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Monitoring CFM and brain diagnostics of premature infants

***Abstract**. The paper presents the application of the transforming EEG signal into highly compressed CFM record in clinical useful. A lot of information created by EEG record (hundreds of samples per second per each channel) and which require interpreting with specialist knowledge are transformed into time compressed. This paper presents monitoring and brain diagnostics of premature infants. Is described a general principle CFM methods and mechanisms used for therapy.*

Streszczenie**. W pracy przedstawiono zastosowania wysokiej kompresji sygnałów EEG po transformacji w postaci impedancyjnej w badaniach przewietrzania klatki piersiowej. Określono podstawowe parametry obrazów medycznych uzyskiwanych metodą tomografii impedancyjnej. Podano preferowane metody rozwiązania zagadnienia odwrotnego oparte o algorytmy liniowe wykorzystujące aproksymację badanych obiektów przy zastosowaniu metody elementów skończonych.* (Monitoring CFM i diagnostyka mózgu wcześniaków***).

Keywords: EEG - electroencephalography, CFM - cerebral function monitor, brain diagnostic, signal processing method
Słowa kluczowe: EEG - elektroencefalografia, CFM - monitorowanie funkcji mózgu, diagnostyka mózgu, metody przetwarzania sygnałów

Introduction

Premature babies, especially those born before the 32th week of pregnancy show a very high incidence of mortality as well as show tendency toward delayed psychomotor development later in life. This group of newborns often shows symptoms of intracranial bleeding as well as leukomalacia-related changes. Perfusion distortions that appear in cases of premature birth cause vessels fracturing and subependymal haemorrhage. Later, haemorrhage may result in: cerebral palsy, epilepsy or damage to eyesight and hearing [6]. Another important clinical problem occurring among premature infants is persisted ductus arteriosus (PDA). It rises the risk of other complications like necrotizing enterocolitis, kidney failure or intraventricular haemorrhage. Therefore PDA is an important factor of mortality and neurological complications [4]. Because of its delicate body, a premature infant is susceptible in the first days of its life to permanent damage, cardiac failure and infections. These problems lead to central nervous system lesions and require intensive monitoring and treatment.

Monitoring and brain diagnostics

Current medical knowledge indicates that there are only two methods allowing for direct, non-invasive and constant monitoring of central nervous system: near infrared spectroscopy and amplitude integrated electro-encephalography, or cerebral function monitor (CFM) [4]. The latter method is discussed further in this paper.

CFM may be used for the following [1,4]: CNS functions evaluation, initiating hypothermia treatment and monitoring the process, seizures diagnosis and treatment monitoring, premature infants – monitoring patients weighing less than 1,500g is recommended, perinatal hypoxia, monitoring development, evaluation of record acceleration, meningitis (possible seizures), hydrocephalus (possible seizures), congenital TORCH infections (CNS function monitoring).

In long-term CFM monitoring usually two to four active electrodes are used. This makes keeping correct impedance between skin and electrode easier and translates into better quality of the registered signal as well as directly translates into potential interpretation by a doctor. CFM is a simplified recording of a classic EEG, presented after appropriate transformation and mathematical analysis as a signal trend. It collectively presents hours of brain activity, which allows to evaluate global OUN condition. Consequently neonatologists in children's wards can use it without the need to call upon a neurologist. The method also allows to compare activity of cerebral hemispheres. CFM monitoring focuses on border between irrigation regions of anterior, middle and posterior cerebral arteries [1], since those areas are in high risk of ischaemia [3]. Active electrodes, following the "10-20" system [7], are typically placed in points P3, P4 for two-channel examination and additionally on F3, F4 for four-channel examination [2].

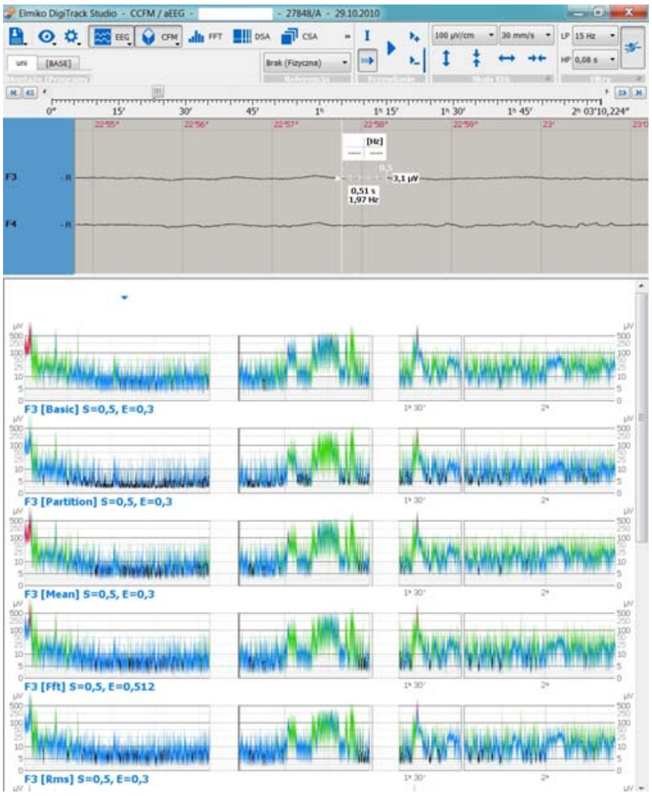

Fig. 1. CFM algorithms comparison. Clinical condition: premature baby born in the 30th week of pregnancy, weight at birth 1350g, hospitalization without central nervous system related complications. EEG curves show a continuous low tension (depression) signal on both leads, amplitude occasionally falls below 3μV, the Partition algorithm much stronger marks the depression but lowers its value

The presented examination has been recorded using a 5-channel 0x39B head box with 500Hz sampling frequency (decimation to 250Hz) produced by Elmiko. On the screen EEG and CFM panels take most of the space, above them we will find a toolbar and controls for adjusting options and parameters like amplitude scale, time scale, filters, montage and references. The default settings for CFM examinations are: filters LP=15Hz, HP = 2Hz (0.08s), active notch filter, amplitude scale 100μV/cm, time scale 30mm/s.

The EEG panel shows the signals recorded during the examination, the signals' names are located on the left. The signals are montage and displayed according to the parameters set with the controls. The panel is divided with vertical time interval times, drawn every 1 second, to the left of each line the corresponding time is displayed (real time or the time elapsed since the examination started). In figure 2 colored rectangles can be seen on the signal. They indicate electrode-skin impedance at the moment. Presenting a post-factum impedance value is important to correctly interpret the examination's results. In figures 2, 3 and 4 the measuring tool is visible. It is a software tool used to evaluate p-p amplitude and frequencies during a selected data fragment.

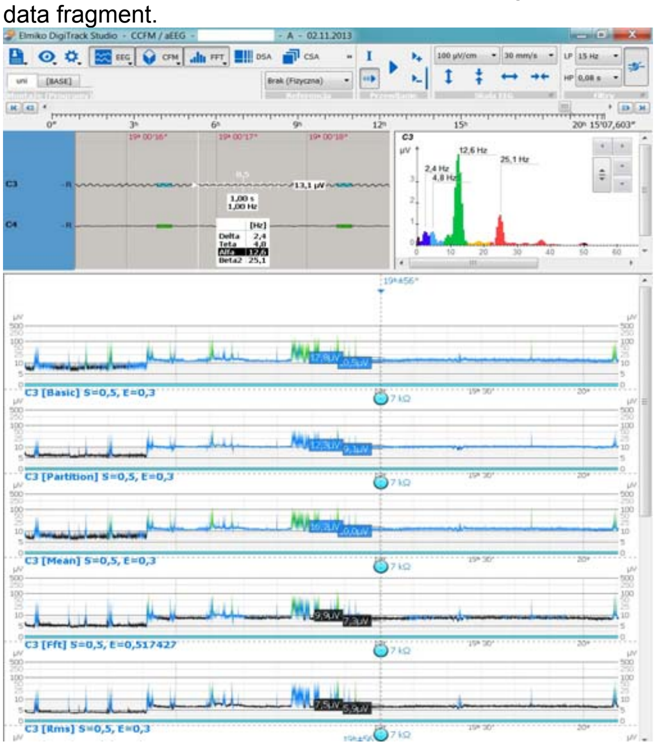

Fig. 2. CFM algorithms comparison. Clinical condition: child born in the 35th week of pregnancy, weight at birth 2,710g, hospitalized on 30 days after birth due to cardiac arrest that occurred at home, where he was resuscitated by medics and transported to the hospital. After admittance condition classified as serious, EEG shows no bio-electric brain activity, examinations show lack of reactions and multiple organ dysfunction syndrome due to serious hypoxia. The baby died after 24 hours after hospitalization. Channel F3 clearly very noisy, comparing with another channel F4 and stronger filtration shows that only the FFT algorithm successfully dealt with interferences and shows a correct CFM recording. On the EEG's right side a FFT spectrogram is displayed, clearly showing dominating value of oscillating interferences unrelated to the brain's activity. In this particular case of noise, the FFT algorithm works much better than Partition, even in depression

CFM panel is located on the bottom of the screen and is divided into sections that present a trend for each channel. Colored classification of CFM samples is a unique and very important feature that allows us to quickly evaluate our patient's condition. The colors correspond with main types of clinical conditions: black is used to mark depression (state - depending on literature - below 5 or 10μV); green shows a Burst-suppression occurrence (signal between 10-65μV), red - high amplitude signal, at least 50μV (Epileptic Like Activity, or EPI); blue is used for signals that are within the limits of what's normal. In figure 2, below the trend there is information about electrode-skin impedance for the given CFM sample (in this case the impedance is very low). The illustrations also show the name of the channel where the trend was calculated and the name of algorithm used as well as CFM sample's size and the length of the epoch used in calculations. The trend is presented (Y axis) in semi logarithmic scale, 0-10 range, in linear scale, above the logarithmic scale. It is a very popular way of presenting signals and allows us to emphasize changes below 10μV as very important. In figure 4 CFM trends are complemented with oxygen saturation trend (purple curve) and pulse (gray curve)

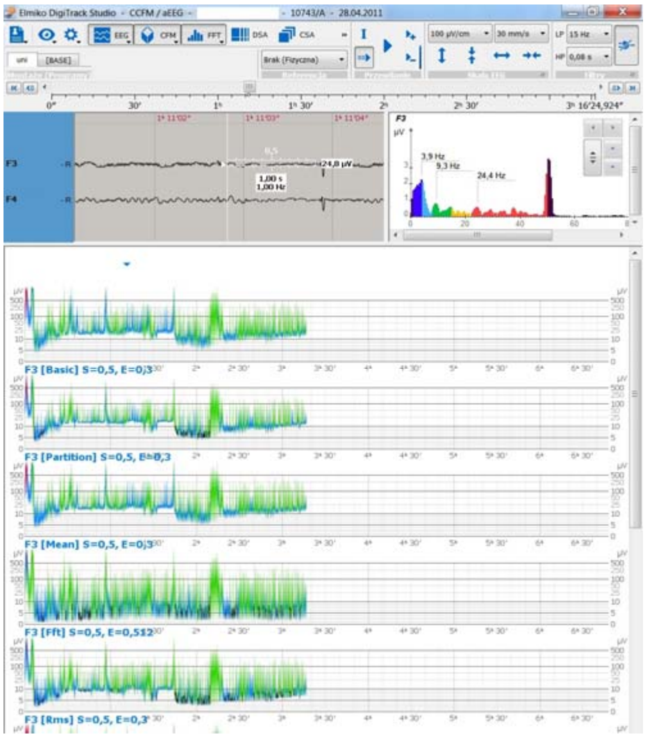

Fig. 3. CFM algorithms comparison. Clinical condition: a baby born in the 28th week of pregnancy, weight at birth 1,250g, grade 3 intraventricular hemorrhage. Channel F3 is noisy 50Hz - again, only FFT algorithm correctly presents the lead's condition

Clinical experience shows that EEG to CFM transformation is very useful and delivers more information; thus it should be developed and adapted to various clinical situations (pathologies).

However, determining in a given period (called CFM sample) a value that would show a representative brain activity level is not easy and can be done in many different ways. Hence the idea to test various CMF algorithms. Algorithms can be presented in two basic groups: ones operating on time-related data and the other operating on frequency data. The former analyze the signal's shape, amplitude and instantaneous power. Frequency algorithms analyze the total power of the signal's elements. Both algorithm groups allow for a lot of maneuvering space because of changeable CFM sample's size, period's length, sample's division into subintervals, averaging, modifications of the spectral analysis window, overlapping windows, signal filters etc.

There was a reason for implementing a number of chosen algorithms. Different algorithms provide different results - the differences are not significant, but clear. First evaluation cannot unambiguously decide the algorithm's advantage thus the analysis is needed.

The algorithms used in the study are based on the notion of CFM sample, CFM sample's length and epoch's length. Five algorithms were implemented at the first attempt. "Basic" - a basic algorithm with peek-to-peek value designation throughout the whole CFM sample. "Partition" – works like "Basic", but divided the sample into 5 sub-divisions. "Mean" – works like "Basic", but instead calculating throughout the sample it does so in its many fragments which are defined by the epoch's length. "FFT" algorithm does calculations in the frequency domain. The signal's total power root in appropriate frequency ranges is determined. "RMS" algorithm defines root mean square from the samples taken in the range of the epoch's length.

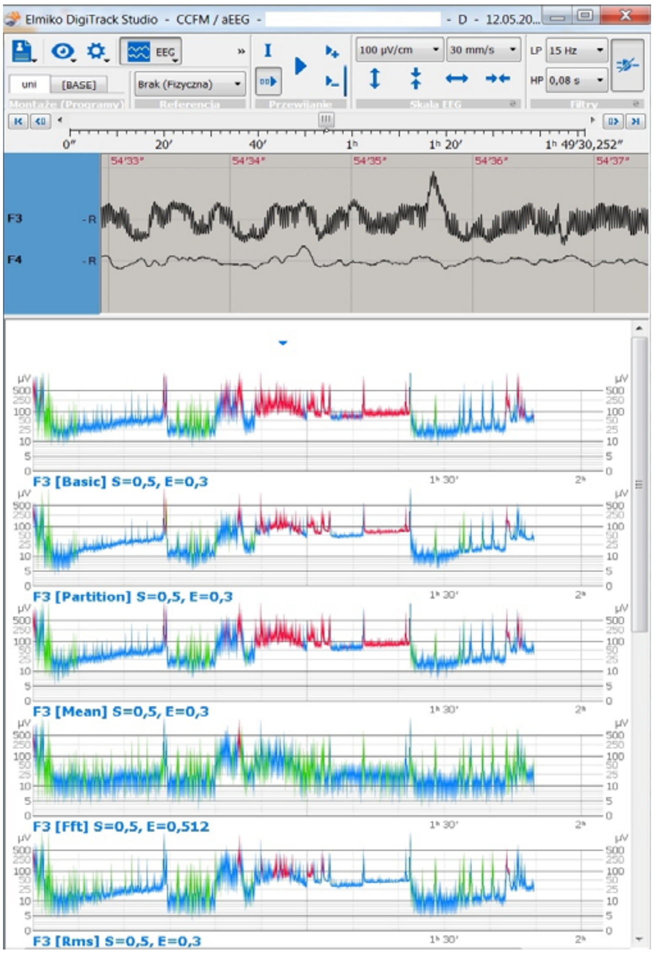

Fig. 4. CFM algorithms comparison. Clinical condition: baby carried to full term, weight at birth 4190g, hospitalized due to sepsis and meningitis, serious condition throughout the infection. Channel F3 noisy 50Hz similarly to Fig. 3 - once again only the FFT algorithm correctly shows the lead's state. The picture clearly illustrates raising noise starting with the 5th minute and ending with 30th and their growing influence on all the algorithms except the FFT

Summary

These analyses clearly show that different EEG to CFM transformation algorithms provide significant differences in the signal a doctor receives to evaluate and interpret. The first phase of testing resulted in finding two algorithms that in given situations provided results more in accordance with the child's clinical condition. In the future we will attempt to develop both algorithms and test on different clinical cases. Perhaps we will also try to merge the advantages of both of the algorithms and develop a new transformation method.

Therefore it is very important to refine CFM monitoring methods to achieve clearer results. Moreover it would be very useful to monitor the patients with regard to the occurrence of specific dysfunctions or pathologies.

After analyzing the presented work we believe that CFM examinations conducted with different transformation algorithms are a major improvement, since using the right algorithm should allow medical personnel to easier evaluate the present brain condition of a premature baby and thus - to react appropriately. It is clear that the choice - and use - of an algorithm strongly influences what the CFM looks like and in turn influences the doctor's interpretation. Moreover, analyzing CFM recordings and comparing them with patients' clinical conditions lead to singling out two algorithms out of the tested five. Partition and FFT algorithms seem to be the most effective in clinical evaluation (Fig. 1 and 2).

Constant CFM monitoring allows physician to react quickly to changes in child's health. In case of seizures it allows to administer proper medicine and monitor its effectiveness. AEEG findings may influence decision regarding other diagnostic studies like: intracranial ultrasonography, echocardiography, blood gas analysis, glucose level, acid base balance, inflammatory markers. In case of diagnosed hypoxia CFM allows to qualify the child for therapeutic hypothermia. Thus further development and improvement of the CFM method, especially Burst Suppresion Online analysis, is very important since it will make the information collected during monitoring more valuable and will allow physicians to react faster and more appropriately to the occurring condition. Good visualization of Burst Suppression by using an appropriate CFM algorithm is an important problem we are signaling here and which will be the focus of our further research.

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