphasic" by this definition. The phrase "with triphasic morphology" should be added to the appropriate term when this modifier applies. This modifier applies to PDs and SW, but not RDA; it can also be used to describe sporadic discharges.

c. *"***Anterior-posterior lag***" or "***posterior-anterior lag***"*: A lag is present if there is a consistent measurable delay of >100 ms from the most anterior to the most posterior derivation in which it is seen, or vice versa (EEG 23) (Diag. 33); specify typical delay in milliseconds from anterior to posterior (negative = posterior to anterior lag) in both a longitudinal bipolar and a referential montage, preferably with an ipsilateral ear reference. This applies to PDs or the spike/sharp wave component of SW.

d. Polarity: Specify for the dominant phase (phase with the greatest voltage) only. Should be determined in a referential montage. Describe the *typical* discharge. Applies only to PDs and the spike/sharp component of SW, not RDA. Categorize as:
   i. Positive
   ii. Negative
   iii. Dipole, tangential
   iv. Unclear

D. ELECTROGRAPHIC AND ELECTROCLINICAL SEIZURES

1. *Electrographic seizure* (ESz) (largely based on the Salzburg criteria)[11,12] is defined as either:

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

b. Any pattern with definite evolution as defined above and lasting ≥10 s (EEG 24a, b and c) (Diag. 34).

NOTE: Whether to maintain or eliminate the "10 second rule" (clearly an arbitrary cutoff) was a matter of significant debate among the authors and the greater EEG community surveyed during creation of this version of the nomenclature. However, as there was no consensus or convincing new literature to change this, we maintained the status quo in this matter. Hopefully, future investigations will help determine the proper minimum duration for defining a seizure, if there is one.

2. Electrographic *status epilepticus* (ESE) is defined as an electrographic seizure 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[15]. The 20% cutoff, lowered from the prior 50%, is based on expert consensus and on one study in critically ill children in whom the risk of neurological decline was significantly greater when the maximum hourly seizure burden was >20%[21]. A similar cutoff was identified in neonates with hypoxic-ischemic encephalopathy[22].

NOTE: *"Possible electrographic seizure"* and *"possible electrographic SE"*: These terms are synonyms for patterns on the ictal-interictal continuum (IIC); see section F below. For the sake of standardized reporting, the pattern should be described using the RPP modifiers (section C) and identified as meeting criteria for the IIC. For this reason, *"possible ESz"* and *"possible ESE"* have not been defined; but can be used synonymously with IIC in EEG impressions or when communicating with referring clinicians.

3. *Electroclinical seizure* (ECSz) is defined as:

Any EEG pattern with either:

a. Definite clinical correlate time-locked to the pattern (of any duration) (EEG 25) (Diag. 35), OR
b. EEG ***AND*** clinical improvement with a parenteral (typically IV) anti-seizure medication (EEG 26a and b) (Diag. 35).

NOTE: The EEG pattern during an "electroclinical seizure" does not necessarily need to qualify as an "electrographic seizure". For example, if static 1-Hz PDs have a clinical correlate, this would not qualify as an electrographic seizure, but would qualify as an electroclinical seizure. Many seizures would however qualify for both *"electrographic"* and *"electroclinical"* seizures, and these should be reported under both terms.

NOTE: An *electroclinical* seizure can be of any duration, including <10 s, if (and only if) there is a definite clinical correlate. By definition *electrographic* seizures can only be ≥10 s duration. An evolving electrographic pattern lasting <10 s qualifies as either an evolving RPP (e.g., "evolving RDA"), or "evolving BIRDs" (see section E).

NOTE: Any seizure or status epilepticus without prominent motor activity can also be referred to as "nonconvulsive." The term "nonconvulsive" is preferred over "subclinical" as it is usually unclear if the electrographic activity is contributing to the patient's impaired mental status; if it were contributing, it would still be nonconvulsive, but would not be subclinical.

NOTE: The term "nonconvulsive" can be applied to both electrographic and electroclinical seizures. All ESz and ESE alone (without clear clinical correlate) would be nonconvulsive. However, any ECSz or electroclinical status epilepticus (ECSE) without prominent motor activity could also be termed nonconvulsive.

4. Electroclinical *status epilepticus* (ECSE) is defined as an electroclinical seizure for *≥10 continuous minutes or for a total duration of ≥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."[15] In any other clinical situation, the minimum duration to qualify as SE is ≥10 mins.

4b. ***Possible electroclinical status epilepticus***: *Possible* ECSE is an RPP that qualifies for the IIC that is present for ≥10 continuous minutes or for a total duration of ≥20% of any 60-minute period of recording, which shows EEG improvement with a parenteral anti-seizure medication

BUT without clinical improvement. This remains largely in line with *"possible NCSE"* as defined by the Salzburg criteria.

NOTE: Possible ECSE cannot include patterns that already qualify as ESz/ESE.

NOTE: If parenteral anti-seizure medication leads to resolution of ESz/ESE *AND* clinical improvement, then these should be reported as ESz/ESE *AND* ECSz/ECSE (similar to how an isolated seizure can be both an ESz and an ECSz).

NOTE: For patients with prior known developmental and epileptic encephalopathy, in order to qualify as electroclinical status epilepticus, the EEG pattern needs to represent either:

a. an increase in prominence or frequency of epileptiform discharges compared to baseline, with an observable decline in clinical state; OR
b. EEG and clinical improvement with a parenteral (typically IV) anti-seizure medication (Diag. 36).

NOTE: As a principle, all EEG data have to be put into clinical (history, clinical presentation, physical examination) and paraclinical (laboratory, toxicology, cerebral imaging) context in order to help establish or reject the diagnosis of status epilepticus.

NOTE: If any of these phenomena (ESz, ECSz, ESE, ECSE) are stimulus-induced (reproducibly brought about or exacerbated by an alerting stimulus), then they warrant an "SI-" prefix, as described in section C 3g above.

E. <u>BRIEF POTENTIALLY ICTAL RHYTHMIC DISCHARGES (BIRDs):</u> (Largely based on Yoo JY et al, JCN 2017)[14]

BIRDs are defined as focal (including L, BI, UI or Mf) or generalized rhythmic activity >4 Hz (at least 6 waves at a regular rate) lasting ≥0.5 to <10 s, not consistent with a known normal pattern or benign variant, not part of burst-suppression or burst-attenuation, without definite clinical correlate, and that has at least one of the following features:

a. Evolution ("evolving BIRDs", a form of definite BIRDs) (Diag. 37a)

b. Similar morphology and location as interictal epileptiform discharges or seizures in the same patient (definite BIRDs) (EEG 27) (Diag. 37b and c)

c. Sharply contoured but without (a) or (b) (possible BIRDs) (Diag. 37d)

NOTE: Paroxysmal fast activity lasting ≥0.5 to <10 s qualifies as BIRDs, whether generalized (also known as generalized paroxysmal fast activity, or GPFA) or focal.

NOTE: Although they are termed "brief", technically all BIRDs are "very brief" as they are <10 s.

F. THE ICTAL-INTERICTAL CONTINUUM

The Ictal-Interictal Continuum (IIC). This term is synonymous with "possible electrographic seizure" or "possible electrographic SE". The IIC is a purely electrographic term that is not a diagnosis; it requires careful interpretation in the full clinical context. A pattern on the IIC is a pattern that does not qualify as an ESz or ESE, but there is a reasonable chance that it may be contributing to impaired alertness, causing other clinical symptoms, and/or contributing to neuronal injury. Thus, it is *potentially ictal in at least some sense*, and often warrants a diagnostic treatment trial, typically with a parenteral anti-seizure medication. Although this is a concept under development and with no broad consensus, the following patterns can be considered to be on the IIC:

a. Any PD or SW pattern that averages >1.0 Hz and ≤2.5 Hz over 10 s (>10 and ≤ 25 discharges in 10 s) (EEG 28) (Diag 38a); or

b. Any PD or SW pattern that averages ≥0.5 Hz and ≤1.0 Hz over 10 s (≥5 and ≤10 discharges in 10 s), and has a plus modifier or fluctuation (EEG 29a,b and c, EEG 30) (Diag. 38b and c); or

c. Any lateralized RDA averaging >1 Hz for at least 10 s (at least 10 waves in 10 s) with a plus modifier or fluctuation (Diag. 38d and e). This includes any LRDA, BIRDA, UIRDA, and MfRDA, but not GRDA.

AND

d. Does not qualify as an ESz or ESE (Section D above).

NOTE: If treatment of a pattern on the IIC with a parenteral anti-seizure medication leads to improvement in the EEG ***AND*** definite clinical improvement, this would meet criterion B of an ECSz or ECSE. If treatment of an IIC pattern with a parenteral anti-seizure medication leads to improvement in the EEG ***BUT NOT*** clinical improvement, this would be *possible* ECSE.

NOTE: If the IIC pattern is stimulus-induced (reproducibly brought about or exacerbated by an alerting stimulus), then it warrants an "SI-" prefix, as described in section C 3g above.

G. <u>MINIMUM REPORTING REQUIREMENTS IN CLINICAL CARE</u>: The recommendations from the ACNS Consensus Statement on Continuous EEG in Critically Ill Adult and Children, Part II (Herman ST et al, JCN 2015)[23] are repeated here for convenience:

1. First 30-60 minutes (equivalent to a "standard" or "routine" EEG). This should be reviewed as soon as possible and reported to the clinical team.
2. Each 24-hour period.

   A written report should be completed at least once per day. If significant changes occur in the record during this time period, then additional epochs should be reported separately as needed, either verbally or in writing.

NOTE: We recommend communicating updates to the clinical team at least twice per day except in unusually stable circumstances.

H. <u>OTHER TERMS</u>:

1. <u>Daily Pattern Burden</u> is defined as the total duration of a pattern per 24 hours. For example, if GPDs were present for 33% of the record for 12 hours, then 10% of the record for 12 hours, the Daily GPD Burden would be 4 hours + 1.2 hours = 5.2 hours.
2. <u>Daily Seizure Burden</u> can be calculated similarly: e.g., six 30-second seizures in one day would have a Daily Seizure Burden of 3 minutes.

   NOTE: <u>Hourly pattern burden</u> and <u>hourly seizure burden</u> can be calculated and reported in a similar manner as the daily burdens, as can maximal <u>hourly burden</u> of each.

3. Daily Pattern Index is defined as Daily Burden X Mean Frequency (Hz). In the above example, if GPDs were at 1.5 Hz, the Daily GPD Index would be 5.2 h x 1.5 Hz = 7.8 Hz-hours. Similarly, an hourly pattern index can be described. For example, 1.5-Hz LPDs with prevalence of 20% for one hour would have an hourly pattern index of 12 mins x 1.5 Hz = 18 Hz-mins.

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ABBREVIATION LIST:

ACNS = American Clinical Neurophysiology Society
BI = Bilateral Independent
BIRDs = Brief Potentially Ictal Rhythmic Discharges
BTC = Bilateral Tonic-Clonic
CAPE = Cyclic Alternating Pattern of Encephalopathy
CCEMRC = Critical Care EEG Monitoring Research Consortium
ECSz = Electroclinical seizure
ECSE = Electroclinical status epilepticus
EDs = Epileptiform Discharges
EDB = Extreme Delta Brush
EEG = Electroencephalography
ESE = Electrographic Status Epilepticus
ESz = Electrographic Seizure
G = Generalized
GPFA = generalized paroxysmal fast activity
Hz = Hertz (i.e., per second)
IIC = Ictal-Interictal Continuum
L = Lateralized
Mf = Multifocal
PDs = Periodic Discharges
RDA = Rhythmic Delta Activity
RPP = Rhythmic or Periodic Pattern (i.e., PDs, RDA or SW)
SE = Status epilepticus
SI = Stimulus-Induced.
SIRPIDs = Stimulus-Induced Rhythmic, Periodic or Ictal-Appearing Discharges
ST = Stimulus-Terminated
SW = Spike-and-wave or sharp-and-wave
UI = Unilateral Independent
+ = Plus = Additional feature which renders the pattern more ictal-appearing than the usual term without the plus
    +F = Superimposed fast activity
    +R = Superimposed rhythmic activity
    +S = Superimposed sharp waves or spikes, or sharply contoured

DIAGRAM LIST:

32c. Bilateral Independent Extreme Delta Brush
33. Anterior-posterior (AP) lag
34. Electrographic seizure (ESz)
35. Electroclinical seizure (ECSz)
36. Electroclinical seizure (ECSz) – known prior epileptic encephalopathy
37a. Brief Potentially Ictal Rhythmic Discharges (BIRDs) (definite)
37b. Brief Potentially Ictal Rhythmic Discharges (BIRDs) (definite)
37c. Brief Potentially Ictal Rhythmic Discharges (BIRDs) (definite)
37d. Brief Potentially Ictal Rhythmic Discharges (BIRDs) (possible)
38a. The Ictal-Interictal Continuum (IIC)
38b. The Ictal-Interictal Continuum (IIC)
38c. The Ictal-Interictal Continuum (IIC)
38d. The Ictal-Interictal Continuum (IIC)
38e. The Ictal-Interictal Continuum (IIC)

EEG LIST:

EEG 1 Burst-attenuation pattern: Bursts (≥0.5 s AND >3 phases) of generalized activity, in between bursts there is lower amplitude background activity (<50% of the background/bursts, but ≥10 μV i.e. not suppression).

EEG 2 Burst-suppression pattern: Bursts (≥0.5 s AND >3 phases) of generalized activity on a suppressed (<10 μV) background.

EEG 3 Identical Highly-Epileptiform Bursts: The pattern is burst suppression. The first 0.5 s of each burst appears visually similar in all channels, qualifying as identical. Each burst also contains 2 or more epileptiform discharges occurring at an average of 1 Hz or faster within a single burst, qualifying as highly epileptiform.

EEG 4 Identical Non-Highly-Epileptiform Bursts: Burst suppression pattern, with each burst approximately 1 s (≥0.5 s) and containing 4 – 6 phases each (>3 phases). The first 0.5 seconds of each burst is visually similar in all channels, qualifying as identical bursts. Although there is an epileptiform discharge in each burst, there are not consistently 2 or more in each burst and not occurring at greater than 1-Hz frequency; therefore, this is not highly epileptiform.

EEG 5 Generalized Periodic Discharges (GPDs): 1 Hz sharp GPDs.

EEG 6 Generalized Rhythmic Delta Activity (GRDA):1.5 Hz frontally predominant GRDA. If the lower amplitude faster (alpha range) frequencies are not present in the background when the GRDA is not present, then this would qualify as GRDA+F.

EEG 7 Lateralized Periodic Discharges (LPDs): 0.5-1 Hz spiky LPDs. 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).

EEG 8 Bilateral Independent Periodic Discharges (BIPDs): Periodic spike wave occurring at 0.3-0.5 Hz in the left posterior quadrant (arrows). At the same time, there is another periodic spike wave population occurring at 0.5-1 Hz in the right posterior quadrant (asterisks).

EEG 9 Unilateral Independent Periodic Discharges (UIPDs): 1-1.5 Hz Periodic Discharges (PDs) maximal at F3. At the same time there are independent 0.5-Hz PDs in the central region. The two PD patterns in the same hemisphere qualify as UIPDs. NOTE a focal midline pattern may still be classified in the same hemisphere (unilateral) as an independent pattern in either the right or left hemisphere. *Courtesy of Dr. Jong Woo Lee.*

EEG 10 Unilateral Independent Rhythmic Delta Activity (UIRDA): 1.5-Hz Rhythmic Delta Activity (RDA) in the right frontal region (solid box). At the same time, there is 1-Hz RDA in the right temporal region (dashed box). The patterns are independent from each other but are both in the same hemisphere (so unilateral).

EEG 11 Multifocal Periodic Discharges (MfPDs): Three independent lateralized periodic patterns occurring at the same time, with at least one in each hemisphere (2 on the right and 1 on the left). Blunt PDs left fronto-central at 0.75 Hz (boxes), sharp PDs at F4 at 0.33 Hz (arrows) and spiky PDs at P4 at 0.2-0.25 Hz (asterisks). *Courtesy of Dr. Luis Octavio Caboclo.*

EEG 12 GPDs (frontal predominant): 1 Hz GPDs, characterized by a marked frontal predominance and a sharp morphology. Despite background attenuation, the discharges are <0.5 s and thus do not qualify as bursts.

EEG 13 LPDs (bilateral asymmetric): Sharply contoured LPDs. In this case they are clearly lateralized to the left hemisphere but can be seen in both hemispheres (for example at F4). These are still classified as a lateralized pattern (LPDs) but are bilateral asymmetric.

EEG 14 Generalized Spike-and-Wave (GSW): 1.5-Hz generalized frontally predominant polyspike-and-wave. 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.

EEG 15 Stimulus Induced - GRDA (SI-GRDA): Stimulating the patient (in this case via suctioning) results in 1.5-Hz GRDA.

EEG 16 LRDA with evolution: LRDA 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. NOTE: The pattern only lasts 9 s and therefore does not meet the ≥10 s cut off for an electrographic seizure. It also only reaches a maximum of 3 Hz. If the rhythmic activity were >4 Hz with evolution this would be classified as definite BIRDs.

EEG 17 LPDs with fluctuation: LPDs that fluctuate in frequency between 0.5 and 1 Hz.

EEG 18 GPDs+F: 1-1.25 Hz sharp GPDs with superimposed low amplitude quasi-rhythmic fast activity (highlighted in boxes).

EEG 19 LPDs+F: 1-Hz spiky LPDs in the right hemisphere, each associated with a short run of fast activity (ellipses).

EEG 20 LRDA+S: 2-Hz LRDA with superimposed repetitive sharp waves (several marked with asterisks) (LRDA+S). The superimposed low amplitude fast activity is also present on the right hemisphere and should not be recorded as +F.

EEG 21 BIPDs+F: Bilateral independent periodic discharges at 0.5-1 Hz, 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.

EEG 22 Extreme Delta Brush (EDB: 1-Hz periodic delta brush pattern (i.e., there is a clear interval between each consecutive delta brush waveform). Using the current terminology, this would be best characterized as 1-Hz GPDs+F of blunt morphology, where each discharge is a

delta wave. Fast activity occurs in a stereotyped relation with each delta wave (in this case at the crest and on the downslope [ellipses]). This is better seen in the blown-up section of the EEG in the box. If this pattern were abundant or continuous it would be definite EDB, but if only occasional or frequent it would be possible EDB. *Courtesy of Dr. Nicolas Gaspard.*

EEG 23 GPDs with triphasic morphology and A-P lag: GPDs at just under 1.5 Hz. In this case there is also triphasic morphology and an anterior-posterior lag, highlighted with the diagonal line in the upper right of the figure.

EEG 24a Electrographic seizure (ESz): Definite evolution in a pattern lasting at ≥10 s, and also averaging >2.5 Hz for ≥10 seconds (either criterion would suffice to qualify as an ESz). There was no clinical correlate to this seizure i.e. not electroclinical.
EEG 24b Electrographic seizure (ESz) cont.
EEG 24c Electrographic seizure (ESz) cont.

EEG 25 Electroclinical seizure (ECSz): The spike and polyspike pattern at C3 is associated with right hand twitching (EMG trace at the bottom of the page). *[From Hirsch LJ, Brenner RP. Atlas of EEG in Critical Care. London: Wiley, 2010. With permission.]*

EEG 26a Electroclinical seizure (ECSz): A medically ill hospitalized patient became acutely confused. The EEG demonstrates abundant generalized (posterior predominant) sporadic epileptiform discharges and admixed fast rhythms. NOTE: The discharges are never persistent for 6 cycles (i.e., it is not periodic or SW). As it is not an RPP it does not meet current consensus criteria for the IIC. NOTE: The pattern is also not >2.5 Hz (>25 discharges per 10 s), therefore it also does not qualify as an ESz or ESE.
EEG 26b Electroclinical seizure (ECSz): After parenteral anti-seizure medication the EEG normalized, with complete resolution of any epileptiform features. Over the next few hours, the patient's confusion also resolved. Both the EEG pattern and the patient's confusion resolved with parenteral anti-seizure medication. This therefore meets criterion B of an electroclinical seizure (even though the "pre" EEG does not meet criteria for an ESz or the IIC).

EEG 27 Brief Potentially Ictal Rhythmic Discharges (BIRDs): Focal 5-Hz sharply contoured rhythmic activity lasting 4.5 and 2 seconds (underlined). This activity has a similar location and morphology as the interictal sporadic discharges (box), making these definite BIRDs.

EEG 28 Ictal-Interictal Continuum (IIC) – Focal: Continuous fluctuating 1.5-2 Hz LPDs+R over the right temporal region. Not >2.5 Hz and therefore not an electrographic seizure, but with a reasonable chance it may be contributing to impaired alertness, causing other clinical symptoms, and/or contributing to neuronal injury.

EEG 29a Ictal-Interictal Continuum (IIC) – Generalized: The record begins with 1-Hz GPDs. Not qualifying as IIC. Cont.

EEG 29b Ictal-Interictal Continuum (IIC) – Generalized: As the recording continues the EEG begins to change, with GPDs fluctuating between 1 Hz and very briefly up to 1.5 Hz. Now qualifying as a pattern on the IIC. Cont.

EEG 29c Ictal-Interictal Continuum (IIC) – Generalized: Later in the same record, the GPDs are now occurring between 1.5-2 Hz, and the background EEG has gained intermittent low amplitude fast activity and intermittent rhythmic delta activity (GPD+FR). Even this pattern does not qualify as definitively ictal (not evolving or >2.5 Hz for ≥10 s), although it is more likely to be ictal than the prior figures from the same patient and day (showing the continuum concept), and likely warrants treatment or at least a trial of an IV anti-seizure medication, depending on the full clinical situation. The clinical impression of the EEG report may conclude that this is probable nonconvulsive seizure or nonconvulsive status epilepticus regardless; and should include what percent of the record is on the IIC or likely ictal.

EEG 30 Ictal-Interictal Continuum (IIC) with Quantitative EEG (QEEG). The figure demonstrates the concept of the IIC. Panels A and B show the Color Density Spectral Array (CSA) for the left hemisphere (A) and the right hemisphere (B). The CSA displays EEG power by frequency band. The y axis is frequency (from 0 to 30 Hz), the x axis is time (in this case showing a 12-hour trend). The amount of power at each frequency is demonstrated by the intensity of the color on a Z scale. If there is no power the QEEG is black, through to high power, which demonstrates intense red then pink and white colors. The QEEG demonstrates that over the 12 hours of the recording the power in each hemisphere is slowly and gradually reduced across all frequencies. Panel C shows the EEG at the respective time points (arrows). Near the beginning there are 1-1.5 Hz posterior predominant GPDs with fast and rhythmic activity (GPD+FR), high amplitude (note the 15 uV/mm sensitivity), a pattern on the IIC, not qualifying as definitively ictal, but interpreted (clinical impression) as probable nonconvulsive status epilepticus. By the end of the recording the periodic pattern, fast activity and rhythmicity have resolved, now only demonstrating diffuse dysfunction with abundant sporadic epileptiform discharges (clearly not ictal, and not on the IIC). The middle panel shows a state in between the two. The cutoff point where the highly epileptiform patten becomes "interictal" is not easily defined. This demonstrates the concept of the IIC, a spectrum of EEG findings from interictal to potentially ictal, at times progressing into definite electrographic seizures and status epilepticus. There is no abrupt transition between ictal and non-ictal, but rather a gradual continuum. *[Adapted from Hirsch LJ, Brenner RP. Atlas of EEG in Critical Care. London: Wiley, 2010. With permission.]*