7 Steps to Assess Every aEEG

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INTRODUCTION

Over the last decade, amplitude-integrated EEG, aEEG has gained in popularity, but many Neonatologists state that they feel uncomfortable reading aEEG patterns and most say they have never received any training on aEEG (1,2).

As a brief review, aEEG is derived from the EEG signal collected from surface or needle electrodes placed over the central and parietal regions. The EEG signal is filtered, rectified, and compressed and then plotted every 15 seconds on a semi-logarithmic scale at a rate of 6 centimeters per hour. Normative voltage for the five most common aEEG patterns has been published for both term and preterm infants. (3,4)

There are currently three common ways that aEEG is utilized at the bedside:

- Assess background pattern to look for severity of brain injury
- Assess for the presence of sub-clinical seizures
- Assess for changes in background patterns over time that might indicate the effectiveness of medications and other neuroprotective interventions, like therapeutic hypothermia.

Although aEEG was historically used to select infants for some of the randomized control trials for hypothermia, this is no longer deemed necessary for determining eligibility for cooling in the era of clinical cooling for HIE. However, there may be a role for the use of aEEG to assess infants with "mild" encephalopathy who may benefit from cooling, or enrollment in future trials, who do not initially qualify for cooling based on the clinical exam score alone.

Since aEEG monitors have switched from paper to digital devices, there have been many enhancements that have increased their reliability but also their complexity. Due to its popularity, aEEG is now available as an optional display for most continuous video-EEG monitors. This integration allows for bedside care providers to assess the real-time brain function of infants in the NICU while still recording a comprehensive array of EEG. This dual set-up offers the advantage of easy bedside review of aEEG and full reporting and remote access by the neurodiagnostic and neurophysiology team.

Other monitors offer what is known as multi-modal monitoring which integrates several streams of monitoring data (i.e., aEEG, NIRS, HR, Sats, and BP) on to one screen for easier interpretation of changes in both neurologic and physiologic vital signs. These devices are especially useful for big data analysis for neonatal research projects as well as for clinical use.

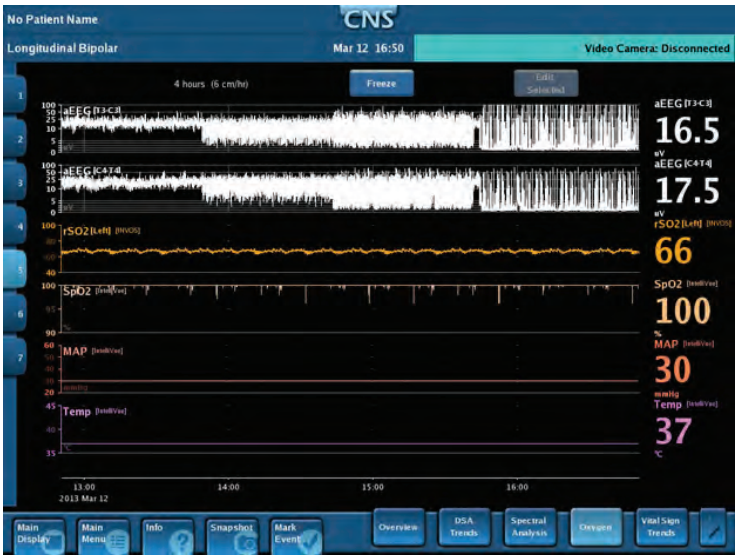

Fig 1 -Multi-Modal CNS Monitor - Image Source: Moberg Research.

7 STEP METHOD

It is easy to be overwhelmed with the task of interpreting aEEG if you do not have a systematic way to approach your assessment.

In the sections that follow I will outline a comprehensive yet simple system that I developed after years of training NICU providers around the world, I call it my "7 Step Method" and coincidentally, each step begins with the letter S:

- Story
- Signal Quality
- Strength of Background
- Sleep-Wake Cycles
- Symmetry
- Seizures
- Stability

Step 1: Story (Infant History)

Before you assess the aEEG tracing itself, stop and think about why aEEG was ordered for this baby in the first place, and what information you are seeking from the aEEG.

- Is the baby encephalopathic?
- Are you considering cooling the baby?
- Are you hoping to identify electrographic-only (i.e., sub-clinical) seizures?
- Are you using the aEEG to manage anti-epileptic medication dosage?

- Are you using the aEEG to trend the baby's background brain activity over a few days to determine the severity of injury or watch the recovery of injury?

After you have determined why the baby is being monitored and what information you are seeking, then it is important to consider the factors that might complicate your interpretation and findings.

History: Consider the infant's labor, birth, and even prenatal history and determine if any risk-factors exist for brain injury or dysfunction.

Exam: Take both the physical and neurological exam into account. Always assess the condition of the scalp. Edema will give you a dampened aEEG and a high impedance signal, which we will cover in the next step.

Medications: Some medications can have a dramatic effect on the aEEG background pattern and may falsely alarm you. A quick review of all ordered and recently administered medications is always a good idea.

Age: Gestational age and corrected age both impact EEG and aEEG waveforms so be sure you know the baby's age before you review the aEEG.

"After you have determined why the baby is being monitored and what information you are seeking, then it is important to consider the factors that might complicate your interpretation and findings. "

Step 2: Signal Quality

Before you go any further with your assessment, you must ensure that the electrode impedance is acceptable. In the EEG world, the lower and more balanced the impedance values, the better. The international standard for quality EEG tracings is impedance less than or equal to 10 Kilo-Ohms (kOhms). (5)

Each EEG and aEEG machine you encounter will have a different way to display and trend the impedance value, but the most important thing is that your entire team knows how to find these values and that you have a protocol in place that requires a review of impedance at least every few hours to ensure a quality recording. There are typically no audible alarms on EEG or aEEG monitors, but many of the stand-alone aEEG devices do offer visual indicators of high impedance that can alert staff to attend to an elevated value quickly.

The impedance values you see on the monitor will vary based on the type of electrodes used. Needle electrodes have been used widely throughout the world for decades and have the advantage of quick application and stable, low impedance values (0 to 2 kOhms). They are used for up to 5 days in most centers without risk to the site or systemic infection. The biggest risk to consider when using needles is the risk to staff as needle-sticks are not uncommon if the electrodes become dislodged.

As an alternative to needles, there are many skin or surface electrodes available. They range from peel-and-stick hydrogel electrodes (similar to those used for ECG) to disposable plastic, or reusable metal, cups or disks electrodes that are attached to the scalp using a conductive paste. EEG departments commonly use these cup and disk electrodes for full EEG monitoring.

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New pre-measured electrode systems and caps are entering the neonatal market to simplify and standardize the electrode application procedure. One such device, the Incereb neon was developed by an EEG tech in Ireland and is showing promise for those who use aEEG infrequently or who have limited access to techs on nights and weekends.

The disadvantage of using any of the non-invasive electrodes is that the skin must be prepped before the electrodes are applied. A water-based exfoliant product is typically used to cleanse the application sites gently. While this technique is not difficult, it does take patience and practice to be able to perform quickly and without injuring fragile neonatal skin.

As EEG and aEEG amplifiers have improved over the years, they can typically compensate for higher impedance values, but as a general rule, try to keep your impedance balanced and below 10

kOhms.

Step 3: Shape and Strength of the aEEG band

The good news is that there are only 5 neonatal aEEG patterns.

The first, most mature aEEG pattern is named Continuous Normal Voltage (CNV). This pattern is expected in term newborns starting around 35-36 weeks and is considered normal until approximately 44 weeks post-conceptual age normal. (3)

The next pattern, Discontinuous Normal Voltage (DNV), is expected and considered to be normal for premature infants. This pattern is also seen in term infants with HIE and who are undergoing therapeutic hypothermia. Most experts consider this pattern to be strongly predictive of a favorable outcome in the HIE/Cooling population; especially after 48 hours of life. (6, 7)

The remaining three patterns, Burst Suppression (BS), Continuous Low Voltage (CLV), and Inactive/Flat tracings (FT), are not considered to be normal regardless of gestational age; however, they may be expected patterns based on the infant's history. (3)

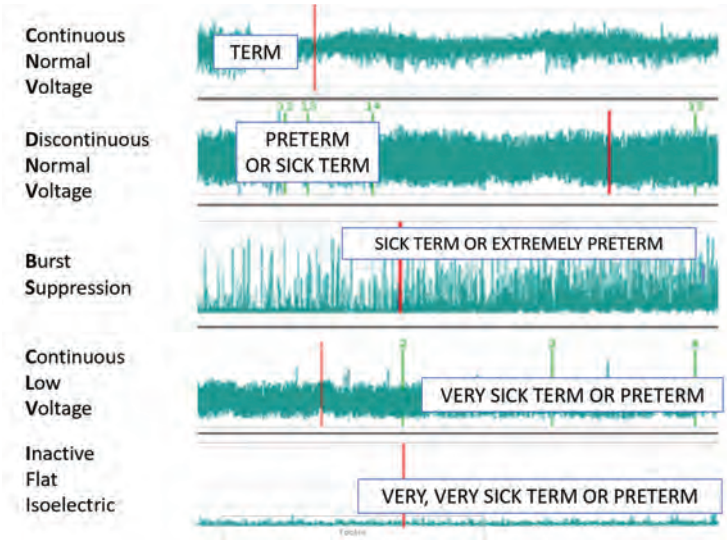
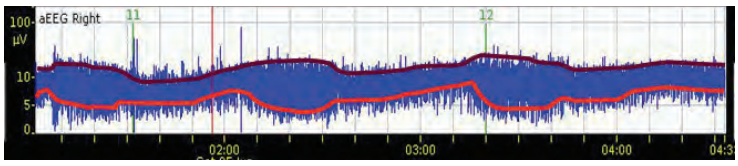


Fig 2 -Image Courtesy of Karl Florian, Munich

Each of the five patterns has a distinct visual appearance which can be learned over time, but an alternative to this subjective method of classification is to compare patterns to published voltage limits. I have provided a summary of the voltage limits and pattern classifications for the five basic aEEG patterns in the table on the next page.

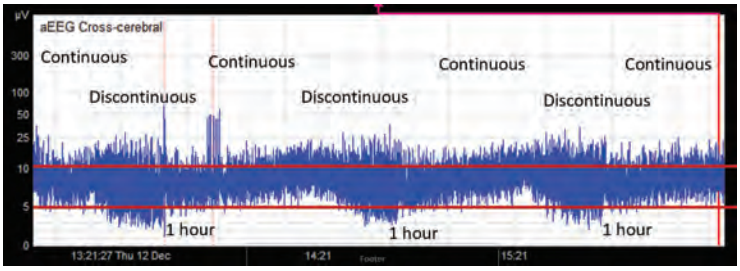
When using voltage to describe the aEEG band, you must assess the upper edge and the lower edge of the band, which correspond to the minimum and maximum voltages recorded and integrated into a single "pen-stroke" every 15-second epoch.



Step 4: Sleep-Wake Cycles

While we can look at an infant and determine if they are asleep or awake, we know very little about the quality of their sleep just by looking at them.

A mature sleep-wake pattern is seen on aEEG as an alternation from continuous normal voltage to discontinuous normal voltage. The continuous normal voltage is seen during wakeful periods and active sleep periods, and the discontinuous pattern is seen during quiet sleep periods.



Cyclicity can be seen on the aEEG of extremely premature infants (as young as 28-30 weeks) and becomes more organized and well defined as the infant matures.

A mature sleep-wake pattern emerges by 32 to 34 weeks gestation, and each cycle lasts for approximately 20-40 minutes (if not interrupted) and has a smooth entry and exit.

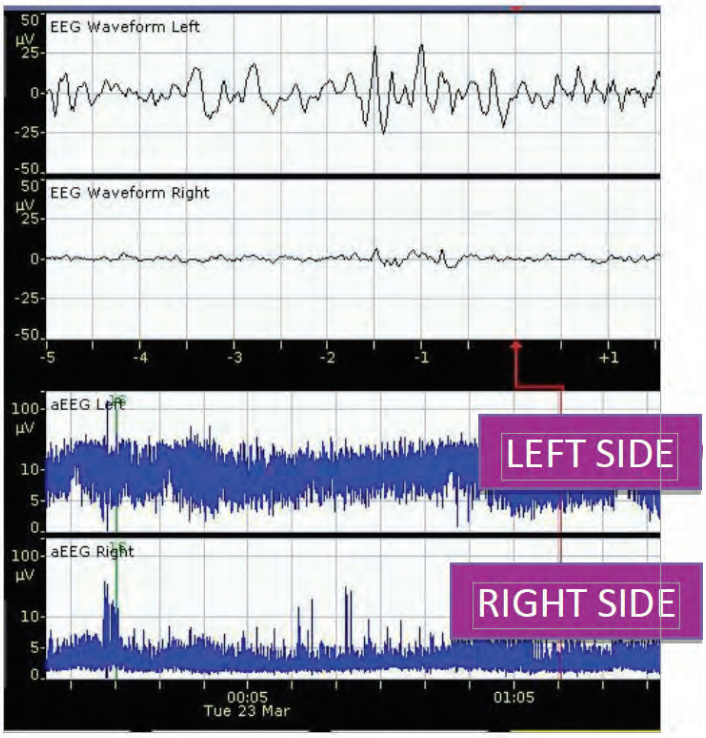
Due to rapid brain development and changes in sleep patterns in the first weeks of life, the typical alternating pattern seen in the term infant (also known in the literature as trace alternant) is no longer apparent after 44 weeks post-conceptual age.

For infants with HIE, the presence and onset of sleep-wake patterns on aEEG during the first three days of life has been shown to be very highly predictive of long-term neurodevelopmental outcome. (6, 7)

Step 5: Symmetry

Modern, digital, aEEG monitors give you the ability to apply more than one pair of sensors to the baby's head (this is a blessing and a curse). The downside is you have to apply more sensors to the baby, but the blessing is that the extra sensors allow you to compare the electrical signal from each hemisphere of the brain.

Each electrode pair will collect and display one channel of EEG signal. Each channel of EEG will then become its own separate aEEG waveform. Assess each aEEG pattern, right and left, separately. Evaluate the shape and voltage of each of the aEEG patterns (just like in STEP 3) and then compare them. You may also be able to see that seizures arise from one hemisphere more than the other. We will cover seizures in more detail in the next section.



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Are the patterns similar or different?

If asymmetries are present, then investigate.

- Verify that the electrodes are applied symmetrically across the head. Electrodes that are too close together will give a falsely low voltage pattern, and electrodes that are further apart will give you a wider aEEG band.
- Localized edema can cause a dampening of the electrical signal and give the impression that one hemisphere of the brain is suppressed.
- If everything looks good with the head and the electrodes, then you may want to consider imaging the infant to determine if there may be a unilateral or focal ischemic injury.

Step 6: Seizures

Although beyond the scope of this paper, we would likely agree that neonatal seizures are a complex problem for the neonate. Subclinical seizures are more common than ever imagined, medications are only modestly effective, and our ability to identify seizures clinically is depressing. (8)

Seizures have been observed on EEG as repetitive, rhythmic electrical discharges from the brain that last for more than 10 seconds. (9) On aEEG, seizure patterns are often described as a rapid increase in both the upper and lower margins of the aEEG.

Although aEEG is not a perfect tool for seizure detection, it is far better than relying solely on our clinical assessment skills.

The most common pitfalls when it comes to using aEEG for identification of seizures include:

1. One or two channels of EEG may miss a focal seizure occurring in an area away from the recording electrodes
2. Short seizures (less than 1 or 2 minutes) will likely be missed on aEEG due to the dense time compression that occurs to create the aEEG band

Pattern Classification	Minimum Voltage	Maximum Voltage	Other features
1. Continuous Normal Voltage	> 5	> 10	A thin band with sinusoidal alterations every hour
2. Discontinuous Normal Voltage	< 5	> 10	Wide band, with good variability
3. Burst Suppression	0-3	> 25	Wide band, with no baseline variability
4. Continuous Low Voltage	< 5	< 10	Dense pattern that
5. Inactive/Flat	< 5	< 5	Often contaminated with artifacts due to the lack of cerebral activity

Table 1: Adapted from Amplitude-integrated EEG classification and interpretation in preterm and term infants. Hellstrom -Westas, L., Rosen, I., de Vries, L. S., & Greisen, G. (2007). Neoreviews, 7(2), 76-86

3. Low voltage seizures might not cause a change in the appearance of the aEEG

4. Seizure detection algorithms are not widely available in all markets, and those that are available have limited reliability (about 80%)

As with any assessment tool, if you understand its limitations, then you can determine how and when to incorporate it into your practice. The important point to keep in mind is that aEEG is significantly better than clinical assessment alone. All aEEG monitors in use today simultaneously display both the raw EEG and the aEEG tracings, which significantly improves the accuracy and reliability of seizure detection. (10)

Video-EEG continues to be the gold standard for seizure diagnosis; however, in times of limited resource, expertise, and staff, aEEG is a valuable complementary tool, especially for bedside care providers.

Step 7: Stability of the aEEG Background Pattern

In order to harness the power of aEEG, you really should be monitoring infants over long periods of time (days, not hours) and then looking at the aEEG trend every few hours.

It can also be fascinating to observe changes in the aEEG trend from hour to hour, shift to shift, and day to day. Especially in combination with other changes in the infant's clinical picture.

Special Note -- For infants with HIE: The background aEEG pattern within the first three days of life, especially after 48 hours, has been well-document as strongly predictive of long-term outcomes even in the era of therapeutic hypothermia (6). Also, the onset of sleep-wake cycling in this population has also been shown to have strong positive predictive of outcome (with or without therapeutic hypothermia). (7) As we saw in Step 4, sleep-wake cycling is much easier to assess using aEEG than traditional EEG recordings.

CONCLUSION

Assessment of aEEG may seem overwhelming at first glance but using a systematic approach like the "7 Steps" outlined in this article can provide a template to follow both in bedside review and documentation in the patient record.

As a quick recap of the 7 steps in a comprehensive aEEG recording review, your assessment should include:

- A review of the infant's story (why the infant is being monitored with aEEG)
- The signal quality (impedance)
- The background (by pattern recognition or voltage limits)
- The presence or absence of sleep-wake cycling
- Inter-hemispheric symmetry and areas with possible seizures
- Finally how the background aEEG pattern compares to previous periods in time.

Research programs around the globe continue to investigate aEEG, expand our understanding of its benefit in novel populations and continue to confirm that in dedicated hands, aEEG is a powerful tool for the NICU. If you have not yet become a fan of aEEG technology, it is my hope that this article has piqued interest and that you will feel more confident in using aEEG the next time you see it being used in your NICU.

It appears that aEEG is here to stay in the NICU (for now) and although it is not a perfect tool it does offer the opportunity to trend an infant's brain activity right at the bedside at any time. We can use aEEG to identify subclinical seizures, assess the effectiveness of prescribed therapies and even to counsel parents; especially at times when other resources and expertise are not available.

MORE RESOURCES:

To learn more about aEEG Interpretation there are several online and in-person educational opportunities.

A great video with an overview of aEEG by Dr. Courtney Wusthoff, Neonatal Neurologist, Stanford University -

https://www.vido.wiki/video/gGHjkrQCB6g/evidence-based-neonatology.html

Brigham & Women's Hospital in Boston is offering their bi-annual Neonatal Brain Monitoring & Imaging Workshop in October of this year at www.newbornbrainworkshop.org. The next International Brain Monitoring & Neuroprotection meeting will be held in Ireland in October 2020 and traditionally has offered a half-day workshops for those with both the beginner and advanced aEEG skills.

You can also visit the author's website - www.synapsecare.com - for a listing of free and paid resources. I have recently revised my 7 Step E-Book which is available as a free download at courses.synapsecare.com and now includes 8 short training videos that accompany the E-Book. The Online aEEG Mastery course by Synapse Care Solutions is a comprehensive training for individuals and teams.

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Discslosure: The author is the owner of Synapse Care Solutions and creator of several online education programs for individuals and groups related to aEEG, Brain Cooling and Neuro-Protective Care. Kathi is a paid consultant to Aspect Imaging, Neotech Products and Moberg Resarch.

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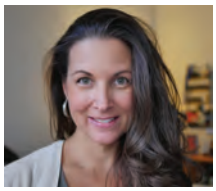

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