CONTINUOUS EEG MONITORING, ELECTROGRAPHIC SEIZURES, AND THE ICTAL-INTERICTAL CONTINUUM

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INDICATIONS FOR CONTINUOUS EEG MONITORING

Persistent altered mental status (AMS)	**Inadequate neuro exam**
Ongoing poor arousal after generalized, convulsive seizures Supratentorial brain injury with AMS (particularly mental status fluctuates or is poor out of proportion to injury) Unexplained AMS without known CNS injury	Need for paralysis in patient with high risk of seizure (hypothermia or on extracorporeal membrane oxygenation (ECMO)) Need for pharmacologic sedation (elevated intracranial pressure and refractory status epilepticus)
Paroxysmal events	**Prognostication**
Witnessed seizure without return to baseline Clinical events: Motor events, paroxysm autonomic spells, paroxysmal increase in intracranial pressure to rule out seizure etiology Routine EEG demonstrates periodic patterns: Generalized periodic discharges (GPDs), lateralized periodic discharges (LPDs), etc. (see below)	Particularly in traumatic brain injury, hypoxic-ischemic damage, subarachnoid hemorrhage, and cardiac arrest Unfavorable patterns: isoelectric, burst suppression, periodic patterns, and seizures Favorable: continuity, reactivity to stim, sleep arch, and spontaneous variability For more details on cardiac arrest neuroprognostication, see page 253

Continuous EEG is also used in vasospasm monitoring – see page 237 for more details.

TERMS

The American Clinical Neurophysiology Society recently updated their standardization for critical care EEG terminology [1]. The wide variety of features that may be reported in a continuous EEG report is outside the scope of this chapter. However, below is a summary of what will be included in a continuous EEG report. For more information and further details, see the ACNS terminology guidelines and refer to the Salzburg criteria for seizures [2].

C. S. W. Albin, S. F. Zafar (eds.), *The Acute Neurology Survival Guide*,
https://doi.org/10.1007/978-3-030-75732-8_50

A. **Background** will include information about the symmetry, the predominant frequency, the presence of reactivity and continuity, state changes, voltage, and presence of a breach. AP gradient and posterior dominant alpha rhythm will also be noted, if present.
   - Note that burst suppression (included in continuity) is defined as a pattern of attenuation/suppression alternating with higher-voltage activity with 50–99% of the record consisting of attenuation.

B. **Sporadic epileptiform discharges**: the presence of spikes, polyspikes, and sharp waves as applicable and the frequency of their presence from rare to abundant.

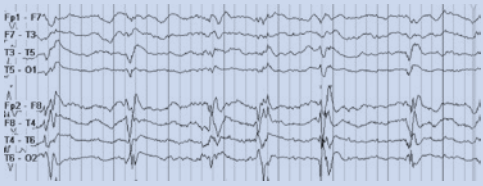
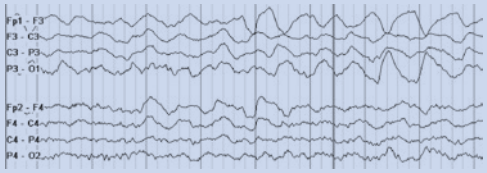
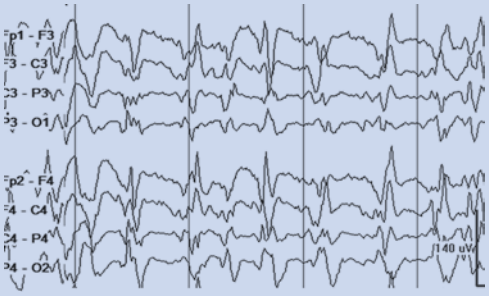
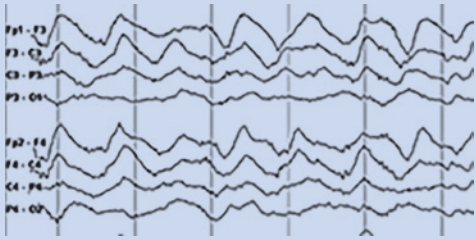
C. **Rhythmic and Periodic Patterns**
   - Main term 1: generalized, lateralized, bilateral independent, unilateral independent, multifocal
   - Main term 2: periodic discharges, rhythmic delta activity, spike-and-wave/sharp-and-wave
   - Will be modified by the duration, frequency, phases, sharpness, if stimulus induced, if there evolution/fluctuation, and if there are "+" features.

D. **Electrographic seizures** (defined briefly as epileptiform discharges average >2.5 Hz for ≧10 seconds, or any pattern with definite evolution lasting ≧10 seconds) or electrographic status epilepticus (ESz for ≧ 10 continuous minutes or ≧20% of the total duration of a 60-mmin period)
   - Electroclinical seizures/status has the same electrographic definition but requires a definite clinical correlate time-locked to the pattern *or* EEG *and* clinical improvement with IV anti-seizure medication.

E. **Brief potential ictal rhythmic discharges**: focal or generalized rhythmic activity >4 hz lasting 0.5–10 seconds that are not part of a burst suppression pattern and without a definitive clinical correlate.

F. **Ictal-interictal continuum (IIC)**: The ACNS defines a pattern on the IIC as one that does not meet the definitions of electrographic seizures or electrographic status epilepticus, but has features to suggest that it may be contributing to altered mental status, other clinical symptoms, and/or to neuronal injury.
   - Periodic discharges (PD) or sharp-wave (SW) pattern that is between 1 and 2.5 Hz over 10 seconds
   - A PD or SW pattern between 0.5 and 1 hz that persists for >10 seconds and has a plus modifier or fluctuation
   - Any lateralized RDA (rhythmic delta activity) averaging >1 Hz for at least 10 seconds. With a plus modifier of fluctuation

EXAMPLES OF COMMONLY ENCOUNTERED CONTINUOUS EEG FINDINGS

LATERALIZED PERIODIC DISCHARGES (LPDS)	LATERALIZED RHYTHMIC DELTA ACTIVITY (LRDA)
Lateralized sharp waves or spikes made have associated slow waves. Commonly encountered in stroke, intracerebral hemorrhage, subarachnoid hemorrhage, tumors, abscesses, Creutzfeldt-Jakob disease, herpes simplex virus, and other infectious/autoimmune pathology. LPDs are highly associated with seizures especially in the setting of acute illness, metabolic disturbances, or focal lesions	Usually reflects the presence of a focal lesion; associated with the risk of acute seizures, especially nonconvulsive status epilepticus
	
GENERALIZED PERIODIC DISCHARGES (GPDS)	**GENERALIZED RHYTHMIC DELTA ACTIVITY (GRDA)**
Tend to be seen in diffuse processes: toxic-metabolic encephalopathy, sepsis. But may also be seen in herpes simplex virus encephalitis and autoimmune encephalopathies. Can be associated with NCSE	A nonspecific pattern that may be seen in profound encephalopathy, post-ictally or with inflammatory, degenerative, traumatic, or toxic-metabolic disorders
	

2HELPS2B SCORE [3]

Predicts seizure risk. The authors propose the 2HELPS2B score can be reported after 1 hour of screening with IV sedation minimized.

Score = 0, cEEG not needed (although 90 mins of screening should be considered in patients with coma).
Score = 1, at least 12 hours of monitoring. If the score increases to ≥2 during 12 hours, monitor at least 24 hours.
Score ≥ 2, at least 24 hours of cEEG.

RISK FACTOR	SCORE
Frequency >2hz[a]	1
Independent sporadic epileptiform discharges	1
LPD/BIPD/LRDA	1
Plus features (superimposed rhythmic, fast, sharp)[b]	1
Prior seizure[c]	1
Bilateral independent periodic discharges	2
Total score	0–7

[a]Frequency of any periodic or rhythmic pattern of more than 2 Hz except generalized rhythmic delta activity
[b]Plus features include superimposed rhythmic, fast, or sharp activity only on LRDA, LPDs, or BIPDs
[c]Prior seizure includes a remote history of epilepsy or recent events suspicious for clinical seizures
[d]Predicted seizure risk based on the 2HELPS2B model

Predicted Seizure Risk[d]
0 = <5%
1 = 12
2 = 27%
3 = 50%
4 = 73%
5 + = 88%

MANAGEMENT OF THE ICTAL-INTERICTAL CONTINUUM FINDINGS

It is important to determine if there is an epileptic clinical correlate – said differently, does "fixing" the EEG improve the clinical picture?
It is also important to determine if there is a major metabolic derangement that needs to be corrected, particularly for generalized periodic discharges.

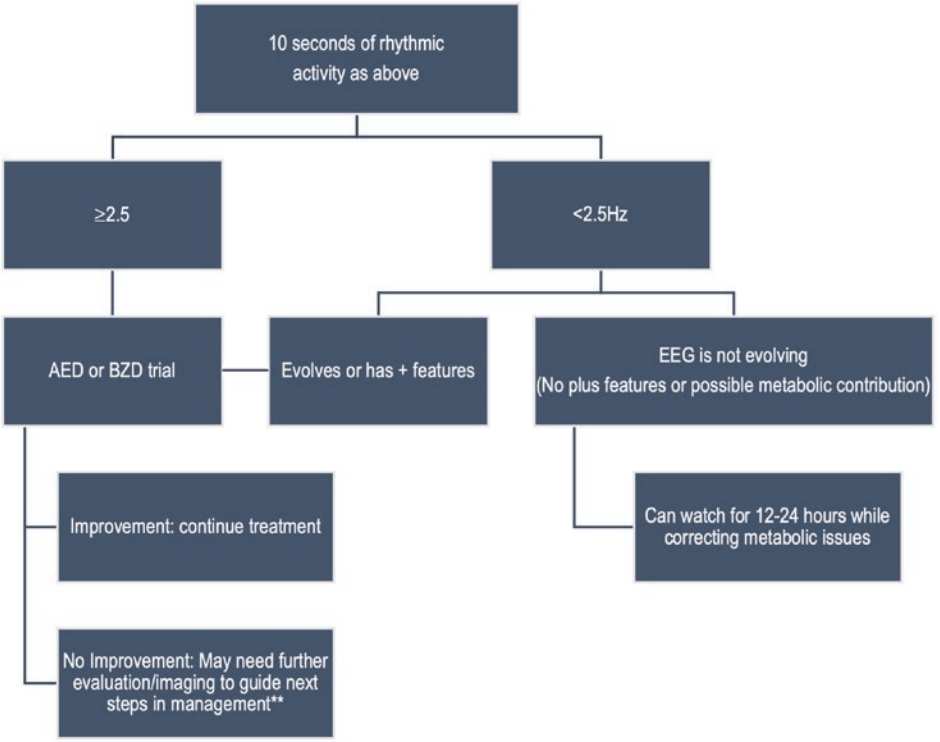
As defined above, if the report contains 10 seconds of a rhythmic pattern that differs from the background including:

- Periodic discharges (PD) or sharp-wave (SW) pattern that is between 1 and 2.5 Hz over 10 seconds
- A PD or SW pattern between 0.5 and 1 hz that persists for >10 seconds and has a plus modifier or fluctuation
- Any lateralized RDA (rhythmic delta activity) averaging >1 Hz for at least 10 seconds, with a plus modifier of fluctuation

then it is reasonable to consider a treatment trial, either a benzodiazepine or a parenteral form of a "Stage II" AED (VPA, LEV, fos-PHT, or LAC). **It is very important to communicate the timing of administration to the epileptologist or have the bedside provider mark it as a "push button" event**.

A PROPOSED ALGORITHM FOR THE TREATMENT OF IIC PATTERNS

A simplified algorithm based on that proposed in Clinical Neurophysiology [4]



*If the EEG improves with administration of AED but there is no clinical improvement, then continue to monitor as clinical improvement may be delayed. Continued trial of AED is likely warranted.

**If the EEG continues to have features of the IIC, it is important to use clinical judgment. Can consider a longer AED trial, advanced neuroimaging as with SPECT or PET, or discontinue AEDs and continue to evaluate for an underlying cause such as a toxic-metabolic, infection, and structural abnormality that may contribute to or cause “cortical irritability.”

REFERENCES

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3. Struck AF, Ustun B, Ruiz AR, et al. Association of an electroencephalography-based risk score with seizure probability in hospitalized patients. JAMA Neurol. 2017;74(12):1419–24.
4. Rodríguez V, Rodden MF, LaRoche SM. “Ictal–interictal continuum: a proposed treatment algorithm.” Clin Neurophysiol. 2016;127(4):2056–64.