How to set up a Neurocritical Care Unit with continuous EEG service

Patients in the intensive care unit can frequently experience seizures, especially those suffering from traumatic brain injury (TBI). If undetected, seizures can be life-threatening and difficult to recognize clinically, especially non-convulsive seizures. In TBI patients, seizure activity can occur at later stages of injury, sometimes even more than seven days post-injury. To detect neurological deterioration and prevent secondary brain injury, it is critical to accurately monitor TBI patients over extended periods of time.

Continuous Electroencephalography (cEEG) is one of the most effective and inexpensive ways to dynamically detect and record changes in both brain activity and function. However, many aspects of cEEG monitoring remain unclear and the ICU staff is usually not well trained in EEG interpretation. In this guide, you will learn the key practical aspects of setting up a Neuro Critical Care Unit with cEEG service to monitor and manage TBI patients.

Identify and minimize artifacts with video EEG monitoring

From an electrical point of view, the ICU is not a friendly environment with several types of artifacts often affecting EEG recordings:

- Environmental artifacts – such as AC current artifact
- Electrode and recording equipment artifacts
- Patient artifacts – movement, pulse, cardiac and sweating artifacts[1]

To learn more about how to collect good quality EEG and artifact handling, click to watch this free eSeminar.

Some artifacts can be minimized or even eliminated by using notch filters or replacing faulty, loose electrodes, while others can be annotated on the EEG recording itself. But what if there is no possibility of annotating the EEG?

Without a video recording, it can be difficult to recognize clinically relevant events from artifacts. An example is distinguishing seizures from rhythmic movement artifacts due to the patient having intermittent tremors of limb(s), which may or may not correlate with an electrographic seizure. This underlines the importance of video monitoring and live annotation features of the EEG system in the ICU.

In addition to video, many cEEG systems are now capable of displaying a substantial amount of data in a single screen, which makes it easier to interpret longer studies, recognize significant changes and intervene in a timely manner.

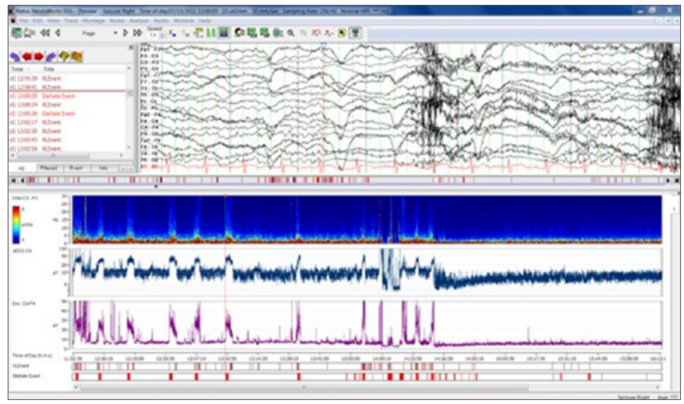
Detect seizures with real-time EEG reviews and quantitative EEG trends

Quantitative EEG trends assist in the interpretation of complex information by displaying a simple graphic with a compressed time scale of the EEG with algorithms that display parameters, such as frequency, amplitude and time. This has been shown to improve the real-time analysis of EEG changes by non-neurophysiological staff, such as ICU nurses, after a period of training and education. Some EEG systems also allow non-expert staff to rely on seizure probability and seizure detection features in real-time reviews.[2]

1"Recommendations for good quality EEG handling." eSeminar, Natus Medical Incorporated, 037884A
2 Swisher C et al. J Clin Neurophysiology 2015; 32: 324-330 & Dericioglu N et al. Epilepsy Research 2015; 109, 48-56

Quantitative EEG trends

Quantitative EEG trends are timesaving compared to the review of conventional raw EEG, which can take up to 24 hours of EEG recording. This means that quantitative EEG trends can reduce the time required for reviewing hours of EEG recordings in the ICU, where recordings can be up two weeks, contaminated by artifacts and the need for immediate review is often pivotal to adjust treatment regimens straight away.



Raw EGG review time compared to quantitative EEG trends.

Frequency-based trends

Quantitative EEG displays, such as Density Spectral Array (DSA) and Compressed Spectral Array (CSA), allows ICU staff to detect seizures by color intensity, instead of waveforms, from long-term EEG data. DSA allows for extended frequency bandwidth analysis and different color schemes to observe sleep cycles and depths of anesthesia.

Moreover, DSA can provide information about the level of sedation in critically ill patients and in combination with qEEG-based (Quantitative Electroencephalogram) tools, to provide a measurement of burst suppression through automated calculation of suppression ratio suppression rate and IBI (inter-burst interval).

Alpha variability graphically displays the variability of alpha frequency components over time. Alpha is associated with states of consciousness – variations in alpha are related to cerebral ischemia and prognostication of vasospasm, especially helpful in ICU patients who suffered from subarachnoid hemorrhage (SAH).[3]

3 https://www.sciencedirect.com/science/article/abs/pii/S0013469497000710

Amplitude trends, such as the envelope, track changes in amplitude with a specialized algorithm that helps in filtering the transitory events but gives evidence to the rhythmic events compatible with seizure identification. Envelope trend can be used for TBI patients or any patient suspected of having seizures.[4]

Amplitude-integrated EEG (aEEG, CFM) provides valuable information about significant changes in amplitude in a semilogarithmic scale for easy identification of background pattern classifications commonly seen in cardiac arrest patients during hypothermia.[5] aEEG is the gold standard in neonatal ICU for detection of seizures on HIE, IVH in newborns.[6]

Use of mixed or transitional staffing models and training for non-specialists

Patients with TBI and other severe neurologic illnesses have better outcomes when managed by a physician and interdisciplinary team with experience and expertise in neurocritical care. As such, one of the most important factors to set up a neurocritical care unit with cEEG service is the staffing model.

The ideal model, of course, includes 24/7 coverage by specialist staff similarly to a neuro telemetry unit for epilepsy patients. However, this model is expensive and not always feasible. For this reason, many ICUs have adopted less resource-dependent staffing models, such as mixed or transitional models. Some units also use remote reporting, where initiation, maintenance and review are shared by neurophysiology and critical care departments.

The Neurocritical Care Society provides guidelines on how to adequately staff your unit, which are accessible via the society website.

In addition to setting up the right team, it is critical to run rolling training sessions for non-specialists. We find that the most common learning objectives are seizure identification and the use and interpretation of the various qEEG trends. The teaching methods can range from large group didactic lectures to self-learning and 1:1 review with experts on EEG. To make sure that the ICU staff is at the top of their game, the educational initiatives should employ some form of final assessment, such as quizzes, or even real-time EEG interpretation.

4 https://journals.lww.com/clinicalneurophys/Abstract/2015/08000/Diagnostic_Accuracy_of_Electrographic_Seizure.8.aspx
5 https://link.springer.com/article/10.1007%2Fs00134-006-0178-6
6 https://publications.aap.org/neoreviews/article-abstract/7/2/e76/87092/Amplitude-integrated-EEG-Classification-and?redirectedFrom=fulltext

Prioritize patients based on the highest risk of seizures or status epilepticus

In most ICUs, you will find a large number of patients but limited resources. For this reason, you need to develop a prioritization protocol based on the highest risk of seizures. At the top of the list are patients with convulsive status epilepticus or at considerable risk of having non-convulsive status epilepticus (NCSE).

Convulsive status epilepticus is defined as prolonged seizures lasting more than five minutes without recovery of consciousness, whereas NCSE is a state of repetitive seizures without prominent motor symptoms. While NCSE is associated with poor neurological outcome, it is difficult to detect because the patients do not have any physically visible clinical manifestations. In fact, studies show that standard EEG misses identifying NCSE in more than 75% of cases while cEEG is able to identify up to 80% of NCSE.[7]

ICU patients with a history of epilepsy, recent GCSE (General Convulsive Status Epilepticus), acute brain insult or fluctuating level of consciousness are at risk of having convulsive and/or non-convulsive seizures.

Accordingly, it is necessary to progressively screen these patients in the ICU and allocate cEEG studies for patients with unexplained stupor, comatose, or those who have high suspicion of seizures.

Next on the priority list are patients who have unclear or repetitive clinical events, abnormal movements, previous recording with an interictal continuum or subarachnoid hemorrhage at elevated risk of delayed cerebral ischemia. Last on the list are patients who have received high levels of sedation or patients that require numerous other neurological medications.

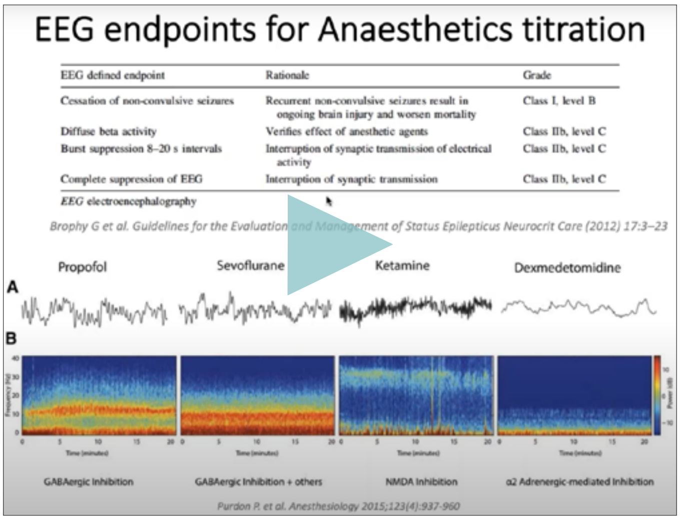
Different anesthetics have different electroencephalographic signatures

cEEG is not only important when used to monitor treatments used for seizure activity, but also when monitoring sedation and anti-epileptic drug effectiveness. Because TBI and other ICU patients tend to stay in intensive care for a very long time, there may be a need to use different intravenous anesthetics to treat them.

However, you need to be aware that different anesthetics, such as Propofol, Midazolam Sevoflurane and Ketamine, have different molecular and neural circuit mechanisms, resulting in different electroencephalographic signatures. These medications can affect the EEG and even result in burst suppression patterns.

7 Friedman D, Claassen J, Hirsch LJ (2009) Continuous electroencephalogram monitoring in the intensive care unit. Anesth Analg, 109(2): 506–23. https://healthmanagement.org/c/icu/issuearticle/quantitative-eeg-in-icu-useful-and-feasible

Occasionally, anesthetics have an unexpected signature, such as Dexmedetomidine, which is a sedative drug, where the patients are actually sleeping and breathing spontaneously, but are very easily woken up just by calling their name. This may not be evident just by looking at spectrograms, as shown below:


EEG endpoints for Anaesthetics titration

EEG defined endpoint	Rationale	Grade
Cessation of non-convulsive seizures	Recurrent non-convulsive seizures result in ongoing brain injury and worsen mortality	Class I, level B
Diffuse beta activity	Verifies effect of anesthetic agents	Class IIb, level C
Burst suppression 8–20 s intervals	Interruption of synaptic transmission of electrical activity	Class IIb, level C
Complete suppression of EEG	Interruption of synaptic transmission	Class IIb, level C

EEG electroencephalography

Brophy G et al. Guidelines for the Evaluation and Management of Status Epilepticus Neurocrit Care (2012) 17:3–23

Keep in mind that there are frequent drug interactions in the ICU and the pharmacology of anti-epileptic drugs and anesthetics is completely altered during critical illness. For this reason, treatment needs to be protocolized. You can find further guidelines on this with the Neurocritical Care Society.[8]

Improve clinical practice with multi-modal monitoring

The integration of data from different neuro monitoring modalities can improve clinical practice in the Neuro ICU. For this reason, most manufacturers are moving towards advanced software integrations with other devices and monitors, such as physiological signal integration.

This allows ICU staff to co-register the EEG and other physiological parameters to be displayed on the monitor, including vital signs, intracranial pressure monitoring (ICP), partial pressure of oxygen to the brain, serial blood pressure, continuous brain tissue oxygen (PbtO2), near-infrared spectroscopy (NIRS), end-tidal CO2 and so on.

This way, if you are looking at EEG trends, you can also look at ICP to see if there is an association with any EEG changes. In fact, ICP monitoring is recommended to reduce in-hospital mortality and two-week post-injury mortality, according to the Brain Trauma Foundation.

8 https://higherlogicdownload.s3.amazonaws.com/NEUROCRITICALCARE/b8b3b384-bfb9-42af-bb55-45973d5054a4/UploadedImages/Documents/Guidelines/SE_Guidelines_NCS_0412.pdf

Recommendations on electrodes, channels, montages and recording duration

The minimum number of electrodes for critical care EEG is 16, according to The American Clinical Neurophysiology Society. If the reduction in the number of leads is down to four or six, this could translate in missed EEG events and thereby limit the review interpretability.

Even though evidence suggests that needle and corkscrew electrodes are less likely to fail in long-term studies, they always carry the risk of scalp injury, skin breakdown, bleeding and needle stick injury for ICU staff. For these reasons, we recommend adopting the standard disposable cup electrodes as shown below, which will also reduce the risk of cross-contamination resulting in infection.[9]

The choice of head box and amplifier very much depends on the number of EEG channels and type of additional channels required, such as EMG and SpO_2. We recommend a standard 10-20 system with 19-25 channels or the high-density array with more than 25 channels, which follows the guidelines from The American Clinical Neurophysiology Society.

A study by professor Jan Claassen at Columbia University[10] found that to detect 90 to 95% of non-convulsive seizures, the EEG recording had to be at least 12 to 24 hours long and up to 48 hours for comatose patients. Accordingly, we recommend following the below recording duration:

- cEEG for four hours if real-time review and no seizures
- cEEG for up to 24 hours in non-comatose patients if no real-time review
- cEEG for up to 48 hours in comatose patients if no real-time review

9 https://neuro-training.academy/download/disposable-single-use-eeg-cup-electrodes-as-a-solution-for-contamination-problems/
10 Claassen J, et al. Neurology 2003.

Pathologies that benefit from cEEG monitoring

TBI | Stroke | Coma | Cardiac arrest | Post-op Neurosurgery complications

TBI | Traumatic brain injury (TBI) occurs when an external force affects normal brain function or pathology. TBIs can range in classification from mild to severe but all classifications pose a risk for neurological decline in the first 24 hours. cEEG monitoring assists the ICU staff in anticipating and preventing secondary injury or irreversible brain damage.

Stroke | Seizures after stroke range from 2% to 9%, and in patients with ischemic stroke the seizures risk increased mortality. For this reason, cEEG is becoming an important method for assessing neurological status in stroke patients.

Coma | Non-convulsive seizures are common in comatose patients, and the majority of seizures in these patients cannot be detected without cEEG monitoring. In addition, cEEG is used to guide management of pharmacological coma for treatment of increased intracranial pressure and identification of patterns compatible with patients' ability to regain consciousness.

Cardiac arrest | Up to 35% of patients with cardiac arrest will also have a seizure, and the presence of seizures after cardiac arrest may have important prognostic implications. qEEG tools, such as amplitude-integrated EEG, can be used to predict outcome after cardiac arrest.

Post-op Neurosurgery complications | Neurosurgical procedures pose a risk of postoperative seizures between 4% to 17%. However, postoperative seizures are not limited to neurosurgical procedures, but can also occur in patients receiving a pancreas, liver, lung, heart, kidney or bone marrow transplant.

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