Chapter 11
Automated Neonatal Brain Monitoring

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ABSTRACT

Monitoring the electroencephalogram (EEG) in sick newborn babies in the neonatal intensive care units (NICU) gives important information about brain function. Seizures are frequently seen in the EEG of the sick neonate, and usually denote serious underlying brain dysfunction. Current clinical practice assumes that neonatal seizures have to be treated to prevent further injury to the brain. Recording of amplitude integrated EEG (aEEG) or the full EEG supports treatment decisions as well as prognostication has become standard practice in many NICUs. aEEG has become popular in recent years due to its user friendliness. A full EEG offers a more reliable window to study the ongoing activity in the newborn brain with high temporal and relatively good spatial resolution. However, the expertise required to register and interpret EEG is not available around the clock in the NICUs. For this purpose, automated monitoring devices have been developed, to assist neonatologists at the bedside and neurophysiologists in reviewing large amounts of monitoring data. The main topic of this chapter is automated detection of neonatal seizures and its possible impact in clinical practice. Three different detection approaches are reviewed: model-based, heuristic and classifier-based. Also a futuristic view on automated EEG analysis systems will be given.

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INTRODUCTION

Newborn brain is vulnerable to various insults in the perinatal period, like asphyxia, stroke, trauma, metabolic disturbances and infections. Among these, perinatal asphyxia is the most common problem, affecting 1 to 6 out of 1000 newborns and often causing neonatal seizures. Asphyxia results from deprivation of oxygen or blood supply and may have severe consequences like permanent brain injury or death. Survivors of birth asphyxia often have sequelae like motor, sensory or cognitive disability or epilepsy. As the survival of neonates being treated in the Neonatal Intensive Care Unit (NICU) has greatly improved over the last decade, the focus is now gradually changing to improving long-term health prospects of critically ill neonates. Continuously monitoring the health status of such neonates at risk using the electrocardiogram (ECG), blood pressure, respiration and the oxygen saturation has become standard practice. In the past, for lack of a direct measure of brain function, neonatologists had to rely on these parameters to ensure that homeostasis was being maintained. Clinical examination is unreliable to monitor brain function and to detect the occurrence of seizures in very sick neonates. Recent advances have made multiple modalities available for the detection and monitoring of brain injury. Examples are biochemical parameters, brain imaging (ultrasound and MRI), neurophysiological tests like EEG, somatosensory and visual evoked potentials (SEPs, VEPs) and Near Infrared Spectroscopy (see Chapter 4 in this book). The importance of continuously monitoring the brain function in the NICU with EEG (Toet & Lemmers, 2009) or by measurement of brain oxygenation (Vanderhaegen *et al.,* 2010) for diagnosis, treatment and prognosis has been recognized.

In practice, the monitoring of the electrical brain activity is done using aEEG or full EEG. aEEG monitoring or CFM™ (cerebral function monitoring) is a commonly used technique that records the brain activity from one or two channels, displaying about 5 hours of data on a single page. Interpretation relies on visual recognition of changes in amplitude of the background activity, recovery of sleep-wake cycles and occurrence of seizure patterns (Bourez-Swart *et al.*, 2009). Interpretation varies according to the expertise of the user. It has gained acceptance in many NICUs because of its apparent simplicity. For detailed information, we refer to Chapter 10 in this book.

Recording the *full EEG* captures much more of the rich brain dynamics in the neonate than aEEG. It is considered the gold standard for seizure detection and (electrical) brain function in general and monitors brain activity with at least 8 channels. However, only few centers have been able to sustain this type of monitoring in the newborn, mainly driven by clinical research. The raw EEG offers a wealth of data, can be used for continuous bedside monitoring, and has the potential to predict at an early stage the health prospects of the neonate. Also, EEG monitoring enables the clinician to start or adjust the appropriate treatment in time, often before definite injury has occurred. Unfortunately, EEG analysis requires particular skills that are not always present round the clock in the Neonatal Intensive Care Unit (NICU). But even if those skills are available, it is very labor-intensive to manually analyze many hours of EEG data. It is clear that a user-friendly and reliable (semi)automated brain monitoring tool is needed to improve the real-time use of multi-channel EEG.

There is no hard evidence that such treatment of seizures indeed improves outcome. However, a recent study suggests a beneficial trend on injury burden seen on MRI (van Rooij *et al.,* 2010). The validity of their conclusion could be questioned due to the small number of included neonates. Also, it is important to realize that treatment with anti-convulsants has side-effects like cardiorespiratory depression, and above all they may interfere with neuronal survival and (re)generation (Stefovska *et al.*, 2008).

Dispite the lack of hard evidence, the current viewpoint of clinicians is that lasting and repetitive