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ELECTROMYOGRAPHY (EMG), ELECTROENCEPHALOGRAPHY (EEG), AND NEUROPHYSIOLOGY IN CLINICAL PRACTICE

February 19-25, 2023
Ritz-Carlton Amelia Island
Amelia Island, FL

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MISSION CRITICAL: EEG IN COMA AND ENCEPHALOPATHIES

David Burkholder, M.D.

DISCLOSURE OF RELEVANT FINANCIAL RELATIONSHIP(S) WITH INELIGIBLE COMPANIES

- Nothing to disclose

REFERENCES TO OFF-LABEL USAGE(S) OF PHARMACEUTICALS OR INSTRUMENTS

- Nothing to disclose

All relevant financial relationships have been mitigated.

LEARNING OBJECTIVES

- Define encephalopathy and coma, and identify the role of EEG in their assessment
- Identify EEG changes reflective of encephalopathy
- Recognize required criteria for identifying electrocerebral silence on EEG

DEFINITIONS

- Encephalopathy
  - Encephalo- = brain
  - -pathy = dysfunction, disease, impairment, etc.
- In the inpatient setting, most commonly lumped in with “altered mental status”
- Several descriptive variables
  - Acute or chronic
  - Static or dynamic
  - Focal or generalized
  - Spectrum of severity – mild to severe

DEFINITIONS

- Coma – a deep state of unconsciousness (unresponsive and unaware)
- May be caused from any number of etiologies
  - Iatrogenic (anesthetic)
  - Hemispheric, brainstem, or diffuse injury
    - Ischemic stroke or hemorrhage
    - Infection
    - Inflammation
    - Trauma
    - Mass or tumor
- Coma is a severe form of encephalopathy

THE ROLE OF EEG

- Etiology
  - Status epilepticus – may be primary or secondary
- Localization
  - More so prior to days of imaging
  - Still helpful if imaging is negative
- Prognosis* - more in anoxic injury than other causes of encephalopathy/coma
- Supporting information for or against brain death if unable to perform a complete brain death examination

COMMON PATTERNS

- Slowing
- Rhythmic delta activity
- Periodic discharges
  - Ictal-interictal continuum

SLOWING

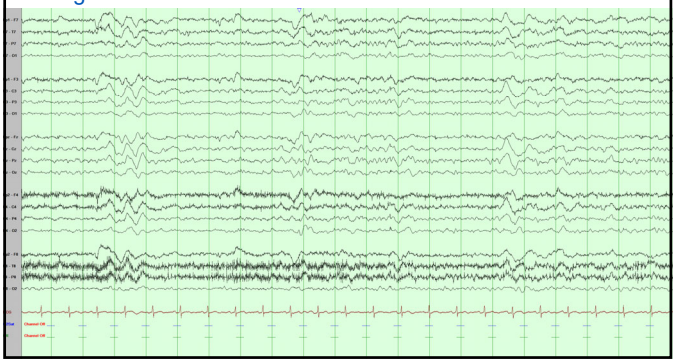
- A general sign of encephalopathy – nonspecific
- Ranges from mild (theta) to severe (delta), and anywhere in between
- May be focal if lesion or focal dysfunction
- Often diffuse in the event of systemic disease

RHYTHMIC DELTA ACTIVITY (RDA)

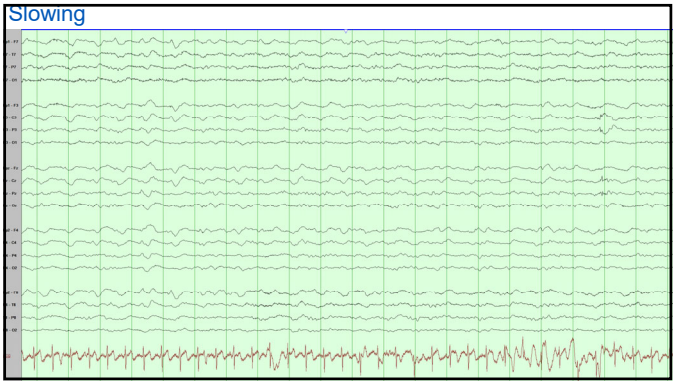
- Repetitive monomorphic waveforms
- >0.5 Hz and <4 Hz
- Little variation in frequency (<50%) between waveform pairs
- At least 6 waves (cycles)
  - If 1 Hz, then 6 seconds
  - If 2 Hz, then 3 seconds
- Generalized (GRDA) or lateralized (LRDA)
  - GRDA – no increased seizure risk compared to non-specific encephalopathy EEGs (~10-15%)
  - LRDA – 25-40% of patients with seizures

Hirsh LJ, et al. J Clin Neurophysiol 2021;38:1-29.
Rodriguez Ruiz A, et al. JAMA Neurol. 2017;74(2):181-188.

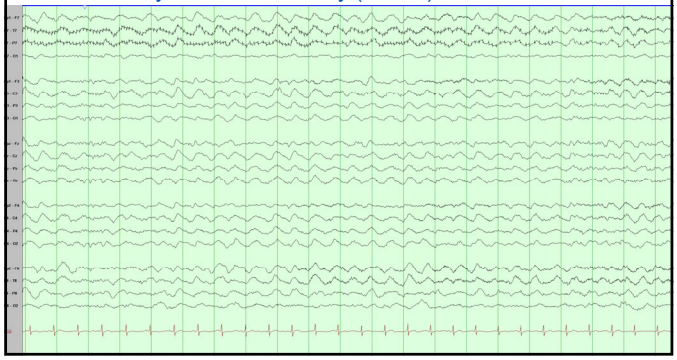
Slowing



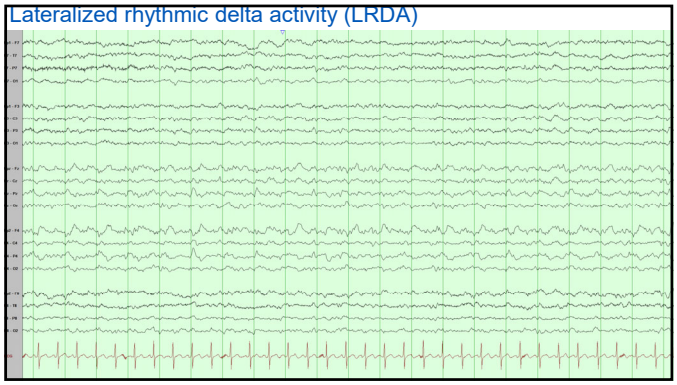
Slowing



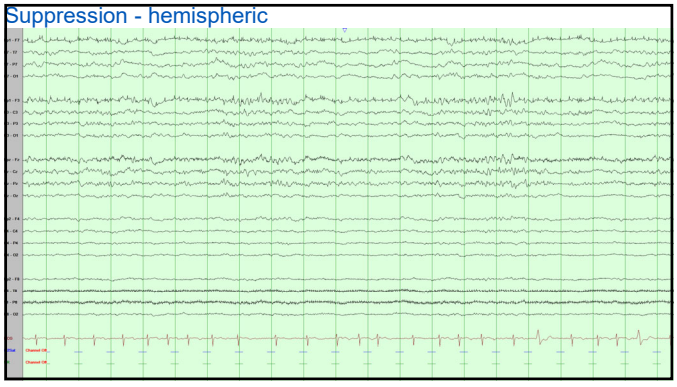
Generalized rhythmic delta activity (GRDA)



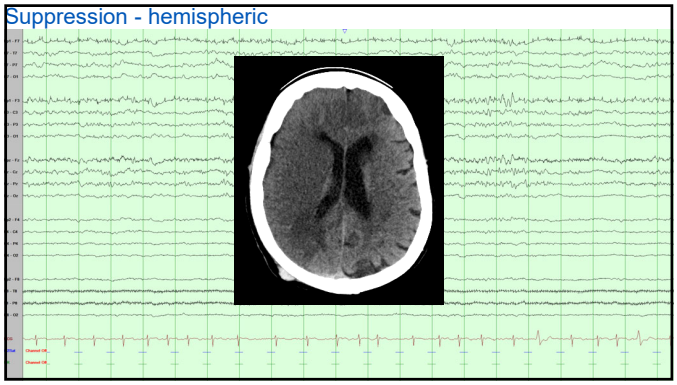
Lateralized rhythmic delta activity (LRDA)



Suppression - hemispheric



Suppression - hemispheric



PERIODIC DISCHARGES

- Same rules as RDA
  - Repetitive
  - >0.5 Hz and <4 Hz
  - At least 6 waves (cycles)
- Location, location, location
  - Generalized
  - Lateralized – single site
  - Bilateral Independent – 2 *simultaneous asynchronous* sites, different hemispheres
  - Unilateral Independent – 2 *simultaneous asynchronous* sites, same hemisphere (including midline)
  - Multifocal – 3+ sites, at least one in each hemisphere

Hirsh LJ, et al. J Clin Neurophysiol 2021;38:1-29.
Foreman B, et al. Clin Neurophysiol. 2016;127(2):1073-1080.
Lin L and Drislane FW. J Clin Neurophysiol. 2018;35(3):189-198.

PERIODIC DISCHARGES

Generalized Periodic Discharges

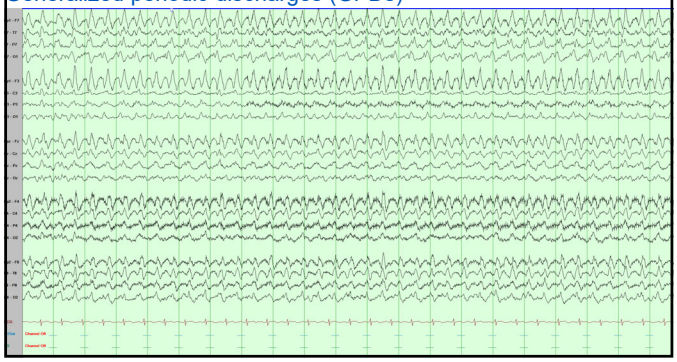
- Can be with triphasic morphology (previously “triphasic waves”)
- Morphology not dependent on cause – i.e. triphasic not necessarily toxic/metabolic
- ~25% of patients with GPDs will have seizures
  - Not morphology dependent
  - May be higher if >2 Hz

Lateralized Periodic Discharges

- Associated with focal cerebral injury or dysfunction
- Can be associated with fast or polyspike components
- More highly associated with discrete seizures, >50% of patients

Hirsh LJ, et al. J Clin Neurophysiol 2021;38:1-29.
Foreman B, et al. Clin Neurophysiol. 2016;127(2):1073-1080.
Lin L and Drislane FW. J Clin Neurophysiol. 2018;35(3):189-198.

Generalized periodic discharges (GPDs)



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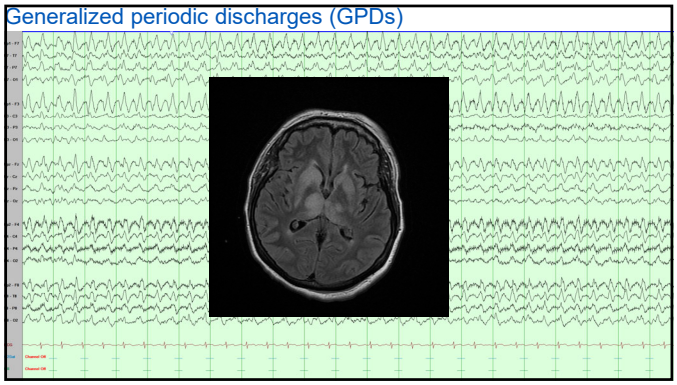
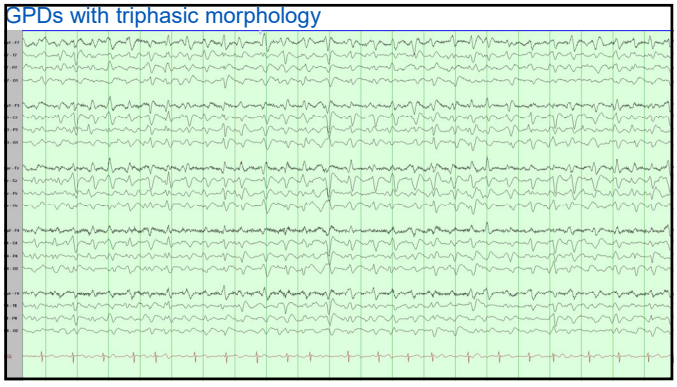
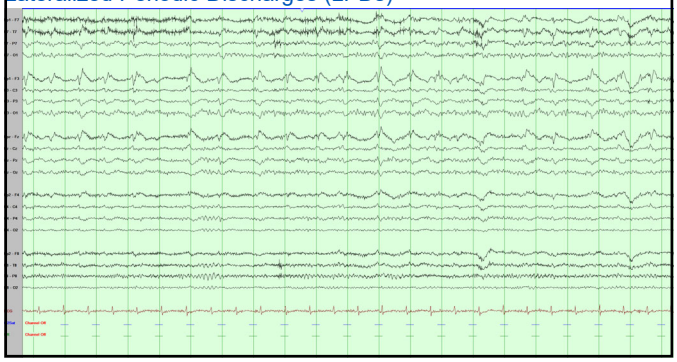


GPDs with triphasic morphology



Lateralized Periodic Discharges (LPDs)



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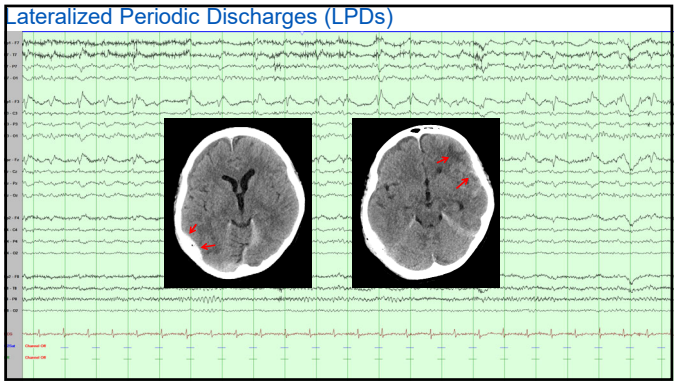
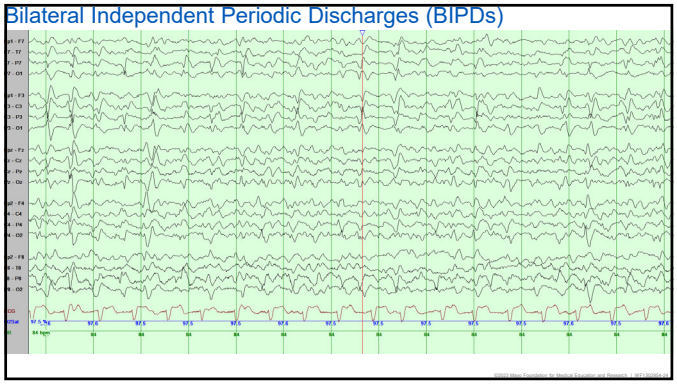


Bilateral Independent Periodic Discharges (BIPDs)

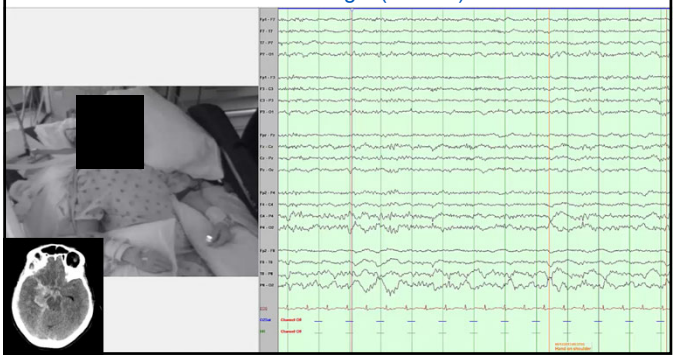


STIMULUS-INDUCED PERIODIC DISCHARGES (SI-PDS)

- Focal, lateralized, or generalized periodic discharges that occur with stimulation
  - Part of the ictal-interictal continuum along with other periodic discharges
  - Formerly called stimulus-induced rhythmic, periodic, or ictal discharges (SIRPIDs)
- **NOT** considered physiologically normal reactivity
- Prognosis?
  - Unfavorable in anoxic brain injury
  - Not necessarily unfavorable in other reasons for encephalopathy

Hirsh LJ, et al. J Clin Neurophysiol 2021;38:1-29.
Alvarez V, et al. Clin Neurophysiol 2013;124(1):204-208.
Braksick SA, et al. JAMA Neurol 2016;73(5):585-590.

Stimulus-Induced Periodic Discharges(SI-PDs)

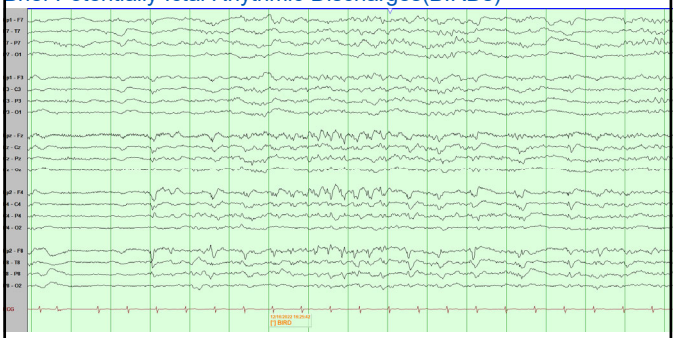


BRIEF POTENTIALLY ICTAL RHYTHMIC DISCHARGES (BIRDS)

- Not quite interictal…but not quite “seizures” (and definitely not avian)
- Increased risk of seizures
- 4+ Hz, at least 0.5 seconds but less than 10 seconds
- At least 6 waves (cycles)
- **No** clinical correlate – if correlate, then it’s an electroclinical seizure
- Classifie as “definite” or “possible” with any *single* criteria
  - Definite
    - Evolution (frequency, spread, and/or morphology) OR
    - Same location as already demonstrated interictal discharges or seizures
  - Possible
    - Sharply contoured, but not meeting either definite criteria

Hirsh LJ, et al. J Clin Neurophysiol 2021;38:1-29.

Brief Potentially Ictal Rhythmic Discharges(BIRDs)



NON-CONVULSIVE STATUS EPILEPTICUS (NCSE)

- May be easy to tell – repeated well-organized focal seizures or absence status epilepticus
- May be difficult to tell with subtle features, persistent encephalopathy

ACNS definition of an ***electrographic*** seizure:

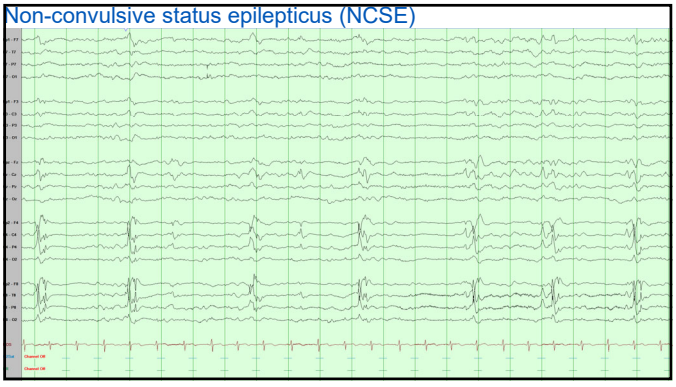
- Epileptiform discharges of >2.5 Hz for at least 10 seconds OR
- Any pattern with definite evolution >10 seconds

ACNS definition of ***electrographic*** NCSE:

- EEG seizure at least 10 minutes
- EEG seizure for at least 20% of any 60-minute epoch

Hirsh LJ, et al. J Clin Neurophysiol 2021;38:1-29.
Beniczky S, et al. Epilepsia. 2013;54(Suppl 6):28-29.

Non-convulsive status epilepticus (NCSE)



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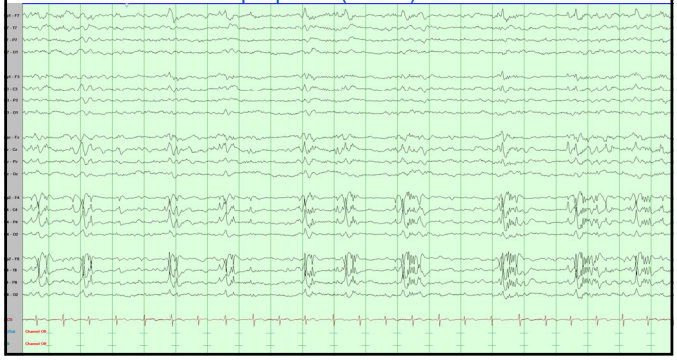

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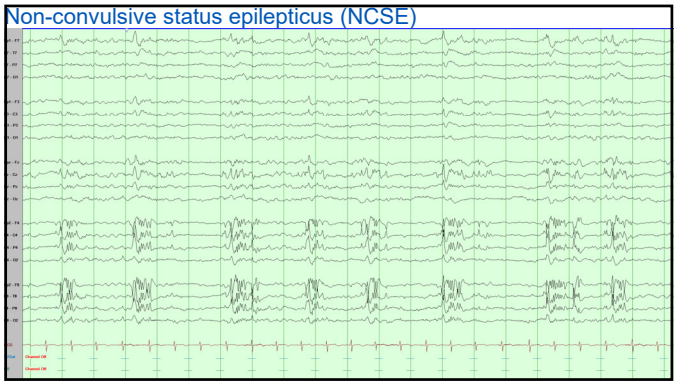

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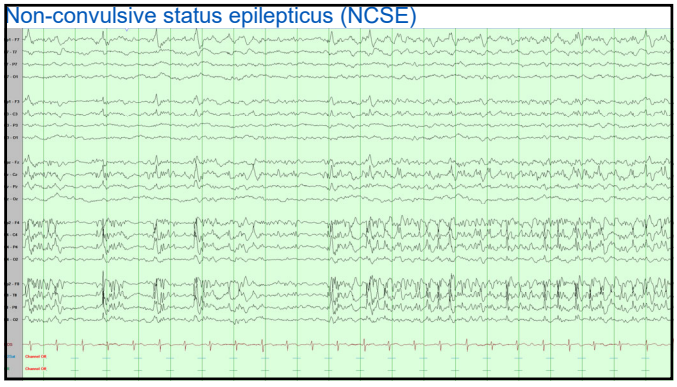

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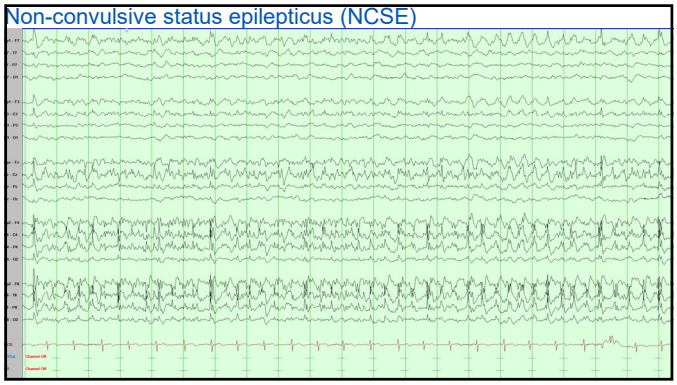

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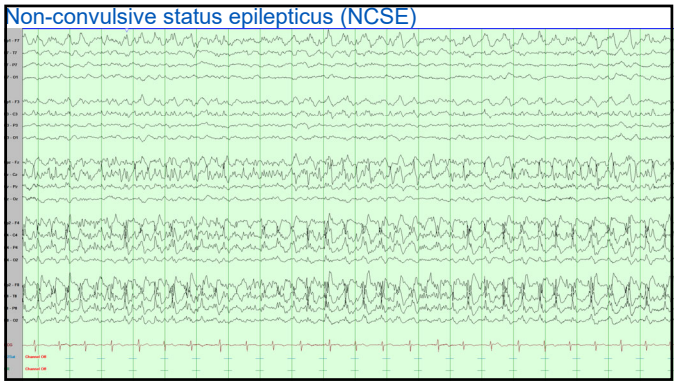

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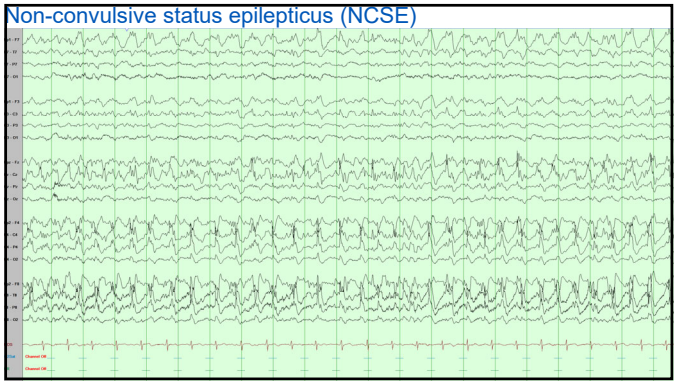

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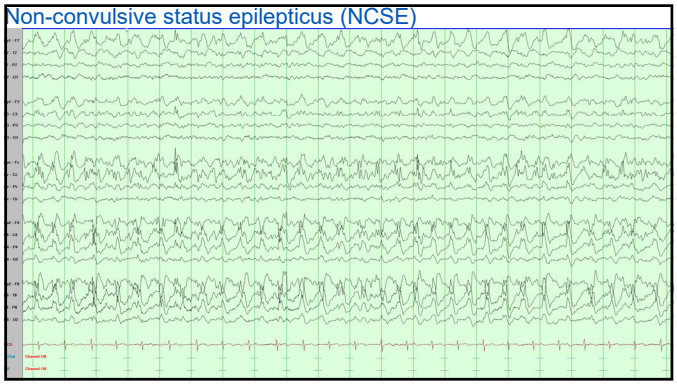

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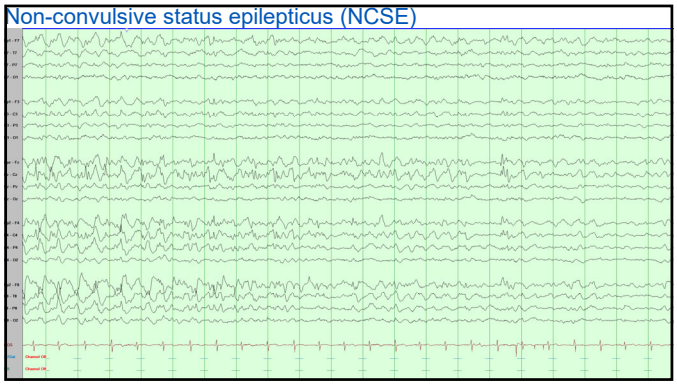

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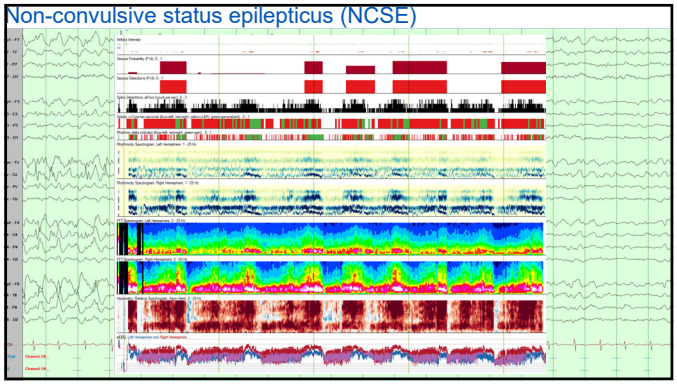


EEG AND COMA

- History, examination, and directed diagnostic testing are helpful for assessing coma
- EEG is not diagnostic of coma by itself
- EEG in the absence of clinical information is not reliably prognostic
- **Results must be interpreted in the context of other clinical and physiologic information**

EEG PROGNOSIS* IN COMA

Good
- Reactivity (not SI-PD)
- Spontaneous variability
- Progression to an improved pattern

Bad
- No reactivity
- Invariant
- Persistent or progressive suppression, or devolution to a worsened background

*Prognosis is primarily dependent on etiology

EEG AND PROGNOSIS – ANOXIC BRAIN INJURY

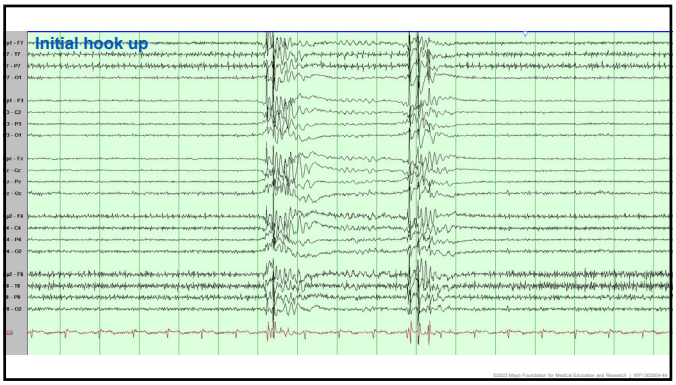
- Anoxic brain injury is the prototypical condition used to assess EEG and prognosis for outcome
  - Diffuse brain involvement
  - Limited other systemic contributors as variables
- Anesthetic use (associated with targeted temperature management) needs to be taken into consideration

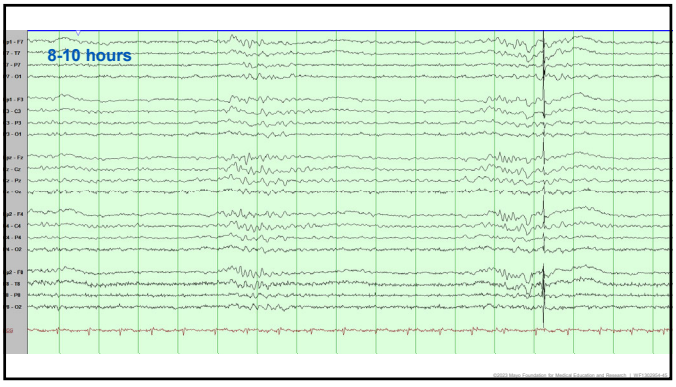
EEG AND PROGNOSIS – ANOXIC BRAIN INJURY

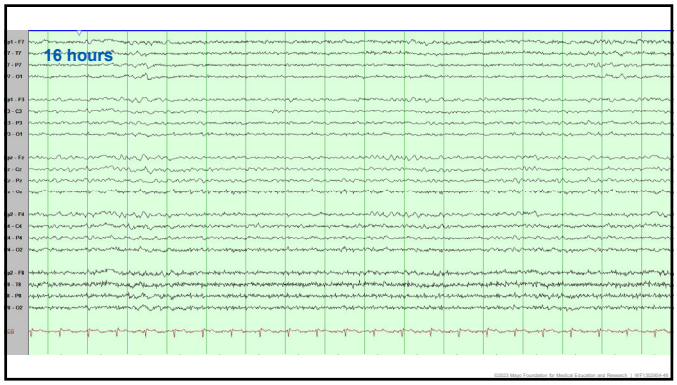
Good (CPC 1-2)	In between	Bad (CPC 3-5)
Continuous any frequency, early	Continuous slowing, late	Discontinuous after 24 hours
	Epileptiform discharges, late	Suppressed background, with or without bursts or periodic discharges
	Heterogeneous burst suppression, early	Low voltage (<10-20 microvolts) after 24 hours
		Epileptiform discharges, early
		Synchronous (stereotypic) burst suppression
		Heterogeneous burst suppression, late

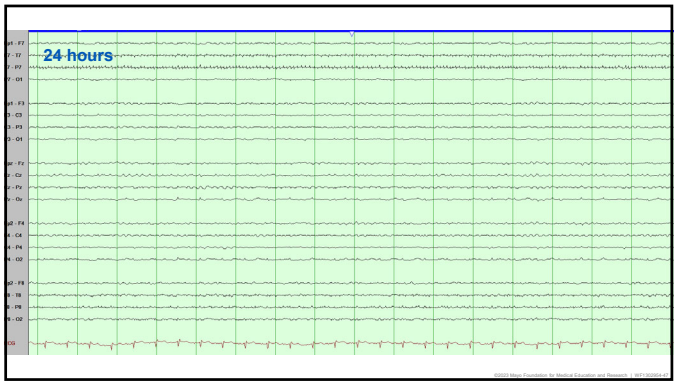
CPC = cerebral performance category

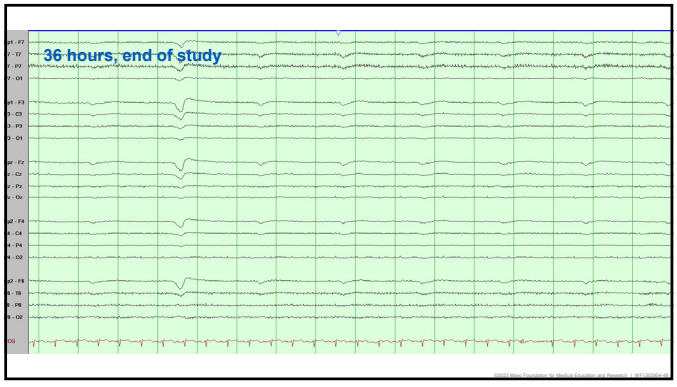
Ruijter BJ, et al. Ann Neurol 2019;86:203-2014.



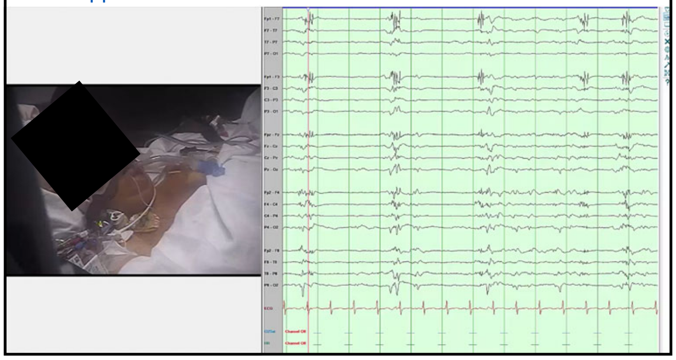



16 hours


24 hours


36 hours, end of study

Burst Suppression



BRAIN DEATH AND ELECTROCEREBRAL INACTIVITY

- EEG can be used as an *ancillary* test if brain death not able to be confirmed using standard clinical examination and apnea testing
- Electrocerebral inactivity (ECI)
- **Is not diagnostic of brain death** – only a complete brain death exam is able to do that
- Specific requirements

MINIMUM TECHNICAL STANDARDS FOR ECI ON EEG

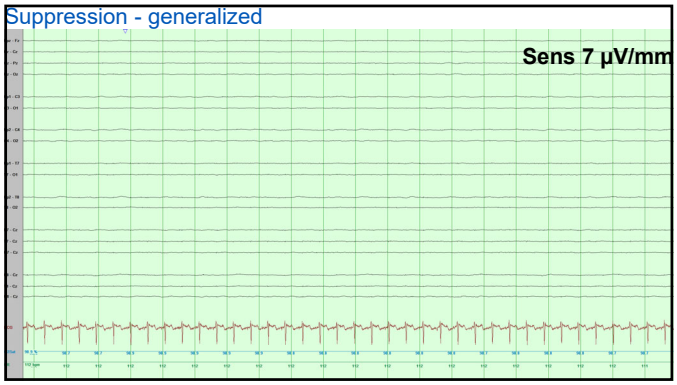
- Full electrode set-up
- Interelectrode distance 10 cm or more on review ("double distance")
- Resistance between 100-10,000 Ohms
- System integrity tested by qualified individual
- High sensitivity review (2 μV/mm)
- HFF: not below 30 Hz
- LFF: not above 1 Hz
- Notch: Ok to use
- Minimum 30 minutes
- No reactivity to any stimuli – actively test!
- Repeat if doubt

TROUBLESHOOTING EEG FOR ECI

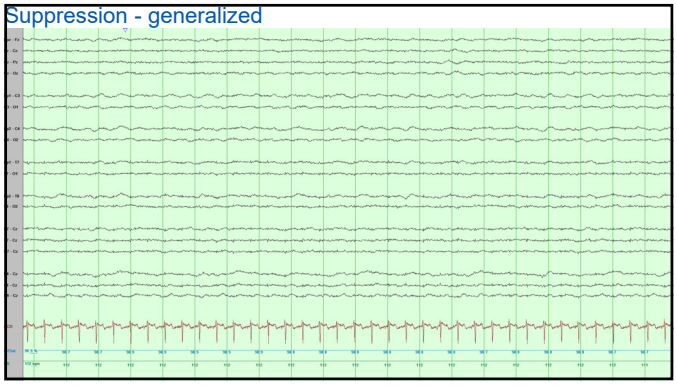
- Barriers to good recordings
  - ICU artifacts – multiple sources
  - ECG artifact – utilize ECG monitor as part of EEG
  - Ballistic artifact from pulse – utilize ECG monitor as part of EEG
  - Respiratory artifact with ventilator – use video monitoring
  - Myogenic artifact – can use neuromuscular blocker if needed

If you aren't sure, then it isn't ECI

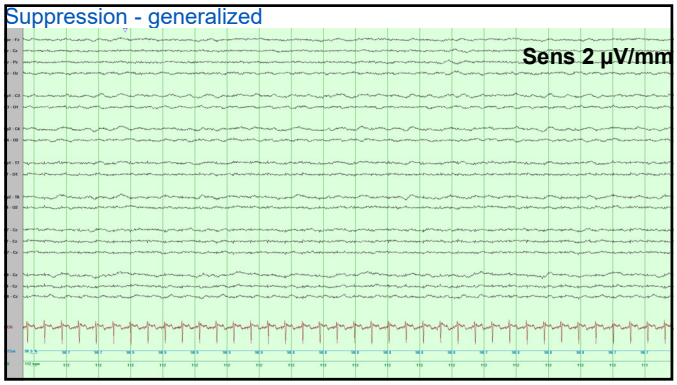
Suppression - generalized



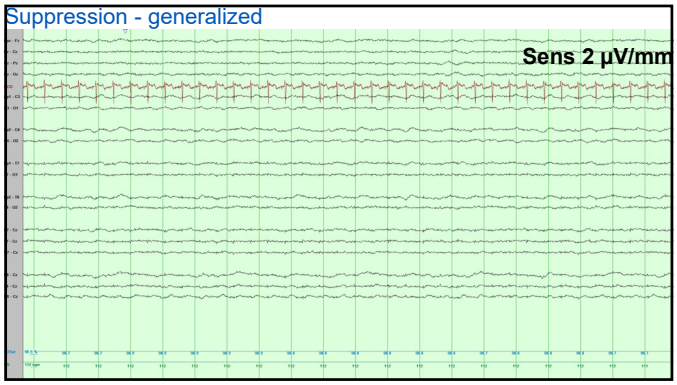
Suppression - generalized



Suppression - generalized



Suppression - generalized



TAKE HOME POINTS

- Encephalopathy is a dysfunction of the brain from any number of potential etiologies that ranges in severity and prognosis.
- Slowing, PDs, BIRDs, and status epilepticus may all be seen in encephalopathy.
- LRDA, LPDs, and BIRDs all significantly increase the likelihood of seizures on the EEG recording.
- In anoxic brain injury, prognosis is best if EEG shows a continuous, reactive and variable background early.
- ECI has specific technical requirements and may provide support for or against brain death but does not replace a comprehensive brain death examination.

THANK YOU!

CEREBRAL PERFORMANCE CATEGORY

1. Independent, with or without mild neurologic or psychologic impairment
2. Independent for ADLs, and can work in a sheltered or accommodating environment
3. Conscious and interactive, but dependent on others for care. May or may not have physical deficits (paresis, etc.)
4. Coma or vegetative state
5. Death/Brain death

Return