

# East of England Neonatal Neuroprotection Regional Guideline for Cerebral Function Monitoring of Neonates

## Clinical Guideline:

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**For use in:** EoE Neonatal Units  
Guidance specific to the care of neonatal patients.

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### AUDIT STANDARDS:

1. The CFM should be attached *only* by personnel who have been trained in its application to infants.
2. The procedure is fully documented

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# Regional Guideline for Cerebral Function Monitoring of Neonates

## 1. Objective of Guideline

- To define which infants should routinely undergo continuous amplitude-integrated EEG (aEEG) monitoring during neonatal intensive care.
- To facilitate prompt cerebral function monitoring of these infants.
- To provide information on prognosis that can be obtained from aEEG trace in the early neonatal period.

## 2. Summary of Guideline

### **2.1 WHICH INFANTS SHOULD BE MONITORED?**

#### **i) Term/ near term Infants**

Cerebral Function Monitoring (CFM) should routinely be used for all infants of gestational age  $\geq 36$  weeks who have one or more of the following:

- a) Evidence of possible hypoxic-ischaemic encephalopathy (HIE) who meet A and B criteria in line with the [EoE HIE guideline](#).
- b) Seizures, definite or possible.
- c) Infants receiving muscle relaxants where neurological assessment is not possible.

#### **ii) CFM may also provide useful information in:**

- Meningitis (requiring intensive care).
- Evidence of extensive structural brain injury or serious congenital brain anomalies (e.g. cerebral infarction, congenital brain haemorrhage/ tumour, hydrocephalus).

#### **iii) Preterm Infants**

The CFM may be less easy to interpret in preterm infants. Nevertheless, it can provide very useful information and so may be considered in some infants of  $\leq 36$  weeks' gestation, e.g.

- Clinical or suspected seizures.
- Encephalopathy.
- Grade 3 or 4 intraventricular haemorrhage.

CFM of preterm infants should be at the discretion of the attending consultant.

#### **iv) Perioperative seizures in infants with congenital heart disease**

Perioperative clinical and electrographic seizures have been associated with neurological impairment in infants with CHD. aEEG can be used to evaluate incidence of seizures, early recovery to normal background activity, and presence of sleep-wake cycle post-surgery,

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### **2.2 WHEN SHOULD MONITORING BE COMMENCED?**

- Apply the CFM as soon as possible to at-risk infants in whom there are any neurological concerns.
- Apply as soon as possible following admission to the NICU of any infant with suspected hypoxic-ischaemic encephalopathy.
- Early application will help facilitate a reliable baseline.

### **2.3 WHO SHOULD ATTACH THE CEREBRAL FUNCTION MONITOR?**

- The CFM should be attached *only* by personnel who have been trained in its application to infants.
- The attendant nurses and medical staff should record events that occur during the period of monitoring by entering details into the monitor: e.g. suctioning, X-ray, reintubation, and episodes of overt/possible seizures. This will facilitate proper retrospective interpretation of the traces and help distinguish artefact.

### **2.4 ATTACHMENT OF THE CEREBRAL FUNCTION MONITOR**

*See specific instrument guide for details.*

Either standard EEG electrodes, gel electrode sets, cup electrodes, or disposable subdermal needle electrodes should be used to attach the CFM to the infant. Attention should be paid to correct placement of the electrodes on the head – particularly for dual channel monitoring. Lead attachment requires time, patience, and careful skin preparation and is a skill that must be learnt. Care must be taken when using subdermal needle electrodes in order to avoid/minimise:

- Pain on insertion
- Potential risk of infection to the baby.
- Risk of needle stick injury for staff.
- Risk of the needle electrode puncturing cooling wraps/mattresses in infants undergoing therapeutic hypothermia.

Needle electrodes should not be used if there is evidence of clotting abnormalities or active bleeding.



**Site the electrodes with the leads directing towards the shoulders.**

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### 2.5 INTERPRETATION OF THE CEREBRAL FUNCTION MONITOR TRACING

\*Please note a free online course on interpretation of Cerebral Function application, monitoring and tracing developed by the Luton and Dunstable Neuroprotection team can be found through visiting the [BAPM website](#).\*

There are 3 parameters that can be measured by a Cerebral Function Monitor (CFM), all of which should be taken into consideration when interpreting and reporting. They are as follows:

1. **Impedance**, which is a measure of the electrical signal's conductivity, will tell you how good the contact is between the electrode and the scalp. It is essential to have good contact with low impedance. Loss of contact can increase artefact in the amplitude-integrated EEG (aEEG) trace making it impossible to be confident in its accuracy. It is not advisable to make decisions around treatment based on an aEEG trace with high impedance. Impedance is measured in Ohms ( $\Omega$ ).  $<5\Omega$  is very good and  $5-10\Omega$  is acceptable. If it is  $>10\Omega$  efforts should be made to reduce this and the corresponding aEEG trace should be ignored. When reporting the aEEG the impedance should be documented as part of this. EEG impedance may be affected by electrode placement and localized oedema at the site of electrode placement.
2. **Raw-EEG**, this is the raw electrical signal measured directly from the electrodes before it is rectified and compressed by the monitor into the aEEG trace. It is important to inspect this when reporting as it helps to identify seizures and artefact, and to differentiate between the different background patterns.
3. **Amplitude-integrated EEG (aEEG)** is the rectified and compressed trace that the monitor makes from the raw-EEG. By compressing the EEG to 1hr/6cms, the aEEG gives information on cerebral function and this can be assessed by looking at its characteristics as outlined in the following paragraphs.

The aEEG pattern descriptions used in the study of Toet *et al.* [2] were as follows:

- **Continuous normal voltage with cycling of sleep stages.** Continuous background activity with voltage 10–25 (–50)  $\mu\text{V}$ , with the band of aEEG activity altering in width, indicating cycling of sleep stages.
- **Continuous normal voltage.** Continuous background activity, voltage 10–25 (–50)  $\mu\text{V}$  but without sleep stages.
- **Discontinuous normal voltage.** Discontinuous trace, voltage predominantly  $>5\mu\text{V}$ .
- **Burst suppression.** Discontinuous trace with periods of very low cortical activity ( $<5\mu\text{V}$ ), intermixed with bursts of higher amplitude. [**severely abnormal**]
- **Continuous low voltage.** Continuous background pattern of very low voltage (around or below  $5\mu\text{V}$ ). [**severely abnormal**]
- **Flat tracing.** Mainly inactive (isoelectric tracing) of extremely low voltage ( $<5\mu\text{V}$ ). [**severely abnormal**]

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- **Epileptic activity** may also identified by single or repetitive events (at a frequency of less than once per hour), with sudden sustained cortical activity.
- **Status epilepticus** is indicated by repeated epileptic activity, resulting in a regular pattern of increased cortical activity (sawtooth pattern).

Examples of these pattern descriptions are found in **Table 2**.

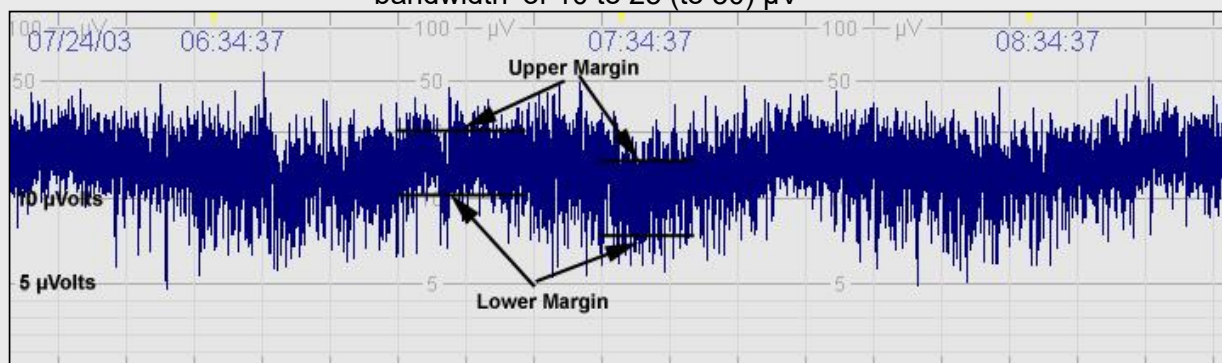
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**Table 2:** A classification of aEEG patterns for preterm and term infants (from Hellström-Westas et al., 2006<sup>[3]</sup>)

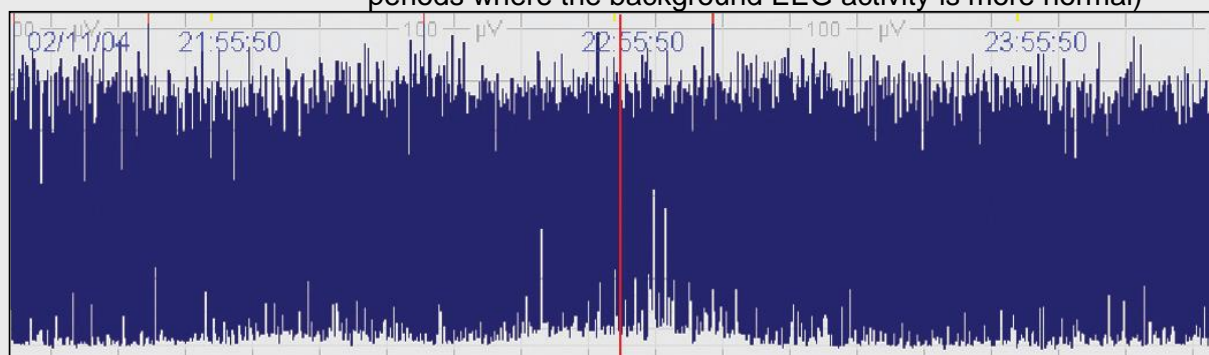
### 1. BACKGROUND PATTERN

Describes the dominating type of electrocortical activity in the aEEG trace.

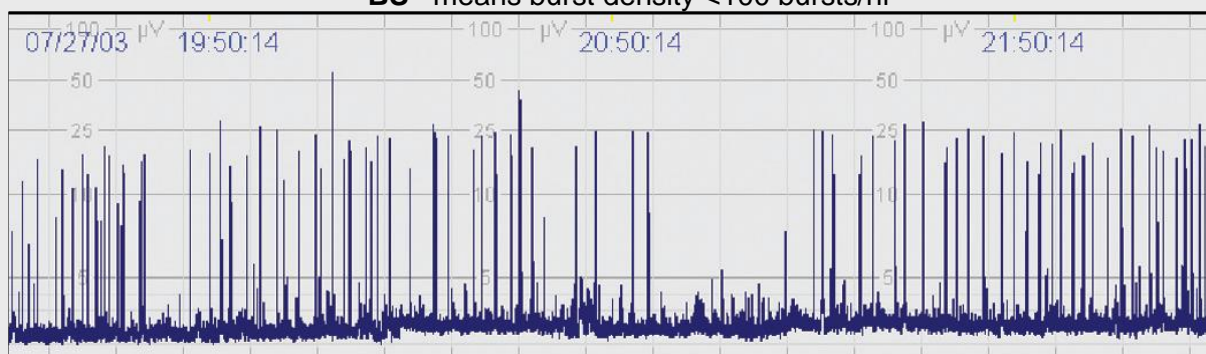
- **Continuous (C):** Continuous activity with lower (minimum) amplitude of the 'bandwidth' around (5 to) 7 to 10  $\mu\text{V}$  and maximum amplitude of the 'bandwidth' of 10 to 25 (to 50)  $\mu\text{V}$



- **Discontinuous (DC):** Discontinuous background with minimum amplitude variable, but below 5  $\mu\text{V}$ , and maximum amplitude above 10  $\mu\text{V}$ . ("Discontinuous" refers to a raw EEG appearance where there are alternating periods of relative inactivity/ low voltage interspersed with periods where the background EEG activity is more normal)

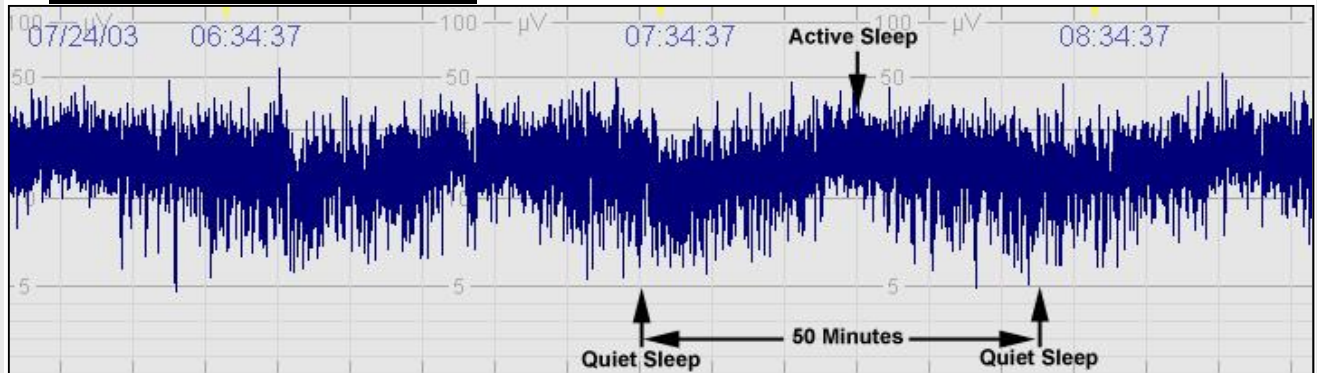


- **Burst suppression (BS):** Discontinuous background with minimum amplitude without variability at 0 to 1 (2)  $\mu\text{V}$  but with 2-3 second long bursts of amplitude  $>25 \mu\text{V}$   
**BS+** denotes burst density  $>100$  bursts/hr  
**BS-** means burst density  $<100$  bursts/hr



- **Low voltage (LV):** Continuous background pattern of very low voltage (around or  $<5 \mu\text{V}$ )
- **Inactive/ flat trace (FT):** Primarily inactive (isoelectric tracing) background below 5  $\mu\text{V}$

## 2. SLEEP-WAKE CYCLING

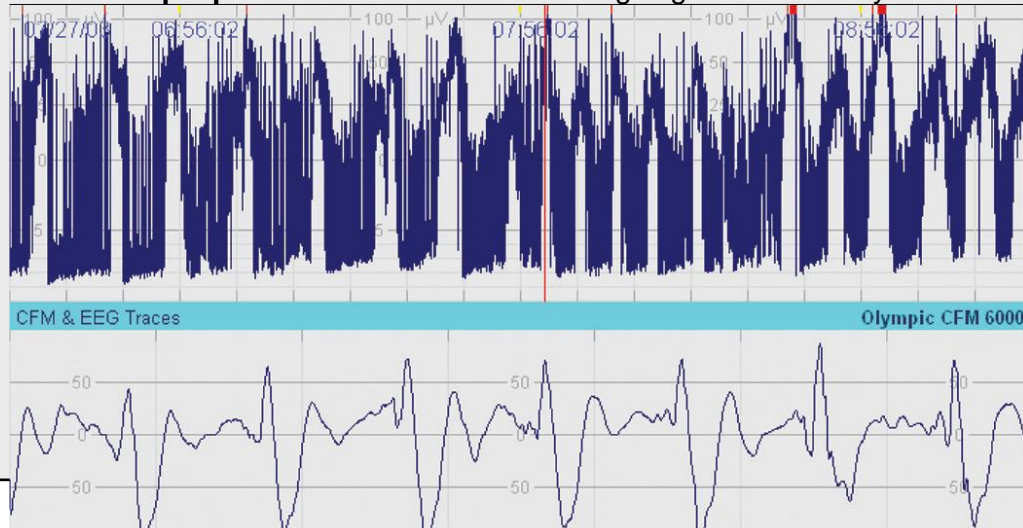


- Sleep-wake cycling (SWC)** A normal finding in the aEEG. Characterized by smooth sinusoidal variations, mostly in the minimum amplitude. Broader bandwidth represents discontinuous background activity during quiet sleep, and narrower bandwidth corresponds to the more continuous activity during wakefulness and active sleep
- No SWC:** No cyclic variation of the aEEG background
- Imminent/immature SWC:** Some, but not fully developed, cyclical variation of the lower amplitude; not developed as compared with normative gestational age-representative traces
- Developed SWC:** Clearly identifiable sinusoidal variations between discontinuous and more continuous background activity, with cycle duration >20 mins

## 3. SEIZURES

Epileptic seizure activity is usually seen in the aEEG as an abrupt rise in the minimum amplitude and a simultaneous rise in the maximum amplitude, often followed by a short period of decreased amplitude. The raw EEG should show simultaneous seizure activity, with a gradual build-up of high amplitude waves and then decline in frequency and amplitude of repetitive spikes or sharp-wave or activity with duration of at least 5 to 10 sec.

- Single seizure:** A solitary seizure
- Repetitive seizures:** Single seizures appearing more frequently than at 30 min intervals
- Status epilepticus:** Continuous ongoing seizure activity for >30 minutes.



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Although this guideline outlines both classification methods, there is a move to use the latter and more descriptive classification. Not only is it more descriptive but can be used for infants of all gestations rather than just those that are near term. It also uses EEG terminology which provides more synergy between the two monitoring techniques.

### 2.6 ARTEFACT

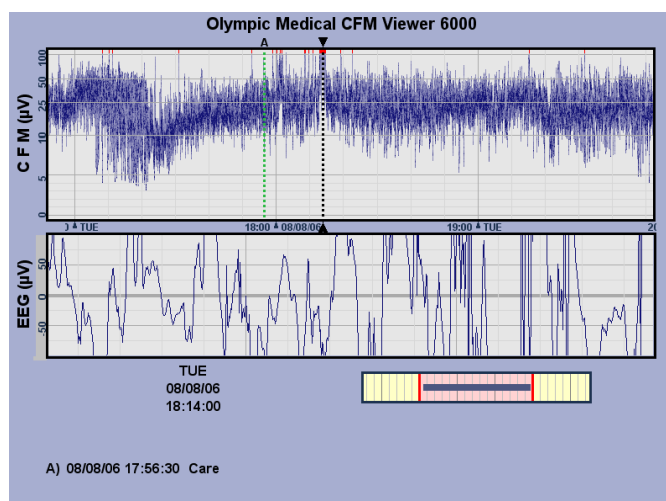
It is important to identify any areas of trace with artefact and discount these areas from any decision-making regarding plan of care or treatment. As with all reporting, -- inspecting the impedance and raw-EEG will help in determining areas of artefact.

There are many causes of artefacts. Environmental sources of artefacts also include devices (ventilators, IV pumps, cooling equipment, handling, feeding or loud noises – these can also make electrographic monitoring difficult to interpret.

Physiological sources include, but are not limited to head, eye, facial or gross body movements, respiratory movement, ECG/ pulse artefacts, jaw movement, sucking, hiccups, sweat.

Artefacts on aEEG together with the difficulty in interpreting raw EEG on CFM monitors, can be misdiagnosed as seizures. Constant rhythmical abnormal activity, which does not evolve or change, is suspicious of artefact. However, these rhythmic activities can be misinterpreted as a seizure on aEEG. Seizure events must show evolution (generally increasing amplitude and decreasing frequency) and resolution of discharges over time with the discharge long enough to allow recognition of onset. The morphology may vary between and within seizures. Seizures may stay localised to one area or propagate to other area.<sup>22</sup> In the absence of typical changes on raw EEG a standard EEG should be organised.

Electrographic artefact may also lead to a 'drift of the baseline' effect in which the baseline tracing becomes falsely elevated in the setting of a severely suppressed background activity. A baseline level above 5 $\mu$ V may be mistaken for a more reassuring pattern. A clue to the presence of ECG artefact in the presence of a suppressed background, as opposed to seizures is that the rhythmical activity does not change in frequency or size.

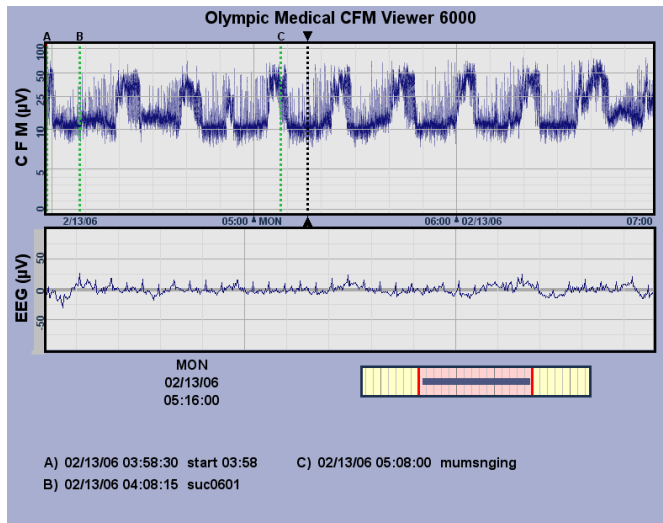


**Figure 1a**

**Figure 1a:** General movement or loss of contact will result in a disorganised appearance of the raw-EEG with a huge variance in voltage. Note the sudden short peak in voltage in the aEEG trace (see dashed black line) that could be suggestive of a seizure if you didn't inspect the raw-EEG.

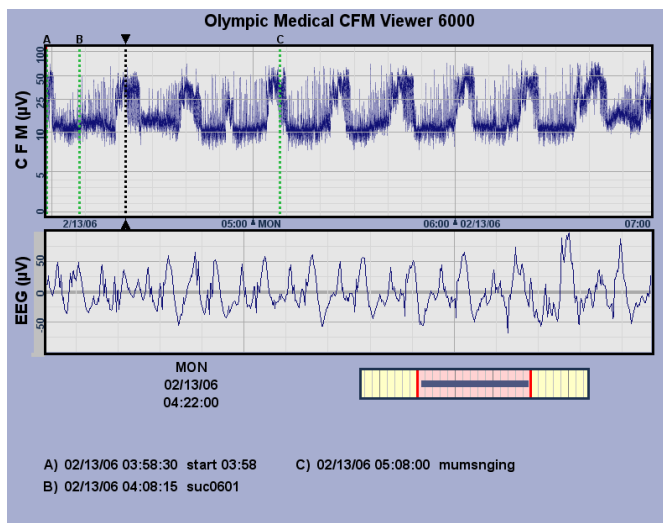
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**Figure 1b**



**Figure 1b:** Other electrical signals, such as ECG, can also be picked up by the CFM. This is especially so if the background voltage of brain activity is low or isoelectric, but this can also happen if the electrode is sitting directly over a scalp vessel. In this example, you can see the raw-EEG shows a regular pattern that doesn't evolve in its morphology. This suggests it is an ECG signal. Notice how it elevates the background aEEG trace to just above 10 microvolts. The aEEG background is very narrow with little continuity and no sleep wake cycling. This suggests it is a continuous low voltage trace but it is sitting at an abnormally high voltage.

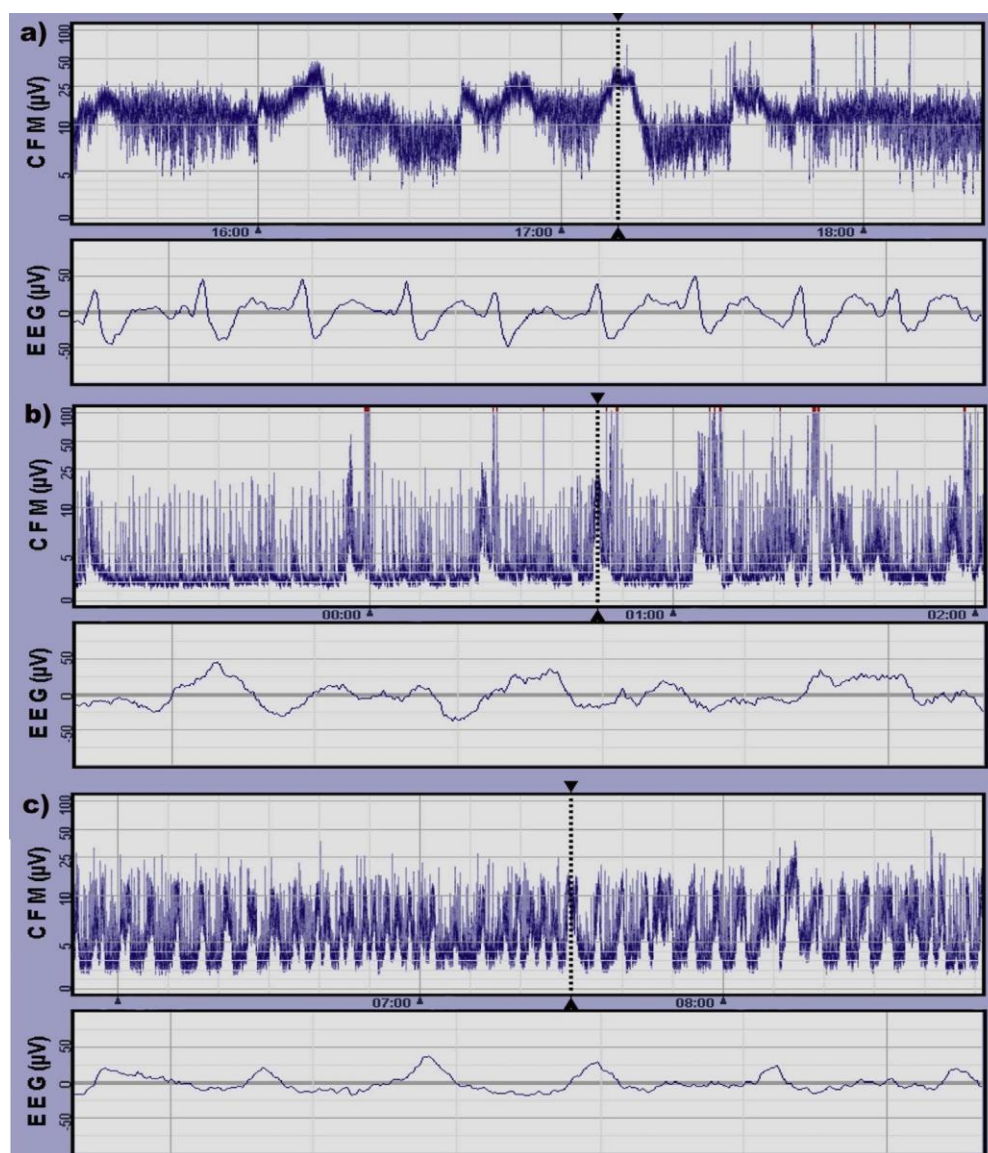
**Figure 1c**



**Figure 1c:** This is taken from the previous trace, however in this example the raw-EEG corresponds to the peaks of the aEEG trace (see the dashed black line). Note the spiky electrical discharge on the raw-EEG that shows some evolution of voltage and morphology that is suggestive of seizures. It shows that although artefact, like ECG, can elevate the overall background aEEG trace we should always be vigilant for seizures. This aEEG shows multiple seizures.

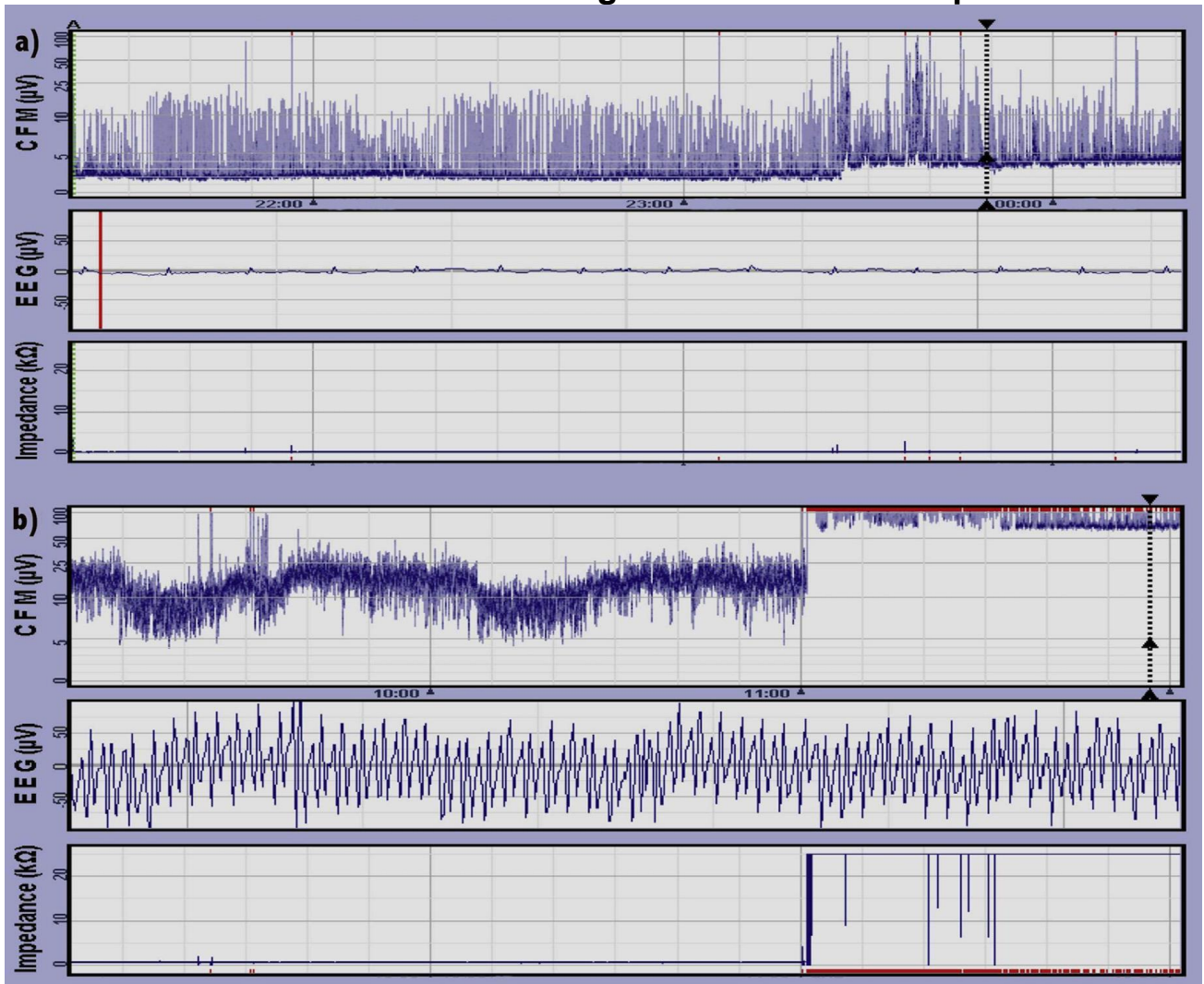
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Figure 2 and 3



**Figure 2** (a) Upper panel: aEEG background is continuous normal voltage aEEG with absent SWC and recurrent seizures; lower panel: a few seconds of single channel EEG at time point marked with the dotted line showing repetitive, rhythmical spike wave patterns indicative of epileptic seizures. Comment: the aEEG reveals a number of episodes of seizure activity where the amplitude increases and bandwidth narrows. (b) Upper panel: aEEG background shows continuous low voltage, no SWC and the aEEG looks like recurrent seizures; lower panel: a few seconds of raw EEG at the point marked with the dotted line showing slow wave activity. Comment: the initial aEEG has a low voltage appearance that is then interrupted but surges in overall amplitude (but still with a narrow aEEG band) that look like seizures. The raw EEG does not show typical pattern, but slow activity that could be respiratory artefact. This is an example where standard EEG should be performed to confirm seizure activity. (c) Upper panel: aEEG background is of low voltage but the surges in amplitude are so frequent this becomes difficult to appreciate. SWC is absent and status epilepticus is noted; lower panel: a few seconds of single channel EEG at time point marked with the dotted line showing rhythmical slow waves in the delta range. Comment: the aEEG trace has the rhythmical, repetitive saw tooth appearance consistent with status epilepticus but again the raw EEG does not show typical features of seizures, highlighting that the raw EEG can be confusing at times. **Where doubt exists, standard EEG should be organized.**<sup>14</sup>

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**Figure 3** (a) upper panel: aEEG background shows low voltage continuous trace with possible superimposed bursts. No SWC is seen. Towards the right of the trace, the band moves upwards. A clinician could assume this is seizure activity or artefact; lower panel: a few seconds of single channel EEG at time point marked with the dotted line. Regular discharges can be seen throughout the window without any change in frequency or size. Comment: this recording is contaminated with artefact. Given the rhythmicity and frequency of the discharges on the raw EEG, this probably arising from the ECG/heart. The bursts of activity in the upper panel probably reflect this artefact, otherwise the aEEG is likely to be flat. (b) Upper panel: aEEG background shows periods of continuous and discontinuous activity. SWC is present and no seizures are present; lower panel: a few seconds of single channel EEG at time point marked with the dotted line displaying rhythmic discharges which do not alter in anyway. Comment: careful inspection of all the information on the monitor reveals that, at the point of potential concern, the electrode impedance dramatically changes, just after 11.00 hours. The trace then becomes affected by artefact. It would be possible for an inexperienced operator to misdiagnose the raw EEG seizure activity, highlighting the need for adequate training<sup>14</sup>

Most cerebral function monitors have an event marking function. This should be utilised for all episodes of care and any episodes of abnormal movements. By doing this you can highlight areas for potential artefact or seizures and for review of the corresponding impedance and raw-EEG.

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### **2.7 EFFECT OF DRUGS ON THE aEEG**

Administration of morphine, phenobarbitone, lidocaine and midazolam may depress aEEG activity. A loading dose of phenobarbitone (10-20mg) may result in moderate depression of background activity. If phenobarbitone loading results in severe depression of the CFM background this may be a sign of more severely compromised cerebral function. Other factors that have been described to cause transient depression of aEEG include hypoglycaemia and pneumothorax.

In preterm infant's surfactant administration may result in a transient aEEG depression for about 10 minutes.<sup>3</sup> Studies demonstrate that morphine treatment causes longer cerebral depression, more discontinuous aEEG/EEG background activity, and a lack of SWC that lasts for 24hrs in extremely preterm babies.<sup>19</sup>

### **2.8 aEEG trace monitoring, review and escalation**

The EoE recommends using a CFM observation chart for monitoring aEEG tracing. The observation chart included in Appendix 1 was adapted from charts shared by Luton and Dunstable and Peterborough City Hospitals. The chart from L&D was developed as a Quality improvement initiative and was found to greatly improve aEEG documentation and staff confidence in interpretation of tracing. Their training course to accompany this chart is now available on bridge the EoE blended learning platform together with a competency checklist in Appendix 2.

The ROME algorithm provides a baseline for nursing CFM monitoring ensuring **R**ecording of findings on observation chart, **O**bservation of Baby, **M**arking events on the CFM monitor, **E**scalating to medical team any changes to baseline observations, limits within the amber or red zone, abnormal movements.<sup>22</sup>

The tracings should be reviewed at each ward round and a full written report of the findings should be made 1 hour into recording (to establish background trace) at 6, 24, 48 hours and on rewarming as the findings on CFM at these time points have important prognostic implications (See Table 4). Full medical review and reporting of CFM should also occur when there are changes to the CFM background or limits within the amber or red observation chart zones, or any suspicion of seizures both clinical or electrographic See chart in appendix 3.

The BLISSA mnemonic provides a structured tool to document the aEEG pattern (**B**ackground, **L**imits (upper and lower), **I**mpedance, **S**WC, **S**eizures, **A**rtefacts). Documentation should also include medication on board during the aEEG tracing being reported.

The clinician's interpretation of the tracing should be communicated to the family and the pertinent discussions recorded in the case notes.

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### **2.9 FOR HOW LONG SHOULD aEEG MONITORING BE CONTINUED?**

Monitoring should be continued until:

- the background recording has become stable for 24 hours
- there have been no seizures for 12–24 hours
- rewarming has been completed for infants receiving therapeutic cooling as this is a period associated with re-emergence of seizures.

All infants having cerebral function monitoring should have a formal EEG performed. The timing and frequency of the EEG will depend on the condition of the infant and resources available. However, an EEG on day 4 (after rewarming) in infants who have been cooled will provide the most useful prognostic information.

### **3. RATIONALE FOR THE RECOMMENDATIONS**

Newborn infants admitted to the NICU have long had routine continuous monitoring of their heart rates, respiratory rates, O<sub>2</sub> saturations and blood pressure. Yet remarkably only in recent years has it been considered important to monitor neonatal brain function routinely using continuous EEG. Neurological status and development is of major concern to both parents and clinicians, and the improvement of long-term neurodevelopmental outcome has rightly become one of the major goals of modern neonatology. These concerns have emphasized the need for tools to detect and quantify brain injury, as a means of assisting clinical decision making as well as predicting long-term outcome. Obtainment of aEEG traces through continuous CFM monitoring provides very useful information about the functional integrity of the brain. CFM monitoring can be commenced immediately after an infant is admitted to the NICU.

Close surveillance of brain function at the bedside is now readily achievable with modern cerebral function monitors. These have been designed for continuous use in the NICU environment and allow clinicians to monitor and record real-time neurological information 24 hours per day. The CFM will detect changes and abnormalities in cerebral function. It will assist clinicians in the direction of care on a day-to-day basis as well as highlight the need for neuroimaging and clinical intervention.

As well as indicating overall brain status, the CFM recording will also clearly indicate seizures, which are one of the main signs of cerebral dysfunction in neonates. Seizure activity has often been monitored by clinical assessment alone. However, a large proportion of seizure activity is either difficult to assess by clinical examination or has no clinical manifestation (“electro-clinical dissociation”). Bedside monitoring with aEEG traces can be used to identify seizure-like events in real time, with review of the raw EEG trace recommended for event validation. aEEG monitoring can also be used to observe the effects of anticonvulsants. The CFM can therefore play a useful role in the management of anticonvulsant therapy and assessment of their effectiveness.

Growing evidence suggests seizures are damaging to neurons in human studies. It is

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unknown to what degree seizures increase damage to the brain, or if they just reflect how a condition has developed over time. Early recognition of seizures may provide a window to lessen the effect of it on the developing brain, and an early diagnosis supports better response to treatment. Pavel et al. identified a significantly lower seizure burden amongst infant treated with anticonvulsants within one hour of seizure, suggesting treatment can be time-critical.<sup>22</sup>

When used in conjunction with other clinical data, and in combination with traditional neurological assessment, the CFM is a unique and powerful tool to aid in the assessment and management of infants at risk of brain injury in the NICU.

### 3. 1 aEEG AND ASSOCIATION WITH NEURODEVELOPMENTAL OUTCOME

Many studies have now evaluated the prognostic accuracy of early cerebral function monitoring in encephalopathic infants. aEEG patterns in the first days of life have been shown to correlate well with later neurodevelopmental outcome. Very abnormal traces in the first 6 hours after birth define a group of infants at highest risk for poor outcome; infants who have burst-suppression, a persistent low voltage, or flat traces have a high risk for death or disability. Conversely infants who show continuous normal voltage or discontinuous normal voltage patterns (without seizures) in the first 6 hrs are likely to survive with little or no sequelae<sup>[3]</sup>.

Also, a continued abnormal aEEG, abnormal aEEG with a high seizure burden is frequently linked to negative neurodevelopmental outcomes.

**Table 3** *Abnormal aEEG background patterns and association with outcome (adapted from Hellström-Westas et al., 2006<sup>[3]</sup>)*

Gestational Age (weeks)	Background Pattern	Outcome
<28	Discontinuous, with high voltage bursts and low voltage interburst periods	Expected in extreme preterm babies
<33	Reduced continuity in first 7 days postnatal	Associated with large IVH; long term outcome not assessed
<33	Burst suppression, continuous low voltage, or flat trace in first 48 hr postnatal	Severe brain damage/death in infants with IVH Grade 3 to 4
≥37	Discontinuous	Normal outcome if present only within the first 6–12 following perinatal asphyxia
≥37	Low voltage	Abnormal outcome after perinatal asphyxia
≥37	Burst suppression	Abnormal outcome after perinatal asphyxia; some infants healthy if aEEG background becomes continuous within 12 to 24 h
≥37	Flat trace	Severely abnormal outcome (death or major handicap) after perinatal

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	asphyxia
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Note: Presence of epileptic seizure activity is always abnormal at all gestational ages; Background activity, including sleep-wake cycling, may be depressed by medications.

### **3.2 USE OF CFM MONITORING TO REFINE PREDICTION OF PROGNOSIS IN HYPOXIC-ISCHAEMIC ENCEPHALOPATHY**

In infants with moderate HIE clinically (Sarnat & Sarnat grade 2), a severely abnormal EEG does suggest a poor prognosis <sup>[4]</sup>. However, spontaneous recovery of aEEG patterns that were severely abnormal in the first hours of life is not uncommon <sup>[5]</sup> and such an early aEEG may reflect dysfunction that can resolve rather than permanent injury. In the study of van Rooij *et al.* <sup>[6]</sup>, a small group of infants (6/65=9%) with a severely abnormal aEEG background trace at <6 hrs of birth, achieved recovery to a continuous normal background pattern within the first 24 hours (61% of whom survived without, or with only mild, disability).

**Table 4** provides a guide to the prognostic interpretation of aEEG in hypoxic ischaemic encephalopathy in the absence of antiepileptic medication <sup>3,13,15</sup>

Age at interpretation	CFM tracing	Prognosis
6 hours	Discontinuous	High chance of cerebral recovery and normal outcome if recovers by 12 hours
	Burst suppression	Risk of poor outcome. If normal by 12-24 hours chance of good outcome (61% mild or no disability)
	Low voltage/Flat trace	Severely abnormal outcome
48 hours	Continuous with SWC by 36 hours	High probability of good outcome 97% if clinically moderate encephalopathy 91% if mod- severe encephalopathy 75% if clinically severe encephalopathy
	Burst suppression Flat trace Low voltage	High probability of severe neurodevelopmental impairment or death 73% if clinically moderate encephalopathy 89% if moderate- severe encephalopathy 96% if clinically severe encephalopathy

### **3.3 ROLE OF aEEG IN THERAPEUTIC HYPOTHERMIA**

Recent studies suggest that an abnormal EEG would improve the selection of infants with HIE and it is reasonable to use aEEG in the first 6 hours of life as another tool for evaluating newborns eligible for therapeutic hypothermia. However, background pathological activity should not be mandatory as entry criteria and normal background activity should not exclude newborns from treatment with hypothermia. <sup>19</sup>

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The BAPM guideline issued in 2020 also recommends the routine use of therapeutic hypothermia in infants with moderate or severe encephalopathy secondary to hypoxic ischaemic brain injury<sup>[7]</sup>. Prompt use of CFM in infants who have suffered significant perinatal distress or insult facilitates early identification of infants most likely to benefit from therapeutic hypothermia.

Whilst severe hypothermia can depress aEEG voltages, studies in animal models have confirmed that hypothermia in the therapeutic range has no effect on the upper and lower margins of aEEG readings<sup>[8]</sup>. Of note, however, hypothermia does appear to delay the onset of sleep wake cycling and increase the time taken for the aEEG to recover<sup>[9]</sup>. This may be because of prolongation of the half-life of anticonvulsants during hypothermia therapy. It is therefore important to ensure that this delay in recovery of aEEG during hypothermia is not used as a basis of communicating a poor prognosis to parents.

### **3.4 NOTE ON COMPARISON OF aEEG WITH STANDARD 12-LEAD EEG**

Advantages of CFM compared with standard EEG are that CFM monitoring is more easily applicable and available, especially during the night-time and out of hours, and is especially suitable for continuous monitoring because it is not limited to being a relatively brief “snapshot” in time. CFM is a reliable tool for monitoring both background patterns (especially normal and severely abnormal) and ictal activity, and aEEG recordings correlate well with formal full EEG findings<sup>10</sup>. Certain focal, low amplitude, and very short periods of seizure discharges (<30 seconds) can be missed on the CFM however<sup>[10]</sup>. Owing to the nature of the single/dual channel recording, it is not surprising that very brief seizure activity, as well as focal seizure activity, may be missed. In the study of Toet *et al.* focal seizures were not identified by CFM in two of 10 children who were noted to have electrical discharges during the simultaneous aEEG-EEG recording<sup>10</sup>.

Thus, notwithstanding the utility of the CFM on the NICU, it is important to appreciate that aEEG lacks the sensitivity of a full 12-lead EEG monitor and therefore cannot, and should not replace a full lead EEG where the latter is indicated. Therefore, infants in whom aEEG recording is undertaken should generally also undergo a standard 12-lead EEG performed by the technicians of the Department of Clinical Neurophysiology.

A systematic review by Rakshasbhuvarkar *et al.* included ten studies, with a patient sample of 433, and found a median sensitivity of 76% and specificity of 85% for seizure detection when aEEG is evaluated **with** raw EEG tracings.<sup>22</sup>

## **4. ROLE OF CFM IN PRETERM INFANTS**

Although aEEG has not been as extensively evaluated in preterm infants as in term infants, aEEG may prove useful in some situations in this population, recent evidence shows that the use of aEEG in seizures and brain function evaluation in preterm newborns has been shown to be beneficial.

In terms of background activity, in extremely pre-term babies, the EEG background is discontinuous, with high voltage bursts and low voltage inter-burst periods. The raw

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EEG tracing may reveal periods of low voltage activity interspersed with brief bursts of high activity.<sup>19</sup> Although more research is needed in this area, dysmaturity (or no maturation) may be a sign of brain injury and altered brain function. This may be useful in determining if an infant is likely to have poor neurodevelopmental outcome, or at the very least help you to identify the most vulnerable preterm infants.

**Infants with IVH:** Infants with large Grade 3 or 4 IVH. Infants with IVH show decreased continuity, lower voltage patterns and more seizures. However, the presence of burst suppression within the first 72 hours of life has been associated with death or neurodevelopmental impairment at 2 years (PPV 63%, NPV91%).<sup>14</sup> The presence of bursts at <130/hr is associated with a worse prognosis than if the bursts are more than 135/hr.<sup>3</sup> Therefore, the aEEG may be useful as an additional tool when considering redirection of care in the setting of large IVHs and also may help in providing helpful counselling information.

Infants with abnormal movements: preterm infants are at risk of seizures especially in the presence of IVH. Seizures are a tricky issue in preterm infants, as they are the ones who are either missed due to short and same voltage of the background activity) or misdiagnosed due to many rhythmic events. The incidence of described electronic seizures in preterm infants vary from 4% to 48%. Intraventricular hemorrhage (IVH), white matter injury, mortality in the neonatal period, moderate to severe cognitive impairment on follow up have all been linked to electrographic seizures in preterm infants. According to research, electrographic seizures in the first week of life are linked to poor outcomes.<sup>19</sup> Pathological trace or discontinuous low voltage trace in infants from 25 to 32 weeks gestational age, displayed sensitivity of 88.9% for severe brain damage in cranial ultrasound results or death.<sup>20</sup>

The effect of antiepileptic medication on the developing brain has not been extensively studied therefore in the presence of abnormal movements the aEEG can help to confirm the diagnosis of seizures prior to starting antiepileptic medication

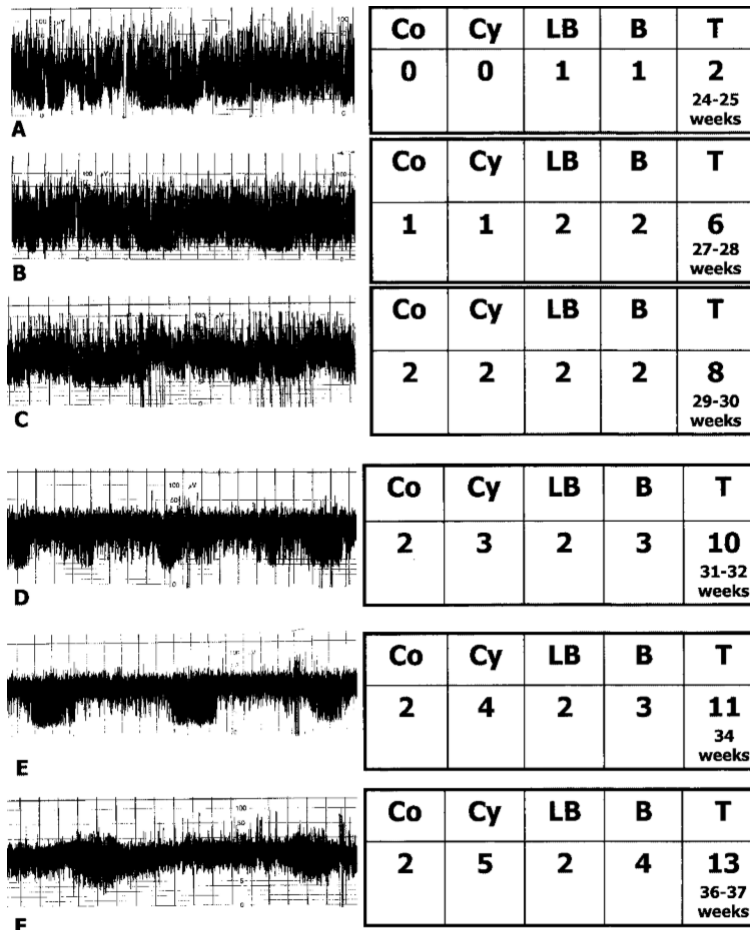
**Post-haemorrhagic ventricular dilatation:** Infants with PHVD have been shown to develop burst suppression and decreased continuity even before signs of increased intracranial pressure become apparent. In the majority these changes resolved upon drainage device placement. In this setting the presence of aEEG changes can support a decision that an infant with PHVD needs treatment.<sup>13</sup>

Sequential recordings: In vulnerable preterm infants, such as those with grade 3/4 IVH or hypoxic/inflammatory brain injury, short weekly recordings may provide information on continuing brain development and maturation of function. It has been shown that the continuity of an aEEG recording increases with gestational age in the preterm population without brain injury (See figure 4).<sup>16</sup> This maturation can be a sign of healthy CNS development.<sup>17</sup> It has also been noted that the presence of continuous background activity and sleepwake cycles within the first postnatal week has been associated with a good neurodevelopmental outcome.<sup>18</sup>

Practical considerations: Electrode choice is important to maintain comfort and skin

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integrity. With this in mind hydrogel electrodes are recommended for use in preterm infants with immature skin and should be gently removed using adhesive remover wipes (Appeel). Disc electrodes can be used for infants with immature skin however care should be taken to monitor skin integrity regularly. The use of subdermal needles is strongly discouraged for this population of infants.



**Figure 4**

The left side of the table demonstrates a progressive series of CFM monitor recordings; the right side shows the component maturation score values for the respective traces. There is a maturation of the tracings from A through F in these recordings. Postconceptional age ranges are indicated. Co, continuity of the recording; Cy, presence of cycling; LB, lower border amplitude score; B, bandwidth; T, total score.

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### Glossary

aEEG	Amplitude-integrated electroencephalogram
CFM	Cerebral Function Monitor
HIE	Hypoxic-ischaemic encephalopathy
IVH	Intraventricular haemorrhage
SWC	Sleep wake cycle

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### APPENDIX 1- CEREBRAL FUNCTION MONITORING OBSERVATION CHART

(Patient label) Hospital number Surname First name DOB NHS Number	Hospital Logo 
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### CFM OBSERVATION CHART

<b>Consider when Documenting:</b> <b>B</b> = Background trace <b>L</b> = Limits (upper and lower) <b>I</b> = Impedance <b>S</b> = Sleep wake cycle (SWC) <b>Seizures</b> / abnormal movements <b>A</b> = Artefact	<b>Guide to completing form</b> <ul style="list-style-type: none"> <li>Impedance – record highest reading.</li> <li>Upper and lower limits</li> <li>SWC; ground lead; seizures and medication write ✓ or x in corresponding box.</li> <li>Additional information to be documented contemporaneously in the notes.</li> </ul>	<b>R</b> = review with medical team after 30 minutes of monitoring; with every neurological review or if condition changes. <b>O</b> = Observe for abnormal movements/ seizures <b>M</b> = Mark all events (e.g. handling, seizures, medication) <b>E</b> = Escalate any concerns to medical team.
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DATE		Frequency of observations; 15; 30 or 60 minutes											
TIME													
LEFT SIDE	100												
	25												
	10												
	5												
	1												
RIGHT SIDE	100												
	25												
	10												
	5												
	1												
SWC seen													
Seizures													
Events/ Medication given													
Ground lead secure													
Impedance Left	21-30												
	11-20												
	0-10												
Impedance Right	21-30												
	11-20												
	0-10												
Escalated Y/N													
Reviewed Y/N													
INITIALS													

Adapted by Wendy Rogers, Neuroprotection Lead nurse for the East of England ODN  
 Original charts from: Luton and Dunstable Hospital; authors Claudia Chetani-Ganado, Neonatal consultant and Helen Doyle, ANNP  
 and Peterborough City Hospital; author Trina Valdez, Practice Development Nurse

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### APPENDIX 2- CEREBRAL FUNCTION MONITORING CLINICAL COMPETENCY CHECKLIST

#### Competency: Cerebral Function Monitoring

The cerebral function monitor (CFM) is used to monitor the brain wave pattern of infants who are identified as having a risk for brain injury and/or seizures.

CFM can be applied quickly in the clinical setting, and offers significant information which helps guide the treatments, management and progress of affected neonates.

Competency	Date	Staff sign	Consultant/Lead Nurse/PDN/ Link Nurse sign
1) Identify babies where CFM monitoring should be considered - Poor condition at birth - Therapeutic hypothermia - Abnormal movements - Intracranial haemorrhage - Term / preterm*			
2) Identify where the CFM machine and consumables are allocated			
3) Recognise appropriate placement of CFM needles/cups - Measurements look appropriate - Needles well secured and covered - Good contact tracing on the CFM - Low impedance			
4) Understand rationale behind hourly CFM monitoring			
5) Create and label events on the CFM machine including - cares / significant handling - clinical seizures/abnormal movements - anticonvulsant medications			
6) Know cut offs for normal upper and lower margins, describe sleep wake cycling and recognise changes in limits during seizures			
7) Know how to check for impedance levels and record them on CFM observation chart			
8) Understand the documentation for completion when CFM monitoring is in place			
9) Know when to escalate for medical review			
10) Be able to - start recording - suspend/restart monitoring - stop recording			
11) Able to clean equipment after use			

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Extended competencies	Date	Staff sign	
12) Be able to start CFM machine and enter patient details			
13) Measure and insert CFM needles <ul style="list-style-type: none"> <li>- Gather correct equipment</li> <li>- Appropriate hand hygiene</li> <li>- Measure and mark head correctly</li> <li>- Insert needles appropriately</li> <li>- Secure needles and connect</li> <li>- Ensure good quality tracing</li> <li>- Document in notes</li> </ul>			
14) Identify background patterns of CFM <ul style="list-style-type: none"> <li>- Continuous Normal Voltage</li> <li>- Discontinuous Normal Voltage</li> <li>- Burst Suppression</li> <li>- Continuous Low Voltage</li> <li>- Flat trace</li> </ul>			

## APPENDIX 3- CEREBRAL FUNCTION MONITORING REPORTING SHEET

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Patient details

**Printed sections from the CFM trace can be stuck in below**

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### References

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