Continuous (Long-Term) EEG Monitoring Guideline

Definition:

Continuous (or "long-term") electroencephalography (EEG) monitoring refers to continuous recording of brain activity via scalp electrodes over a period of hours to days, often in association with time-locked video to correlate clinical findings. Over recent years, continuous EEG monitoring has played an increasing role in inpatient care, both on the general wards and in intensive care units. This is due, in part, to increased recognition of the ubiquitousness of nonconvulsive seizures and nonconvulsive status epilepticus across a variety of clinical situations.

Nonconvulsive seizures (NCS), also called subclinical, electrographic-only, subtle, occult, or silent seizures, have minimal or no overt clinical signs and can only be reliably diagnosed using continuous EEG (CEEG). There is increasing evidence supporting the potentially detrimental effects of NCS and nonconvulsive status epilepticus (NCSE) on clinical outcomes both in neonates and children [1]

The American Clinical Neurophysiology Society has provided evidence-based recommendations regarding indications which warrant continuous EEG monitoring in critically ill adults, children and neonates. Continuous EEG is indicated in the following situations: diagnosis of nonconvulsive seizures, nonconvulsive status epilepticus, and other paroxysmal events, assessment of efficacy of therapy for seizures and status epilepticus, monitoring of sedation and high-dosed suppressive therapy, assessment of severity of encephalopathy and prognostication. Other indications for continuous EEG are: diagnosis of epileptic syndromes or unclassified epilepsy, pre-surgical evaluation for drug-resistant epilepsy, follow-up of epilepsy or in cases of paroxysmal symptoms whose etiology remains uncertain.[38]

Incidence:

Nonconvulsive seizures (NCS) occur in 6-47% of children with altered mental status and in 11-100% of children following acute supratentorial brain injury depending on the type and severity of injury.

Statistics vary regarding the incidence and prevalence of seizures with respect to the age and clinical scenario of a specific population. For example, the incidence of seizures in term infants is 0.5-3 per 1000 live births. In preterm infants, the incidence is even higher, 57–132 per 1000 live births. Nearly 80% neonatal seizures occur in the first 1–2 days to the first week of life. Lower birth weight and gestational age confers increased risk, which is reflected by the increased incidence of neonatal seizures in preterm newborns. [42]

There are common neurological, medical and neurosurgical conditions associated with high likelihood of recording electrographic seizures with or without clinical correlation on continuous EEG. For example, in children seizures are recorded in: 26%-57% following convulsive status epilepticus, 11%-100% of those with

intraparenchymal hemorrhage, 14%-70% of those with moderate-to-severe traumatic brain injury, 16%-100% of those with central nervous system infections, 20%-17% of those with acute ischemic strokes, 16%-79% of those with hypoxic-ischemic encephalopathy, 58% of those with sepsis-associated encephalopathy, 21% of those on extracorporeal membrane oxygenation, up to 71% of those with an epilepsy-related condition. [10]

Guideline Inclusion Criteria:

Critical and non-critical neonates or children post convulsive status epilepticus, with acute encephalopathy, brain injury, paroxysmal events of unknown significance and those undergoing specific protocols and procedures that put them at a high-risk of sustaining neurologic injury.

Guideline Exclusion Criteria:

Epilepsy Monitoring Unit (EMU) patients

Diagnostic Evaluation:

Continuous EEG monitoring involves standardized placement of electrodes by a trained EEG technologist according to the International 10-20 system or a modified neonatal version thereof. Single-channel EKG and continuous digital video are recorded. In the case of neonates, additional leads such as respiratory and oculomotor leads are often used to help discern cerebral activity from infarct. Automated spike and seizure detection software are used.

Monitoring time is an important factor affecting the diagnostic examination results. Longer measurement time is associated with higher detection rate for nonconvulsive seizures, with a rate of 56% with 1 hour and ≥ 80% with a 12 hour recording, suggesting the need for longer measurement time for patients strongly suspected of having NCS. [40]

Critical Points of Evidence

Evidence Supports

1) Monitoring following seizures/status epilepticus (children: if abnormal mental status, ALL neonates)

- Children with persistent abnormal mental status* following convulsive seizures or status epilepticus should be monitored with continuous video EEG (CEEG) for a minimum of 24 hours † to assess for nonconvulsive seizures (NCS) and nonconvulsive status epilepticus (NCSE). CEEG should be initiated as soon as possible.[§,6,7,8,9]

  ** If no improvement in mental alertness in 10 minutes OR no return to baseline by 60 minutes after seizure(s)/status stopped, should have EEG.*

  † Children with a history of epilepsy or with interictal discharges on EEG should be monitored for a minimum of 48 hours.

  § EEG should be ordered STAT once criteria for abnormal mental status met.

- All neonates should be monitored with CEEG for a minimum of 24 hours* after convulsive status epilepticus or other clinically evident seizures to assess for NCS and NCSE. CEEG should be initiated as soon as possible. † [6,7,8,9]

  ** If interictal discharges are present on EEG, monitoring should be extended to a minimum of 48 hours.*

† *EEG should be ordered STAT.*

2) Suspected or confirmed acute supratentorial brain injury (children: if abnormal mental status, ALL neonates)

- Children with suspected or confirmed acute supratentorial brain injury* with altered mental status should be monitored with CEEG for a minimum of 24 hours† to detect NCS and NCSE. CEEG should be initiated as soon as possible.§ [10,1)]

  ** Including intracranial hemorrhage, moderate to severe TBI, CNS infection, brain tumors, hypoxia/ischemia (including acute ischemic stroke and status-post CPR), sepsis related encephalopathy*

  † *If interictal epileptiform discharges or periodic discharges present, should be monitored for a minimum of 48 hours*

  § *EEG should be ordered STAT once abnormal mental status determined.*

- All neonates with suspected or confirmed supratentorial brain injury* should be monitored with CEEG for a minimum of 24 hours† to detect NCS and NCSE. CEEG should be initiated as soon as possible.§ [12,13,14,15,16,17]

  ** Including hemorrhage (SAH, ICH, IVH), TBI (NAT and birth trauma), CNS infection, sepsis-related encephalopathy, suspected HIE (not on hypothermia)*

  † *If interictal epileptiform discharges or periodic discharges present, should be monitored for a minimum of 48 hours*

  § *EEG should be ordered STAT*

3) Abnormal mental status without brain injury or preceding seizures (all children and neonates)

- All neonates/children with unexplained fixed or fluctuating altered mental status* should be monitored with CEEG for a minimum of 24 hours† to detect NCS and NCSE. CEEG should be initiated as soon as possible.§ [10,18,19,20]

  ** including agitation, lethargy, aphasia, neglect, obtundation and coma*

  † *If patient comatose or if interictal epileptiform discharges or periodic discharges present, should be monitored for a minimum of 48 hours*

  § *CEEG should be ordered STAT as soon as AMS recognized*

4) Pharmacologic paralysis/hypothermia/cardiopulmonary bypass (all children and neonates)

- Neonates/children who are pharmacologically paralyzed* and who are at risk for seizures† should be monitored with CEEG for a minimum of 24 hours§ to detect NCS and NCSE. CEEG should be started as soon as possible after initiation of neuromuscular blockade. [10,21,22,23,24]

  ** Including patients undergoing therapeutic hypothermia or extracorporeal membrane oxygenation (ECMO)*

  † *Including cardiac or pulmonary risk factors (severe persistent pulmonary hypertension, need for ECMO, congenital heart defects requiring early surgery using cardiopulmonary bypass) or a history of seizures/epilepsy*

  § *If patient on ECMO or if interictal epileptiform discharges or periodic discharges present, should be monitored for a minimum of 48 hours.*

- All neonates/Children undergoing therapeutic hypothermia protocols following HIE or cardiac arrest should be monitored with CEEG while hypothermic and for a minimum of 24 hours after achieving normothermia to detect NCS and NCSE. CEEG should be initiated as soon as possible after initiation of hypothermia protocol.[25,26,27]
- All neonates/Children who've undergone cardiopulmonary bypass should be monitored with CEEG for a minimum of 48 hours after coming off bypass to detect NCS and NCSE. CEEG should be initiated as soon as possible after coming off bypass.[24]

5) Paroxysmal events

- Neonates/children with paroxysmal events that are suspected to be seizures* should be monitored with CEEG for a minimum of 24 hours or until events recorded † to determine whether the event is ictal or interictal.[28,29,30,31,32]

  ** including clinical events (e.g. sustained gaze deviation, tremulousness, posturing, shivering or jerking) or paroxysmal changes in vital signs (e.g. apneas, oxygen desaturations, tachycardia, increases in intracranial pressures)*

  † If risk factors for seizures present (e.g. pulmonary or cardiac conditions, history of brain injury or seizure) or if interictal epileptiform discharges or periodic discharges present, monitoring should be continued for a minimum of 48 hours or until events are recorded.

6) Slowing or periodic discharges on short-term EEG

- Critically ill children with new periodic discharges or lateralized rhythmic delta activity on routine or urgent EEG should be monitored with CEEG for a minimum of 48 hours. CEEG should be initiated as soon as possible.[33,34]

7) Inborn errors of metabolism/genetic syndromes

- Neonates with suspected or confirmed inborn errors of metabolism or genetic syndrome* should be monitored on CEEG for a minimum of 24 hours to rule out NCS/NCSE. CEEG should be initiated as soon as possible.[35,36,37]

  ** for example, dysmorphology, abnormal preliminary genetic or metabolic screening tests, or CNS malformations of neuroimaging*

8) History of NCS/NCSE and weaning medications

- Neonates/children with a history of NCS/NCSE who are at risk for recurrent seizures* should be monitored with CEEG while anti-seizure medications are weaned and for a minimum of 24 hours afterwards.

  ** In neonates/children with acute acquired brain injury (e.g., arterial ischemic stroke or hypoxic-ischemic encephalopathy) are unlikely to recur soon after the resolution of the acute phase. Conversely, neonates at a high risk for seizure recurrence (e.g., cerebral dysgenesis or malformations, tuberous sclerosis or neonatal epilepsy syndromes) may have a relapse of seizures if medications are withdrawn*

9) Burst Suppression

- Neonates/children requiring* therapeutic † burst suppression should be monitored with CEEG to quantify adequate number of bursts and interbursts to avoid over-sedation.
  See Status Epilepticus protocol

  ** Including refractory status epilepticus, intracranial hypertension*

  † Commonly used drugs are pentobarbital, midazolam, ketamine and propofol infusions

Practice Recommendations and Clinical Management

Diagnosis:

Neonates or children post convulsive status epilepticus or who fail to return to baseline after convulsive seizures, with acute encephalopathy, brain injury, or paroxysmal events of unknown significance and those undergoing specific protocols and procedures that put them at a high-risk of sustaining neurologic injury should be monitored with cEEG for accurate diagnosis of both clinical and subclinical seizures. Indications and recommended durations are provided in the following tables:

Continuous EEG Monitoring Guidelines by Indication

Children

Indication	Priority	Recommended Minimum Duration (hrs)
Persistent abnormal mental status[1] following convulsive seizures or status epilepticus	Stat	24-48[2,3]
Suspected or confirmed acute supratentorial brain injury[4] with altered mental status	Stat	24-48[2]
Unexplained fixed or fluctuating altered mental status[5]	Stat	24-48[2,6]
Pharmacologic paralysis (including ECMO) with risk for seizures[7]	Urgent	24-48[2,8]
Therapeutic hypothermia following HIE or cardiac arrest	Urgent	During cooling, hypothermia, rewarming and for 24 hrs after achieving normothermia[2]
Cardiopulmonary bypass	Urgent	For minimum 48 hrs after off bypass
Paroxysmal events suspected to be seizures[9]	As clinically indicated	For minimum 24-48 hrs or until events recorded [2,10,11]
Critically ill children with abnormal findings on routine or urgent EEG[12]	Urgent	24-48[2]

Call Neurology prior to ordering any continuous EEG studies.
Stat priority = tech to bedside within 15 min. Urgent priority = tech to bedside within 2 hrs. Routine priority = tech to bedside within 6 hrs.

Neonates

Indication	Priority	Recommended Minimum Duration (hrs)
Following any clinically evident seizure(s)	Stat	24-48[2]
Suspected or confirmed supratentorial brain injury[13]	Stat	24-48[2]
Unexplained fixed or fluctuating altered mental status[5]	Stat	24-48[2,6]
Pharmacologic paralysis (including ECMO) with risk for seizures[7]	Urgent	24-48[2,8]
Therapeutic hypothermia following HIE or cardiac arrest	Urgent	During cooling, hypothermia, rewarming & for 24 hrs after achieving normothermia[2]
Cardiopulmonary bypass	Urgent	For minimum 48 hrs after off bypass
Paroxysmal events suspected to be seizures[9]	As clinically indicated	For a minimum of 24-48 hours or until events are recorded[2,10,11]
Suspected or confirmed inborn errors of metabolism or genetic syndrome [14]	As clinically indicated	24-48 hours[2]

Weaning seizure medications with a history of NCS/NCSE[15]	As clinically indicated	24-48 hours[2]
Call Neurology prior to ordering any continuous EEG studies. Stat priority = tech to bedside within 15 min. Urgent priority = tech to bedside within 2 hrs. Routine priority = tech to bedside within 6 hrs.		

1. *Defined as no improvement in mental alertness in 10 minutes OR no return to baseline mental status by 60 minutes after seizure/status epilepticus has stopped*
2. *If interictal epileptiform or periodic discharges present on EEG, should be monitored for a minimum of 48 hours.*
3. *If a history of epilepsy, should be monitored for a minimum of 48 hours*
4. *Including intracranial hemorrhage, moderate to severe TBI, CNS infection, brain tumors, hypoxia/ischemia (including acute ischemic stroke and status-post CPR), sepsis related encephalopathy*
5. *Including agitation, lethargy, aphasia, neglect, obtundation and coma*
6. *If patient comatose, should be monitored for a minimum of 48 hours*
7. *Including cardiac or pulmonary risk factors (including severe persistent pulmonary hypertension, congenital heart defects requiring early surgery using cardiopulmonary bypass) or a history of seizures/epilepsy*
8. *Patients on ECMO should be monitored for a minimum of 48 hours*
9. *Including clinical events (e.g. sustained gaze deviation, tremulousness, posturing, shivering or jerking) or paroxysmal changes in vital signs (e.g. apneas, oxygen desaturations, tachycardia, increases in intracranial pressures)*
10. *Pushbutton by ICU RN required.*
11. *If risk factors for seizures present (e.g. pulmonary or cardiac conditions, history of brain injury or seizure) or if interictal epileptiform discharges or periodic discharges present, monitoring should be continued for a minimum of 48 hours or until events are recorded. Multiple events may be needed*
12. *Including new epileptiform or periodic discharges or lateralized rhythmic delta activity*
13. *Including hemorrhage (SAH, ICH, IVH), TBI (NAT and birth trauma), CNS infection, sepsis-related encephalopathy, suspected HIE (not on hypothermia)*
14. *Including dysmorphology, abnormal preliminary genetic or metabolic screening tests, or CNS malformations of neuroimaging*
15. *In neonates/children with acute acquired brain injury (e.g., arterial ischemic stroke or hypoxic-ischemic encephalopathy), seizures are unlikely to recur soon after the resolution of the acute phase. Conversely, neonates at a high risk for seizure recurrence (e.g., cerebral dysgenesis or malformations, tuberous sclerosis or neonatal epilepsy syndromes) may have a relapse of seizures if medications are withdrawn*

Outcome Measures

- %CEEG - Percentage of patients with indications for CEEG who are monitored or, if not, have a reason documenting why not in their medical record
- Time order/bedside - Time lag between CEEG order placed and tech at bedside
- Time order/running - Time lag between CEEG order placed and study running
- Time run/review - Time lag between CEEG started and initial review by epileptologist
- Time to treat - Time lag between seizure onset and treatment initiation
- %CEEG24 - Percentage of patients with indications for CEEG monitoring who are monitored for at least 24 hours, or have documentation why taken off early
- LengthPostSz - Duration of time CEEG continued after last subclinical seizure
- %NeuroContact - Secondary - Neurology contacted or referral placed if CEEG ordered
- %Seizures - Percentage of patients with indications for CEEG monitoring who have seizures (differentiating clinical, subclinical, or both) during monitoring
- %ChangeMgmt - Secondary - Does CEEG alter clinical management
    - Initiation, escalation or discontinuation of an anti-epileptic medication
    - Extension of the monitoring
    - Ordering of neuroimaging
- LOS - Secondary - Does CEEG use affect length of stay for patient population
- Mortality - Secondary - Is use of cEEG associated with decreased mortality rate

Methods

Existing External Guidelines/Clinical Pathways

Existing External Guideline/Clinical Pathway	Organization and Author	Last Update
PICU, NICU and CICU Clinical Pathway for Children who Require EEG Monitoring	CHOP - Children's Hospital of Philadelphia	April 2019

Any published clinical guidelines have been evaluated for this review using the **AGREE II criteria**. The comparisons of these guidelines are found at the end of this document. **AGREE II criteria** include evaluation of: Guideline Scope and Purpose, Stakeholder Involvement, Rigor of Development, Clarity of Presentation, Applicability, and Editorial Independence.

Review of Relevant Evidence: Search Strategies and Databases Reviewed

Search Strategies	Document Strategies Used
Search Terms Used:	cEEG, EEG Monitoring, altered mental status, Long Term EEG, Electrophysiology
Years Searched - All Questions	1998-2020
Language	English
Age of Subjects	0-18 years old
Search Engines	PubMed, Scholar Google
EBP Web Sites	
Professional Organizations	www.ACNS.org - American Clinical Neurophysiology Society
Joint Commission	
Government/State Agencies	None
Other	

Evidence Found with Searches

Check Type of Evidence Found	Summary of Evidence – All Questions
x	Systematic Reviews
x	Meta-analysis articles
x	Randomized Controlled Trials
☐	Non-randomized studies
x	Review articles
☐	Government/State agency regulations
x	Professional organization guidelines, white papers, ect.

Evaluating the Quality of the Evidence

The GRADE criteria were used to evaluate the quality of evidence presented in research articles reviewed during the development of this guideline. The table below defines how the quality of evidence is rated and how a strong versus a weak recommendation is established.

Recommendation	
Strong	Desirable effects clearly outweigh undesirable effects or vice versa
Weak	Desirable effects closely balanced with undesirable effects
Type of Evidence	
High	Consistent evidence from well-performed RCTs or exceptionally strong evidence from unbiased observational studies
Moderate	Evidence from RCTs with important limitations (e.g., inconsistent results, methodological flaws, indirect evidence, or imprecise results) or unusually strong evidence from unbiased observational studies
Low	Evidence for at least 1 critical outcome from observational studies, from RCTs with serious flaws or indirect evidence
Very Low	Evidence for at least 1 critical outcome from unsystematic clinical observations or very indirect evidence

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