PEDIATRIC NEWBORN MEDICINE CLINICAL PRACTICE GUIDELINES

EEG Neuro-monitoring in the NICU

Clinical Practice Guideline: EEG Neuro-monitoring in the NICU

Points of emphasis/Primary changes in practice:

1- To expand the indications of amplitude integrated EEG (aEEG) and conventional EEG (cEEG) in the NICU.
2- To implement an algorithm delineating the use of aEEG vs. cEEG in the NICU for high risk subpopulations.
3- To standardizing the process of ordering, applying and interpreting EEG monitoring in the NICU.

Rationale for change:

Over the last several years, cerebral monitoring has become the corner stone of the assessment of cerebral function in encephalopathic neonates. In addition, studies continue to show that there are several subpopulations within the NICU that are at risk of electrographic seizures. These subpopulations range from neonates with hypoxic injury, stroke, those at risk of cerebral injury given cardio-pulmonary risk factors, and premature infants.

Standardizing and expanding the use of aEEG and conventional EEG for those at risk neonates will lead to informed management and better outcome of these babies.

Questions? Please contact: Director of Neonatal Neurocritical Care

Clinical Guideline Name	EEG Neuro-monitoring in the NICU
Effective Date	PENDING
Approved By	Pediatric Newborn Medicine Clinical Practice Council 06/09/16 CWN PPG 04/13/2016 BWH SPP Steering 04/20/16 Nurse Executive Board/CNO 4/26/16

This is a clinical practice guideline. While the guideline is useful in approaching the use of amplitude integrated and continuous EEG in the newborn intensive care unit, clinical judgment and / or new evidence may favor an alternative plan of care, the rationale for which should be documented in the medical record.

I. Purpose

a. To provide standardized clinical indications for the use of both amplitude integrated electroencephalography (aEEG) and continuous or conventional electroencephalography (cEEG) in the Neonatal ICU.
b. To standardize the process of ordering, applying, maintaining, scoring, and documenting aEEG and cEEG.
c. To outline the steps necessary to transition from aEEG to cEEG in high risk neonates.
d. To provide a guideline for the length of monitoring necessary to exclude seizures and for adequate assessment of cerebral function.
e. To outline the proper communication between nursing staff and providers as it relates to change in status of the patient.

II. All CPGs will rely on the NICU Nursing Standards of Care.

III. Definitions

Electrographic Seizure (ES): sudden, abnormal EEG event defined by a repetitive and evolving pattern with a minimum 2 mV pp voltage and duration of at least 10 seconds.

Electrographic Status Epilepticus (ESE): present when the summed duration of seizures comprises 50% of an arbitrarily defined 1-hour epoch or if a continuous seizure lasts greater than 30 minutes.

IV. Patient population

This protocol applies to neonates admitted to BWH Neonatal Intensive Care Unit who are critically ill and at risk of neurologic compromise. This includes but not limited to those with suspected hypoxic injury, stroke, meningitis, infants at risk of cerebral injury from cardio-pulmonary risk factors and premature infants.

V. Background/Summary Information

Over the last several years, cerebral monitoring has become the corner stone for the assessment of cerebral function in encephalopathic neonates in whom the examination may not be reliable. It is also vital in the detection of seizures which are often only electrographic or subclinical. Studies continue to show that there are several subpopulations within the NICU that are at risk of electrographic seizures. These subpopulations range from neonates with suspected hypoxic injury, stroke, those at risk of cerebral injury given cardio-pulmonary risk factors and preterm infants. Although cEEG is still considered the gold standard, aEEG has emerged as a very useful tool to monitor EEG trends in the NICU [1-4].

- **Term Infants with Neonatal Encephalopathy**

The value of the cEEG background pattern in the prediction of neurodevelopmental outcome is well established [5]. A poor background pattern; such as burst suppression, low voltage or a flat trace, that persists beyond the first 12 to 24 hours after birth is well known to carry a poor neurological prognosis.

Before therapeutic hypothermia became established as a treatment, a poor aEEG background pattern recorded within 3–12 hours of birth correlated with subsequent adverse neurodevelopmental outcome [6-10].The predictive value of aEEG is improved when combined with clinical examination [10]. Recovery of aEEG within 24 hours was associated with a more favorable outcome[11]. In addition, the onset of sleep wake cycling (SWC) before 36 hours was associated with improved neurological outcome [12].
Continuous EEG monitoring continues to be important after therapeutic hypothermia has been established. Although aEEG has been used in the inclusion criteria of hypothermia trials [13, 14], its use as an entry criterion has been challenged [15, 16].The predictive value of aEEG for neurodevelopmental outcome improves over the first 48-72 hours of cooling. The positive predictive value of an abnormal aEEG to detect an adverse neurodevelopmental outcome increases from as low as 35% in first 6 hours to up to 100% at 48-72 hours of life [17-19].

- **Seizure detection**

It is well known that neonatal seizures, or electrographic discharges do not necessarily result in clinical seizures [20]. More than 50% of seizures identified on cEEG/ aEEG in newborn infants may be silent or subclinical [21, 22]. Several studies have shown that, although the initial seizures are often clinical, subsequent seizures after administration of the first anti-epileptic drug could be subclinical in up to 50-85% of patients. cEEG and aEEG can play an integral role in the detection of these subclinical seizures [23-25]. While the impact of electrographic seizures on outcome remains controversial, recent studies suggest that patients with higher seizure burden may be at increased risk of neurologic sequelae [26, 27].

The use of aEEG has also extended to other conditions which put infants at risk of seizures in the neonatal period, including meningoencephalitis, metabolic disorders, congenital malformations, post–open-heart surgery, extracorporeal membrane oxygenation (ECMO) and lastly very low birth weight premature infants with intracerebral hemorrhage [28-33].

- **Premature Infants**

Studies utilizing continuous EEG monitoring during the first days of life showed that development of IVH and cerebral echodensities were associated with early amplitude depression and the presence of epileptic seizures, mainly subclinical [32-35]. Several cEEG and aEEG studies have shown early background depression to correlate with the severity of periventricular-intraventricular hemorrhage[30, 31]. Furthermore, postmortem studies of preterm infants with IVH, have shown that the number of damaged brain structures correlated even better with aEEG abnormality than with the degree of IVH [34]. On the other hand, presence of SWC at the end of first week of life was associated with better outcome [36]. It was also suggested that aEEG can show changes in post hemorrhagic hydrocephalus before development of signs of increased intracranial tension. These changes could be reversed by proper and timely management [37]. In addition, recent studies of early aEEG monitoring in extremely preterm infants suggest that seizures are very prevalent in the first 3 days of life in very premature infants with high seizure burden associated with severe brain injury and poor neurodevelopmental outcome [38].

VI. Guideline

- **Indications of Continuous Monitoring in the NICU**

  Combined aEEG/ cEEG protocol:

  - Therapeutic Hypothermia (Appendix 1)

  aEEG

  - Neonatal Encephalopathy: any neonate presenting with altered mental status
  - Patients on paralytic agent
  - Proven CNS infection

  cEEG:

  - Characterization of events concerning for seizures
  - Term infants with altered mental status associated with structural injury
  - Post cardiorespiratory arrest acute life threatening event (ALTE)
  - Non-accidental trauma
  - Neurology request to assess response to treatment with Anti-epileptics (AEDs)

- **Other conditions with high risk of electrographic seizures in which providers can consider aEEG monitoring in case by case based on best clinical judgment:**
  - High grade IVH (Grade 3 and 4)
  - Post-hemorrhagic hydrocephalus
  - Culture proven sepsis
  - Cardiac or pulmonary risks for acute brain injury (i.e. congenital heart disease, pulmonary hypertension, meconium aspiration, requiring inotropes)
  - CNS trauma
  - Inborn errors of metabolism
  - Cerebral dysgenesis or malformations
  - Neonatal Abstinence Syndrome

- **Modalities of Continuous EEG monitoring in the NICU**

  Combined aEEG/cEEG Monitoring:

  - *Protocol for Neonatal Encephalopathy receiving Therapeutic Hypothermia*
  - Neonates thought to be at high risk for hypoxic injury will be assessed for hypothermia based on the current protocol and started on aEEG on admission. All patients placed on hypothermia will be transitioned from aEEG to cEEG monitoring. cEEG monitoring will

be routinely performed for the initial 24 hours of hypothermia. At that point the cEEG will be assessed by Epilepsy/Neurology and a determination regarding which monitoring modality (cEEG or aEEG) to continue with will be decided. This will be based on the presence of cEEG features that suggest continued high risk of seizure activity (e.g. lateralized periodic discharges (LPDs), burst suppression). If the EEG is determined high risk, the patient will continue on cEEG. If not considered high risk, the patient will be transitioned to aEEG for the duration of hypothermia. If there is concern for seizure at any point during aEEG monitoring, then cEEG will be restarted. Continuous monitoring using a combination of cEEG and aEEG, will be continued through-out the hypothermia process, until 6 hr after re-warming is completed.

- **Amplitude Integrated Electroencephalography (aEEG) as primary modality**
  - aEEG will be used as the primary modality to assess neonates with any type of encephalopathy, following acute post-natal events, patient on paralytic agents, those with proven CNS infections and those at high risk of electrographic seizures.
  - Accurate detection of seizures in newborns can be difficult. Clinical seizures are frequently missed, and non-epileptiform movements are inappropriately documented as seizures. Additionally, neonatal seizures often only occur sub-clinically (electroclinical dissociation). Therefore, aEEG monitoring should be considered for all neonates at high risk of seizures.

- **Continuous Electroencephalography (cEEG) as primary modality**
  - *Characterization of events concerning for seizures:* For events suspicious for seizures cEEG will be requested with the goal of capturing the concerning event
  - *Altered mental status with structural injury:* In instances where neonatal encephalopathy persists in the presence of a structural injury cEEG should be performed for 24 hours
  - *Post cardiorespiratory arrest, acute life threatening event (ALTE), and non-accidental trauma:* Neonates with these conditions are at high risk of electrographic seizures and should be routinely monitored
  - *Assessment of response to Anti-epileptic treatment (AED):* In instances of weaning medications cEEG may be requested by Neurology to assess for electrographic seizures.

- **Duration of Continuous Monitoring (aEEG and cEEG) in the NICU**

  aEEG:

  - **Therapeutic Hypothermia** A combination of aEEG and cEEG will be continued through the hypothermia process and for 6 hours after rewarming is completed. **See Appendix 1 for specific details.**
  - **Infants on paralytic agents:** For the duration that paralytic agent is used.
  - **Evaluation for neonatal encephalopathy and all other high risk patients:** Minimum of 6 hours recording. The Medical Team can decide to extend this on a case by case basis as clinically indicated.

  cEEG:

  - **Seizure detection:** cEEG will continue for a minimum of 24 hours. This may be modified based on concerning background features.
  - **Monitoring after the last seizure:** cEEG will continue for 24 hours after the last seizure. Special attention will be paid to patients with cerebral malformations that are at continued risk despite 24 hours of no seizures. In this population 48 hours is necessary.
  - **Monitoring to assess response to Anti-epileptic treatment (AED):** If Neurology service requests cEEG will continue for 24 hours from the time of medication adjustment to assess for electrographic seizures. Decision to continue past this point will be based on clinical need at the Neurologists discretion.

- **Transition from aEEG to cEEG**

  If the initial aEEG recording is abnormal, this may prompt the transition to cEEG to provide greater detail. Features on the initial aEEG recording which are indications for transition to cEEG include:

  - Concern for electrographic seizure based on aEEG
  - Decision to initiate Therapeutic Hypothermia
  - Encephalopathy with abnormal aEEG background
  - Acute change in aEEG background

  See Appendix 1 for algorithm on aEEG/cEEG monitoring during Therapeutic Hypothermia- with details on timing and reason for transitioning between modalities

- **Technical Consideration Regarding Ordering, Applying, Maintaining, Scoring, Documentiong and Communication:**

aEEG

- **Ordering:** aEEG will be ordered by physician on Epic
- **Applying:**
  - Bedside nurse will acknowledge order in Epic
  - Superusers working that day will be identified at the shift huddle and the aEEG calendar
  - Superuser will be contacted verbally by the bedside nurse or nurse in charge
  - Superuser will apply aEEG electrodes promptly. If superuser is unable to apply leads, covering fellow or neonatologist will be notified.
  - aEEG application will be documented by the aEEG superuser in Epic as a progress note using the smart phrase .AEEGAPPLICATION
  - Application of aEEG will follow Policy and Procedure (Appendix-2)
- **Maintenance:**
  - If possible, patients on aEEG will be preferentially assigned to aEEG superusers as bedside nurses.
  - Bedside nurse will assess signal status for impedance when providing patient cares (minimum of q 4 hours). If indicator is red at any time, bedside nurse will notify superuser , charge nurse or provider (attending or fellow).
  - Superuser will assess skin integrity and electrode placement every 6 hours and document in medical record under "NICU Assessment", "Skin".
- **Interpretation:**

  aEEG will be scored according to background, cycling and presence of seizures (See aEEG scoring sheet, Appendix-3) [39]

- **Background Pattern:**
  - Continuous (C): Continuous activity with lower (minimum) amplitude around 5 to 10 mcV and maximum amplitude of 10 to 50 mcV.
  - Discontinuous (DC): Discontinuous background with minimum amplitude variable, but below 5 mcV, and maximum amplitude above 10 mcV.
  - Burst-suppression (BS): Discontinuous background with minimum amplitude without variability at 0 to 2 mcV and bursts with amplitude >25 mcV.
  - Low voltage (LV): Continuous background pattern of very low voltage (around or below 5 mcV).
  - Inactive, flat (FT): Primarily inactive (isoelectric tracing) background below 5 mcV.

- **Cycling;**
    - No Cycling: No cyclic variation of the aEEG background.
    - Imminent Cycling: Some, but not fully developed, cyclic variation of the lower amplitude, but not developed as compared with normative gestational age representative data.
    - Developed Cycling: Clearly identifiable sinusoidal variations between discontinuous and more continuous background activity, with cycle duration >20 min.

        - aEEG will be reviewed and scored by superuser twice per shift (i.e. every 6 hours).
        - aEEG superuser will be called to bedside any time patient has seizure like activity, change in aEEG pattern or concern for electrodes malfuntion.
        - Neonatologist or fellow will be notified for any change in aEEG background or concern for seizure activity.

- **Doumentation**
    - A daily formal report outlying the prior 24 hours of aEEG will be provided by the Pediatric Epilepsy service and documented in Epic as a consult note.
    - Providers will include aEEG findings in the daily progress notes.

cEEG

- **Ordering:**
    - cEEG may be requested through the Pediatric Neurology ICU consult service.
    - The "Newborn Procedure Referral Form" needs to be signed daily by NICU provider to be available on bedside when cEEG technologist arrives.
    - During working hours this request may be made directly from the Pediatric Neurology ICU resident to technical staff after an order is placed in powerchart
    - A 1 hour baseline read will be requested by the Pediatric Neurology ICU resident after discussion with the Epileptology ICU fellow on call
    - During evening and off hours the request for EEG needs to be discussed amongst the Epilepsy and Pediatric Neurology ICU attending. (An exception is starting therapeutic hypothermia, where Pediatric Neurology ICU resident can directly put the order in). The order should then be placed and a call to the overnight technologist should be made informing them of the order.

- **Applying**
    - cEEG electrodes will be applied by trained neurophysiology technologists.

- **Maintenance:**
  - cEEG electrode quality will be assessed by inspection and impoedance testing by trained neurophysiology technologists on a daily basis.
- **Interpretation:**
  - The interpretation of the cEEG will be based on published ACNS guideline [4]. Details reported will focus on clinical and electrographic state change as well as the degree of continuity based on gestational age, synchrony, reactivity, and presence or absence or normal graphoelements.
- **Documentation:**
  - A daily formal report outlying the prior 24 hours of cEEG will be provided by the epilepsy service

- **Contraindications for Continuous EEG Monitoring:**

  Extensive skin excoriation of scalp. Benefits will be weighed against harms of applying aEEG. Clinical stability will be taken into consideration after the clinical decision to monitor has been made.

  Factors affecting the amplitude of aEEG such as significant scalp edema, cephalhematoma etc, will be considered when starting or interpreting aEEG.

- **Communication Guidelines:**

aEEG:

- Any change in the baseline status of the EEG or if there is suggestion of concern for electrographic seizures, this information should be relayed to the Neonatal ICU resident/PA/NNP/fellow and subsequently the attending.
- If there is high enough concern, the Pediatric Neurology ICU resident should be contacted.

cEEG:

- A baseline read will be provided 1 hour after the cEEG has begun. During the day this request will be made by the Pediatric Neurology ICU resident to the Epileptology ICU fellow. After hours the baseline will be provided by the Epileptology ICU attending and will be requested by the Pediatric Neurology ICU resident.
- Daily reads will be provided at 10-11 AM and PM edits will be relayed at 3 PM to the Pediatric Neurology ICU consult resident.
- The necessity for more frequent reads will be based on the clinical state of the patient and the degree to which the results will change clinical management
- Technologists will only be contacted for matters related to electrodes maintenance, and not for any clinical concerns.

Appendices:

Appendix 1: **Algorithm for EEG Monitoring in Neonatal Hypothermia**
Appendix 2: Guidelines for applying aEEG electrodes
Appendix 3: aEEG Classification Sheet
Appendix 4: Parent sheet for EEG monitoring

- **References**

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