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Continuous brain-function monitoring: State of the art in clinical practice

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Summary Continuous electroencephalographic (EEG) monitoring gives direct information on brain function in newborn infants needing intensive care. To improve the possibilities of long-term monitoring, the EEG is time-compressed and recorded with a reduced number of electrodes. A trend measure of the EEG, the amplitude-integrated EEG (aEEG), has proved capable of giving relevant information in newborn infants of differing levels of maturity. The electrocortical background activity gives information on the level of brain activity, which is associated with outcome in both term asphyxiated infants and in preterm infants. However, the background activity is also affected by several medications, and this must be considered when interpreting the aEEG trace. The aEEG also reveals subclinical epileptic seizure activity, and can be used for evaluation of anti-epileptic treatment. The aEEG should be used as a complement to the standard EEG, and close collaboration between neonatologists and clinical neurophysiologists is necessary for optimal performance of EEG monitoring.

Introduction

Continuous brain-function monitoring with amplitude-integrated electroencephalography (aEEG) is now a daily part of clinical surveillance of sick newborn infants in many neonatal intensive care units (NICUs). During the last decade the aEEG method has become increasingly acknowledged as a method for continuous evaluation of brain function in neonates. One reason for this was the finding that the very early background pattern is sensitive for predicting outcome in asphyxiated full-term infants even during the first postnatal hours.[1,2]

However, the aEEG is not a new method for monitoring cerebral function. The cerebral function monitor (CFM) was created in the late 1960s by Maynard et al.[3] The original CFM was used to monitor brain function in adult patients with status epilepticus, after cardiac arrest, and during surgery. The first neonatal CFM recordings were performed in the 1970s and 1980s, and included normal tracings from term and moderately preterm infants, as well as reports on cerebral recovery after severe hypoxic—ischaemic insults, and of detection of clinically silent seizures.[4—8] The original CFM concept has been developed further, and the method is often called amplitude-integrated EEG (aEEG)

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to denote a method rather than a specific monitor. This chapter will review previous findings and current use of aEEG monitoring in the NICU. In the future, the aEEG and other EEG trends will probably constitute an integrated part of standard clinical monitoring in newborn infants needing intensive-care treatment. The aEEG has mainly been used for the following purposes in newborn infants, which are further discussed below.

1. Evaluation of cerebral recovery after a hypoxic–ischaemic insult.
2. Detection of epileptic seizure activity and evaluation of anti-epileptic treatment.
3. Cerebral monitor as part of the clinical monitoring.

Amplitude-integrated EEG method

The aEEG method is based on a time-compressed semi-logarithmic (linear 0–10 μV, logarithmic 10–100 μV) display of the peak-to-peak amplitude values of a filtered and rectified EEG. The EEG is passed through an asymmetric band pass filter that strongly enhances intermediate EEG frequencies. Most EEG activity below 2 Hz and above 15 Hz is suppressed in order to minimize artefacts from sweating, movements, muscle activity and electrical interference. The bandwidth of the aEEG trace reflects variations in minimum and maximum EEG amplitude (Fig. 1). The semi-logarithmic display enhances identification of changes in the low voltage range, and avoids overloading of the display at high amplitudes. The aEEG display is time-compressed to allow an overview of long-term trends in cerebral activity. Previously the standard speed was 6 cm/h, but with new monitors the speed can usually be customized. The initial CFM concept has been developed and several new monitors are now available. These machines are based on digital EEG; they show the aEEG, but they also display and store the original EEG. This is a major advantage since verification of suspected seizure patterns in the aEEG can be done by evaluating the real EEG, and artefacts caused by e.g. care procedures or high-frequency oscillation ventilation are more easily identified. The number of channels differs between the monitors; some use the original single-channel biparietal recording technique and others offer possibilities of multi-channel EEG recordings.

Normal aEEG tracings in term and preterm infants

Knowledge from neonatal EEG studies can be used when evaluating aEEG. This is relevant especially for evaluation of background patterns and inter-burst intervals (IBIs) and for interpretation and verification of epileptic seizure activity.[9,10] Several studies have described normal aEEG development in term and preterm infants. The aEEGs have been described from various aspects: amplitude (minimum and maximum voltage), pattern and cyclicity corresponding to sleep–wake cycling (SWC). Three early studies described tracings in normal term and moderately preterm infants, one of them also included follow-up.[4,6,11] The findings in these three studies were very similar, although the definitions and classification differed (as in later studies on very preterm infants). The aEEG of term and moderately preterm infants is characterized by a mainly continuous background pattern with minimum voltage above 5 μV. The bandwidth varies with sleep–wake cycling and is

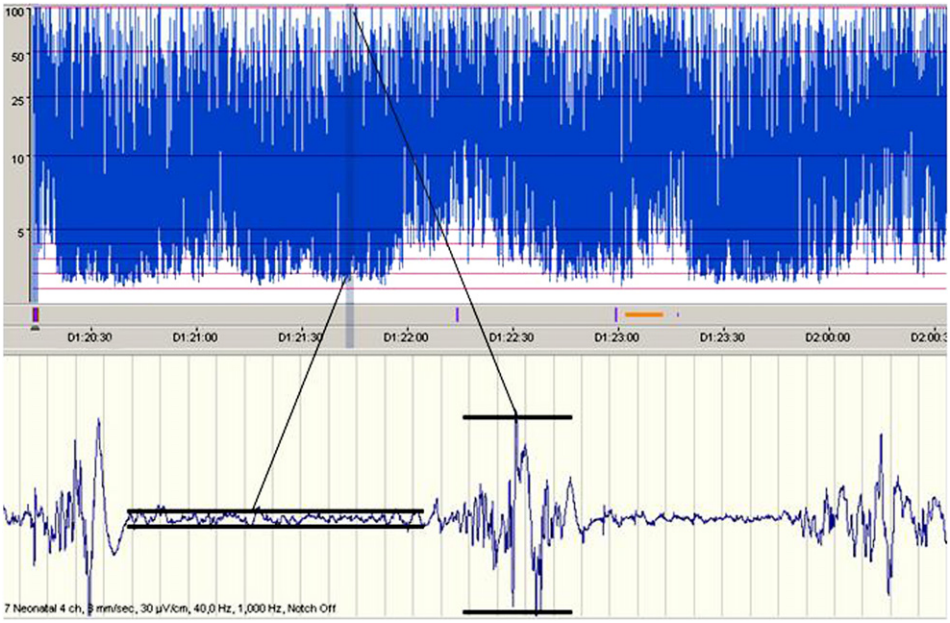

Figure 1 A 4-h amplitude-integrated electroencephalography (aEEG) recording, with 34 s of corresponding EEG below, from a 6-week-old preterm infant born at 24 gestational weeks (i.e. 30 postmenstrual weeks). The aEEG background is discontinuous, the low-amplitude EEG corresponds with the lower border of the aEEG, while the high-voltage bursts of activity in the EEG corresponds with the upper border of the aEEG. The sinusoidal variability in the lower border of the aEEG tracing represents sleep–wake cycling.