Chapter 10
Introduction to the CFM and the Clinical Applications

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ABSTRACT

The cerebral function monitor is a device for trend monitoring of changes in the amplitude of the electroencephalogram, typically recorded from 1-2 pairs of electrodes. Initially developed and introduced to monitor cerebral activity in encephalopathic adult patients or during anaesthesia it is now most widely used in newborns with encephalopathy to assess the severity of encephalopathy and for prognosis. The time to recovery from a moderately/severely abnormal amplitude integrated electroencephalogram trace to a normal trace is strongly predictive of subsequent neurological outcome following neonatal hypoxic ischaemic encephalopathy, including in newborns receiving neuroprotective treatment with prolonged moderate hypothermia. The cerebral function monitor is also used for seizure detection and to monitor response to anticonvulsant therapies. Amplitude integrated electroencephalography compares well with standard electroencephalography when used to assess the severity of neonatal encephalopathy but a standard electroencephalogram is still required to provide additional important information about changes in frequency, and in the synchrony and distribution and other characteristics of cerebral cortical activity. The role of the amplitude integrated electroencephalogram to identify brain injury in preterm infants remains to be determined.

INTRODUCTION

The cerebral function monitor (CFM) was invented more than 40 years ago at the London Hospital, UK, by Douglas Maynard and was first applied clinically by Pamela Prior (Maynard, 1967, 1979; Prior et al., 1971). It was designed as a method for the continuous recording of cerebral electrical activity in adult patients with severe encephalopathy, in most cases following cardiac arrest. The intention was to design a simple device that allowed bedside continuous electroencephalographic (EEG) monitoring in an intensive care unit environment, to detect changes between intermittent standard

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EEG recordings. The device proved invaluable for detecting seizures and deterioration in cerebral activity in unconscious patients and to monitor response to therapy and the depth of anaesthesia (Prior, Maynard, & Brierley, 1978; Prior, Virden, & Maynard, 1973; Prior et al., 1971; Schwartz et al., 1973). The original CFM recorded on heat sensitive paper the change in amplitude of the EEG – usually called the amplitude integrated EEG (aEEG) measured in microvolts (uvolts), and the impedance between the recording electrodes.

A few years after its invention, following a visit to the London unit, Ingmar Rosen and Nils Svenningsen introduced the CFM at the neonatal nursery in Lund, Sweden, to monitor brain function in sick neonates (Bjerre, Hellstrom Westas, Rosen, & Svenningsen, 1983). Subsequently Lena Hellström-Westas from Lund and Linda de Vries from Utrecht, Holland, and others carried out a series of clinical studies that defined the characteristic abnormalities of the aEEG in full term infants with hypoxic ischaemic encephalopathy (HIE) and described its prognostic accuracy for neurodevelopmental outcome following HIE (Bjerre, Hellstrom Westas, Rosen, & Svenningsen, 983; Hellstrom Westas, Westgren, Rosen, & Svenningsen, 1988; Hellstrom Westas, Rosen, & Swenningsen, 985; Hellstrom-Westas, Rosen, & Svenningsen, 1995; Eken, Toet, Groenendaal, & de Vries, 1995; Toet, Hellstrom-Westas, Groenendaal, Eken, & de Vries, 1999). Later Denis Azzopardi (Imperial College London) suggested that the CFM could be used as tool for the selection of infants for trials of neuroprotective therapies (Azzopardi et al., 2000). Following the pilot study, an abnormal aEEG was used as a selection criteria in three randomised clinical trials of moderate hypothermia in infants with HIE (Gluckman et al., 2005; Azzopardi et al., 2009; Simbruner, Mittal, Rohlmann, & Muche, 2010). The success of these trials stimulated the development and production of new digital CFM devices and now the CFM is increasingly routinely used in neonatal intensive care nurseries as part of standard monitoring of infants with HIE (Azzopardi et al., 2008).

The CFM has also been used in preterm infants to detect complications such as intraventricular haemorrhage and for prognostication(Hellstrom Westas, Rosen, & Svenningsen, 1991; Hellstrom-Westas, Klette, Thorngren-Jerneck, & Rosen, 2001). The characteristic changes in the amplitude of the aEEG trace that occur with increasing maturity, analogous to developmental changes in continuity observed on standard EEG, have been defined (Olischar,Klebermass, Waldhoer, Pollak, & Weninger, 2007; Olischar et al., 2004). Delay in the normal developmental changes in aEEG pattern and continuity during the first few weeks after birth may correlate with subsequent neurodevelopmental outcome.

Modern CFM devices in addition to the aEEG also display the unprocessed EEG and some devices can display other EEG parameters such as the power, intensity and spectral edge frequency of the signal. Algorithms for automated seizure detection have also been developed. In the rest of this chapter, CFM refers to the device and aEEG to the trace displayed by the CFM.

TECHNOLOGY

The design of the original device has been described by Maynard and is summarised in Figure 1 (Maynard, 1979). The unique features of the device are: a special wideband filter which weights the EEG spectrum to counteract the normal tendency of slow components to be of larger amplitude; logarithmic compression and envelope detection; and a write out that continually moves between minimum and maximum peak to peak amplitudes of the filtered EEG.

The frequency response of the CFM is shown in Figure 2. The filter is designed to reject most activity below 2 cycles per second so as to eliminate low frequency fluctuations caused by movement. There is a sharp cut off above 15