

# Consensus-based guidelines for EEG monitoring of neonatal seizures in the critical care setting

By the EPICARE Neonatal Seizure Expert Group

## Introduction

Neonatal seizures are a common emergency in intensive care, occurring in about 1-3 per 1,000 neonates born at term (but more common in preterm neonates) (1). In full term neonates, the most common cause of seizure is hypoxia ischaemia due to a disruption in the oxygen supply to the neonatal brain around the time of birth, resulting in encephalopathy. Neonates with a mild or moderate degree of encephalopathy are at very high risk of seizures. Other common causes are stroke, infection, haemorrhage, genetic and metabolic disorders. There is considerable accruing scientific evidence, which suggests that controlling seizures reduces brain damage (2-8) however, seizures remain difficult to diagnose clinically and it is now well established that EEG is essential for accurate diagnosis. Continuous EEG monitoring is not common with most neonatal intensive units (NICUs) relying on the more limited amplitude integrated EEG (aEEG) for continuous monitoring (with intermittent EEG) even though it does not reliably detect all seizures (9-11). Current recommendations for the detection of all seizures in neonates are for the application of a reduced array of electrodes using the 10-20 system of electrode placement (12). Comprehensive guidelines for continuous EEG monitoring of neonates at risk of neonatal seizures do not exist and these EPICARE guidelines provide step-by-step information for this purpose.

## Definition of EEG

- cEEG
  - Routine EEG in neonates minimum of 90 min to including wake and sleep (longer if not both states)
  - EEG monitoring for 24-96hr
- Video
- aEEG
- Other trends
- Polygraphy
  - ECG
  - EMG (bilateral deltoids)
  - Respiration

- O2 saturation (optional)
- Blood pressure (optional)
- EOG (optional)

## Indications

Routine EEG / EEG monitoring min 24 hr

High risk neonates

- Neonatal Encephalopathy
- Stroke / Haemorrhage
- ECMO
- TORCH
- Suspected inborn error of metabolism
- Cortical malformation
- Clinical suspicion of seizures

Also consider EEG for the following

- Cardiac surgery
- Infection (sepsis/meningitis/encephalitis)
- IVH, PVL

## Recording Techniques

- Electrodes:
  - Reduced 10-20 with 9 electrodes: F3/4, C3/4, Cz, T3/4, O1/2 Preterm
  - Full term and tolerated: standard 10-20 montage. Use reduced montage if handling not tolerated in unstable baby
  - aEEG: 4 electrodes C3-P3 and C4-P4 plus ground and reference.
- Digital multichannel EEG system (20 channels plus)
- Electrode placement:
  - Should be the International 10/20
- Montages: Bipolar longitudinal, bipolar transverse, common average, Laplacian, and others as appropriate.
- Polygraph channels
  - Minimum ECG

- EMG
  - Respiration
  - Oxygen saturation where possible
- Sampling rate of 256 Hz or higher.
  - Performance settings:
    - Low frequency response 0.5 Hz or lower.
    - High frequency response of 70 Hz or higher.
    - Noise level less than 1  $\mu\text{V}$  rms.
    - Input impedance of 1  $\omega\text{M}$ .
    - Common mode rejection of at least 40 dB.
    - Dynamic range of at least 40 dB.
  - Sensitivity range +/- 2 – +/-2000  $\mu\text{V}$ .
  - Common mode rejection ratio (CMRR) >100db @ 50Hz.
  - Minimum digital resolution 16 bit analogue to digital converter.
  - Camera with aim to have baby in view at all times – IR camera.
  - Headbox must be outside incubator or if inside must be wrapped in sterile cover. Leads must be bundled in a systematic way (See figure 1).
  - Written informed consent to record and keep video, and to use data in multidisciplinary team meetings.
  - Review of all EEG and video data and seizures should be performed. Annotate at least the first 10 seizures or all of same type, count total number, describe semiology.



*Figure 1 EEG leads should be carefully bundled together*

## Methods of behavioural monitoring

- Video monitoring, ideally HD/wide angled lens.
- Nocturnal infrared video monitoring.
- Audio monitoring.
- Physiologist and nursing staff responsibility to keep patient in camera view.
- Agreed protocol for clinical and behavioural testing during seizure?
- Information for parents/guardians for individual testing during events.

## Electrical safety

All medical equipment must comply with IEC 601-1 (General requirements for safety of Medical equipment) and individual NHS Trust policies.

Perform annual safety test on all medical equipment. To be conducted only by suitable qualified biomedical engineers (BME). (Please note this test is very different from PAT testing of office equipment; PAT testing is **not** appropriate for medical equipment).

Any additional electrical equipment (medical and non-medical) which is brought into the patients' environment on an *ad-hoc basis*, for example, functional stimulation, Event Related Potentials, PCs/laptops used for presenting stimuli (visual/auditory), etc, **MUST** be checked and approved by appropriate BME personnel prior to connecting to patient and/or telemetry equipment.

## Artefact

Common sources – non-biological: ECMO, ventilator, mains, overhead heater, bed heater, High Frequency Oscillation.

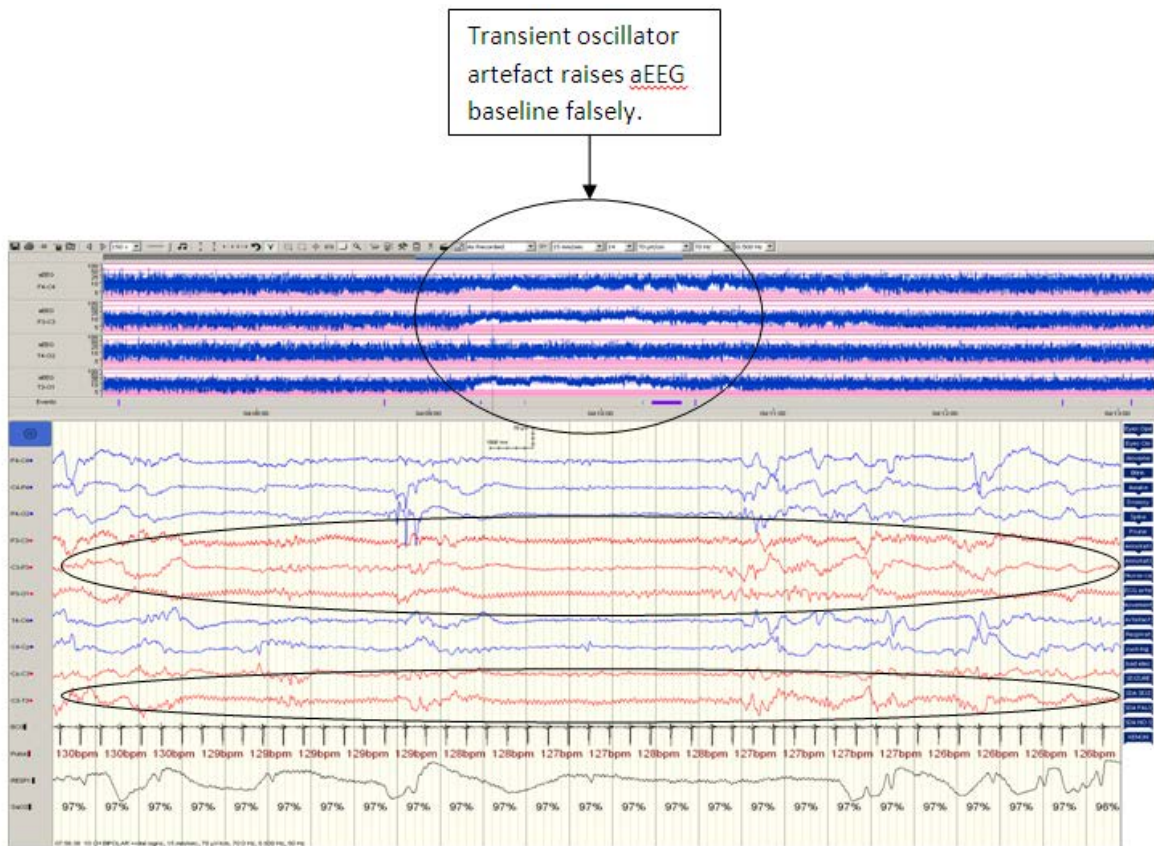


Figure 2 High Frequency Oscillator artefact

Biological: Respiratory and ECG artefact, Patting, hiccups, sucking.

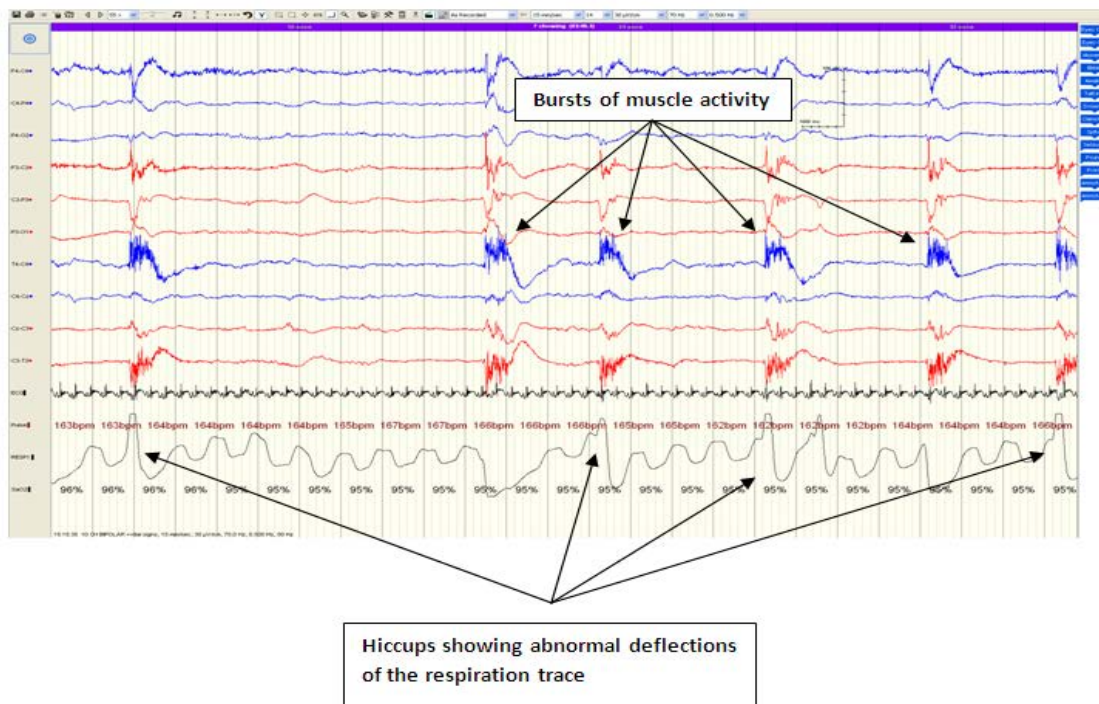


Figure 3 Hiccups on EEG



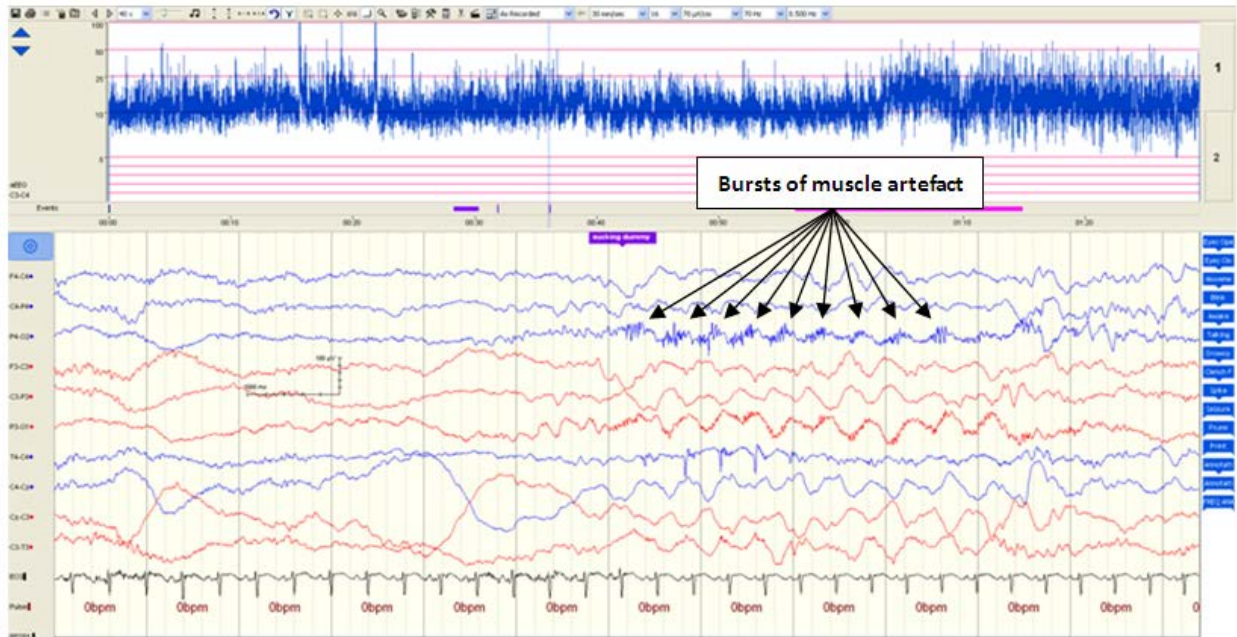


Figure 4 Artefact from sucking seen as repetitive muscle artefact on EEG

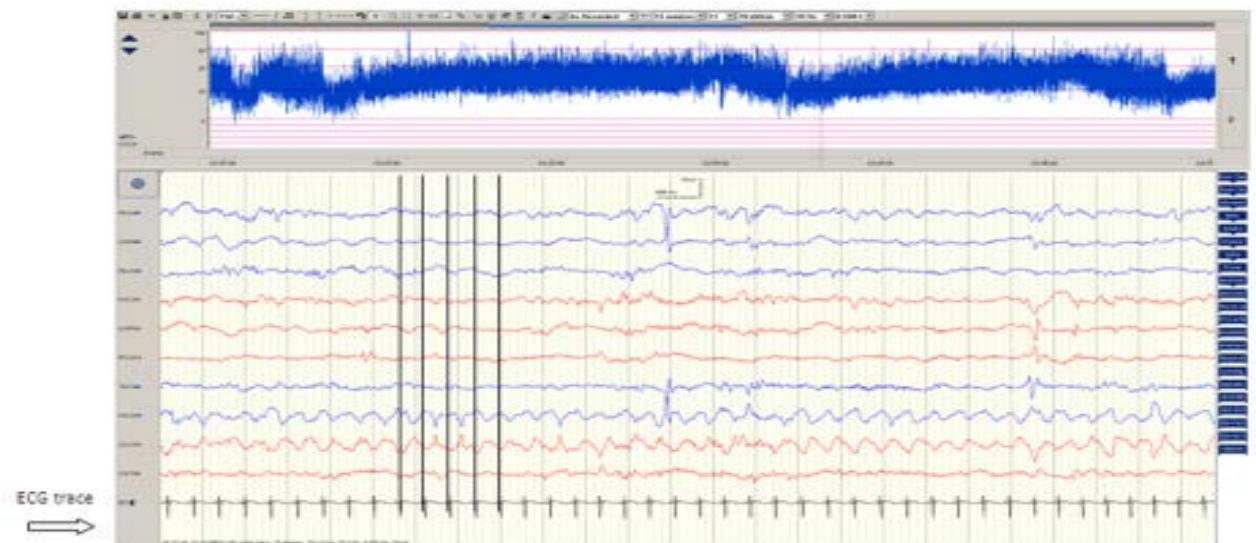


Figure 5 Pulse artefact on EEG

## Data storage

- Adequate storage space on server (depending on video quality and number of cameras 20-40 GB per 24 hours, but this is likely to increase with changes in technology).
- All video/audio monitoring data as well as associated EEG recordings saved until appropriately analysed.

- All EEG data should be stored whereas video data may be reduced in accordance with national and local guidelines. If videos are clipped, clippings need to include all relevant ictal information and a minimum of 3-5 minutes preceding and following the event (longer if the post-ictal phase includes relevant information). All available examples of each identified seizure type should be included if there are less than 10 events per type.
- Storage of relevant data retained until the patient is 25 years of age or 8 years after their death, if sooner.
- Data to be stored and to be used in accordance with the Data Protection Act.
- Data which is to be sent externally **MUST** be encrypted in accordance with local guidelines.

## Annotations of EEG recording

- Annotate all main features of recording.
- Annotate if awake/drowsy/asleep/arousal.
- Annotate good examples of background.
- Annotate all seizure types clinically and electrographically (if more than one type call then type 1, 2, 3 for example). Mark typical/good examples to show at multidisciplinary meeting.
- Estimate seizure burden, number of seizures, average duration, status present?
- Define semiology of captured events (ILAE neonatal seizure classification)

## Review of EEG during recording

- Frequency 2 x 24 hours and more often if clinically indicated
- Seizure record form (see Figure)

## Guidelines for writing the report

The format of the report will vary amongst different hospitals, but the following is suggested:

- **Clinical summary:**
  - Diagnosis
  - Clinical history including GA, CGA, birth history, first seizure, , MRI and if known),family history
  - Current medication.
  - Duration of monitoring, aim of monitoring, treatment changes, and number of captured events.

- **Factual**
  - Interictal Findings, including dominant frequencies, diffuse/focal abnormalities, asymmetries, sleep architecture, epileptiform discharges, and stimulation procedures (auditory, sensory...)
  - Seizure semiology:
    - Description of all seizures types giving specific examples dates/times duration and file details and whether typical/habitual/stereotypical
    - Detailed description of clinical evolution, including EMG features at onset.
    - Any post-ictal features.
  - Ictal Findings:
    - EEG: pre-ictal changes of background, initial electrographic change at seizure onset, evolution and spread of EEG features.
    - Post-ictal EEG features.
  - Physiologist/technicians' name
  
- **Clinical conclusion**
  - Responsibility of the Consultant Clinical Neurophysiologist (medical) or Consultant Paediatric Neurologist.
  - Consultant name.
  - Final report should be recorded in notes
  - Seizure semiology for each seizure type.
  - Ictal EEG changes including pre-ictal changes, EEG at onset, evolution of ictal EEG features, postictal EEG changes.
  - Interictal EEG phenomena, including posterior rhythm, focal or diffuse abnormalities, sleep phenomena, epileptiform discharges, and any other abnormalities.

## Conclusion

Neonatal EEG is essential to detect all seizures in neonates and we have attempted to set out the minimum guidelines required for effective monitoring in the NICU.



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