INVESTIGATION OF THALAMUS ELECTRICAL STIMULATION EFFECTS ON BRAIN ACTIVITY OF COMA PATIENTS

Bareaa ZABACH[1], Sever PASCA[2], Jean CIUREA[3]

La experimentul nostru am înregistrat semnale EEG, înainte, şi după aplicarea stimulării electrice asupra pacienţilor comatoşi in starea vegetativă. Aceste înregistrări au fost analizate ca să ne ajute să înţelegem schimbările provocate in activităţile creierului. Rezultatele experimentale arată că jumătate din numărul subiecţilor investigaţi au un nivel mai ridicat de energie al semnalelor EEG, şi s-a observat că există zone ale emisferelor care au sensibilitate ridicată şi au prezentat cel mai ridicat nivel de energie după stimulare. O perspectivă pentru a continua cercetările în acest domeniu este găsirea unei combinaţii optime între forma de undă şi frecvenţa stimulului.

In our experiment, EEG recordings were made before and after the application of electrical stimulation on patients in the vegetative state. The recordings were analyzed to help us to understand the changes in brain activities. Half of the patients showed higher energy level of the brain activities [1]. It seams like there are some centers on the brain cortex which indicates a higher sensibility for the stimulation. This study leads us to think that, if we can find an optimal combination between the waveform and the frequency of the stimulation, then we may be able to bring around the patient in coma.

Keywords: Brain stimulation, Thalamus stimulation, Vegetative coma.

1. Introduction

A coma is a deep state of unconsciousness, during which the patients are unable to react to their environment. It can be a result of head trauma like in brain injuries or damage, the post-injury swelling in the brain tissue increases the intracranial pressure, forcing itself into the blood vessels decreasing by that the blood pressure and blood alimentation to the brain. Sometimes the sever injuries can end up with death [2][3]. Coma also happens as a result of undergoing or invisible illness, like the cases of nerves infection or intoxication, where the patient may have headache or dizziness, which became more aggressive before

[1] PhD. Student, Dept. of Bioengineering and Biotechnology, University POLITEHNICA of Bucharest, Romania, bareaa75@yahoo.com
[2] Prof., Dept. of Bioengineering and Biotechnology, University POLITEHNICA of Bucharest, Romania,
[3] Medic, Department of Neurosurgery, Bagdazar Hospital, Bucharest, Romania

the coma attacks. Some causes of coma are reversible, others are not. Some of them are called focal processes, where localized abnormalities affect one part of the brain, like tumors. Others are described with the term diffuse processes, and that affects large parts of brain, like in the case of toxins, eventually it alters some body functions. They may affect the liver, kidney, and nervous system [4].

There are terms to describe various levels of unconsciousness and a person's ability to respond to stimuli and in this study the electrical stimulation was applied to patients in a state of coma that is called *Persistent vegetative state*, where the brainstem circuits maintain vital functions like respiratory system functions, sleep-wake cycles, and cranial nerve reflexes, but awareness or consciousness is absent; this is due to the relative preservation of metabolism in brainstem, basal forebrain, and posterior hypothalamus.

2. Thalamus and median nerve stimulation

Nowadays electrical stimulation studies are held out to help coma patient, it is believed that it can improve chemical exchanges between the brainstem and the cerebrum, which is considered to be vital activity for keeping any person aware and conscious

A study of electrical stimulation of the median nerve is mentioned in [9], where electrical impulses are sent from the wrist up to the arm then to the brainstem, through the median nerve.

The pattern of the stimulation in the median nerve stimulation study is similar to the pattern of stimulation in our experiment, except for the place where the stimulation is applied; in our study, the stimulation was applied to the thalamus by an electrode inserted in the nasal cavity, however the aim remains the same for both studies, which is to stimulate the thalamus and brainstem, and consequently stimulating the whole brain functions and enhancing the arousal.

There were no EEG analyzing results published in the median nerve stimulation study [9], but it reported an increasing in cerebral activity, an improvement in speech, an improvement in motor and emotional responses, and an elevation in cerebral spinal fluid concentration of catecholamine especially dopamine, which is involved in maintenance of consciousness and motor control. These clinical observations were consistent with the results and the EEG analysis in our study.

3. Experimental description

This experiment of electrical stimulation for coma patients was held out in Bagdazar Hospital in Bucharest, and conducted by Dr. Jean Ciurea.

It is believed that the thalamus and hypothalamus are important and vital zones in the brain; they are parts of the midbrain and brain stem, which are

implicated approximately in all brain activities. And stimulating these parts of the brain is believed to be helpful in the recovery process from coma.

In some cases of coma, patients do wake up after stimulation, but there is always a big question mark on the efficiency of this method, some doctors are convinced that the electrical stimulation is a reason of recovery, directly or indirectly. While others don't appreciate the method, they assume that the brain heals itself and the patient is waked up.

The scope of this study is to apply electrical pulses to the thalamus area, then to analyze the changes of the EEG registration of patient's brain activity, and notice the modifications that might happen before and after the stimulation, and investigate it's possible contribution in reactivating the patient's brain and restoring consciousness, which deliver a technical evidence of the electrical stimulation effects on brain activity.

EEG signals were recorded by the means of digital system of mapping with 16 channels, developed by Genesys general system S.R.L. while EEG signals were processed using the explorator 16-E program, incorporated in the digital EEG mapping system.

We are seeking the appearance of Alpha or Beta waves in the record. And since they are distinguished by the frequency, the FFT will be very suitable to be used in the experiment.

The stimulator used in this study was especially developed for this study and it delivers two waveforms at its out put, as illustrated in Fig.1.

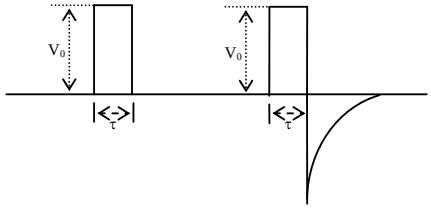


Fig.1. Waveforms obtained at the stimulator output [5]

The negative part of the second waveform means that the total DC current passes through the tissue, and that helps in reducing the reaction between the electrode and the tissue, and makes the second waveform more preferred than the first waveform, especially for long stimulation sessions.

The whole stimulation periods vary from 30 minutes to 6 hours, respecting the protocol to apply stimulation train of pulses for 1 second, followed by a pause period of 5 seconds; the pulses have a range of frequencies between 1-200 Hz.

The stimulation electrode is forced through the nose to inter the nasal cavity, till it reaches the nasal posterior, where it can get a position next to the pterygopalatinum ganglia, which is connected to the pedunculus cerebri.

The pedunculus cerebri is connected with the thalamus area and medulla oblongata, the area we wish to stimulate.

Fig.2 illustrates the digital mapping system for EEG signals, and its connection to the patient.

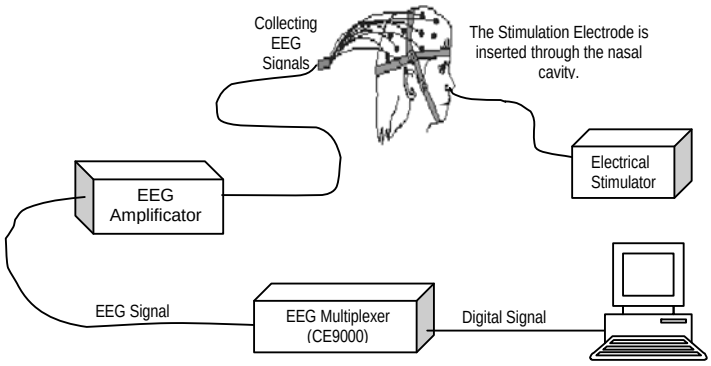
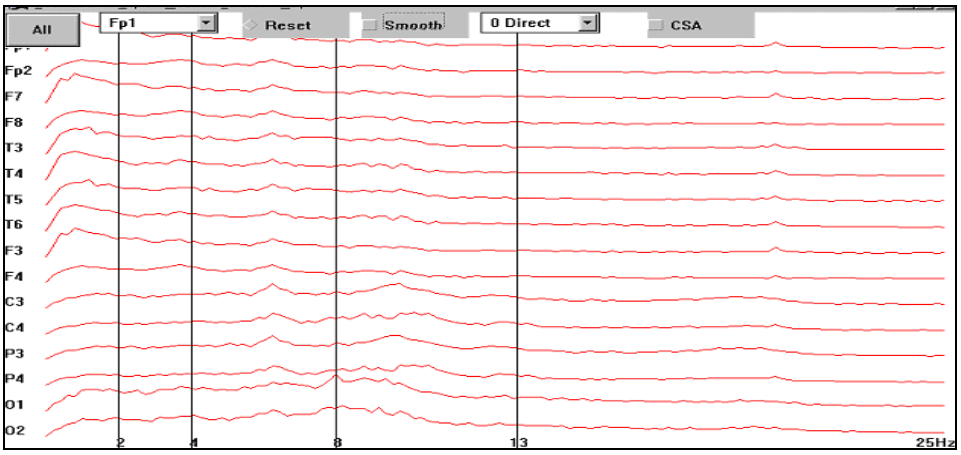
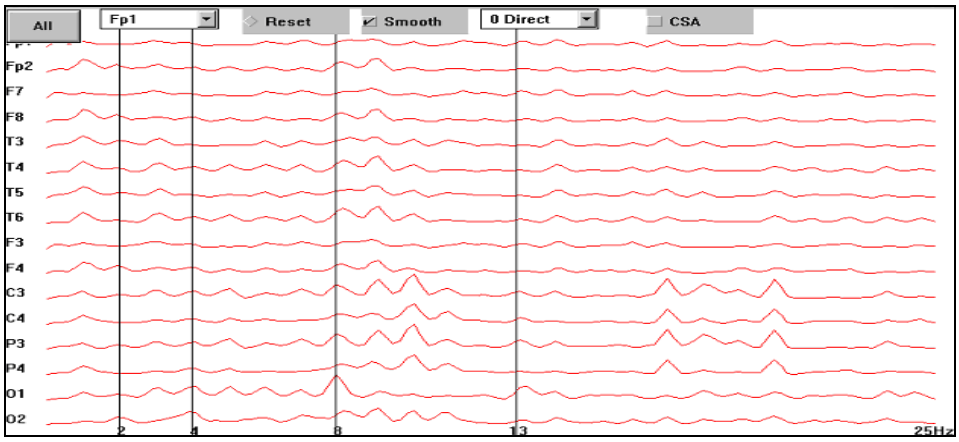


Fig.2. The digital mapping system and its full connection.

In Fig.3 there are some examples of brain activity analysis for EEG registration, where one can see clearly the effect of stimulation to enforce the appearance of alpha and beta waves at high frequencies.



(a)

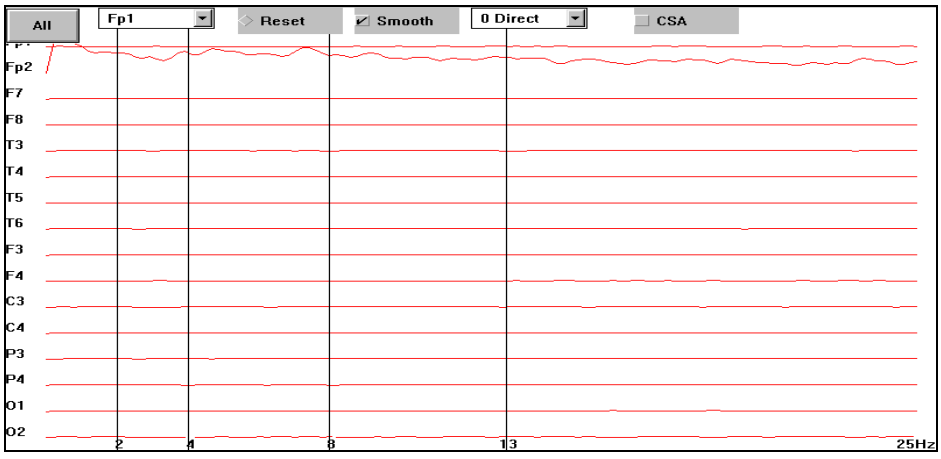


(b)

Fig.3. Brain activity analysis for EEG registration before (a) and after (b) stimulation

Fig. 3(a) shows the energy distributed all over the coma patient cortex. Before applying the stimulation of thalamus area the brain activities have frequencies smaller than 10 Hz, with significant alpha waves at 8 Hz at the optical center.

Fig. 3(b) shows that after a period of stimulation, Alpha and Beta activities appear at C_3, C_4, P_3, P_4, and O_1.



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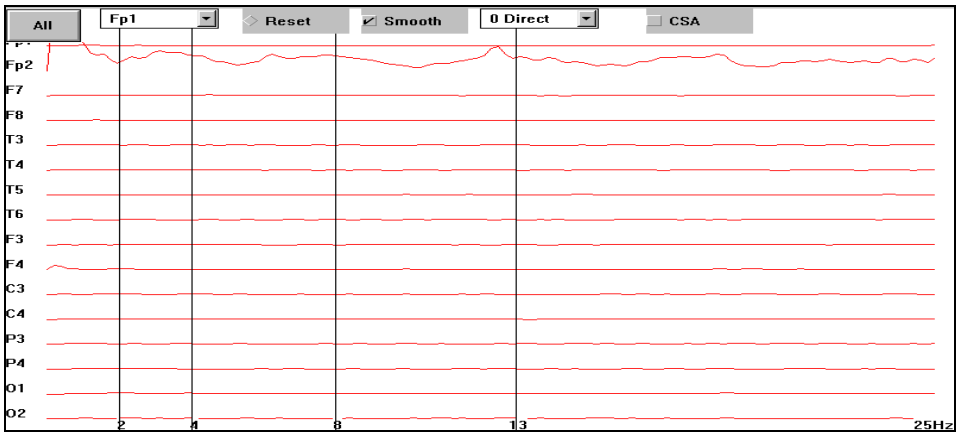

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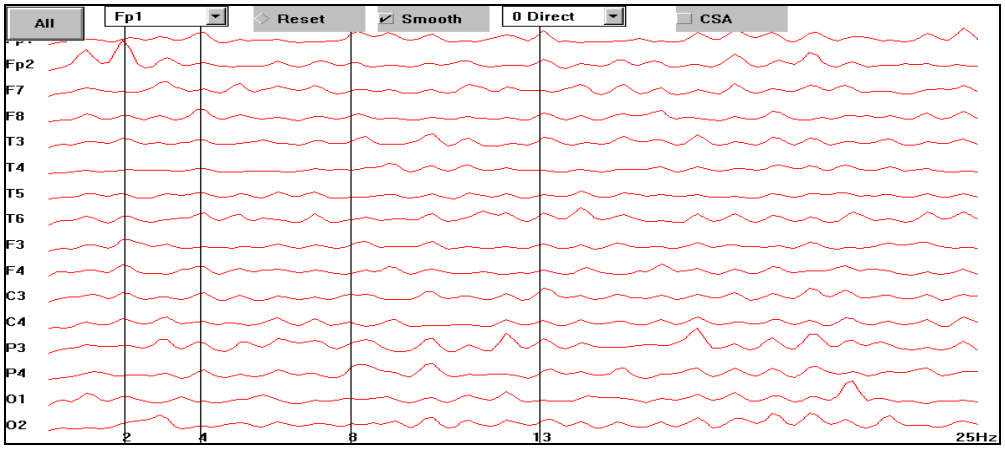

(c)

Fig.4. Brain activity analysis for coma patient, before (a) and after (b), (c) stimulation

Fig.4. represents registration analysis for another coma patient, before applying the stimulation, where we can observe in Fig.4(a) low frequency activities at the Fp_2 site. They are rather delta and theta waves, which indicate the unconscious state of the brain at this particular site, while there is no significant energy at other electrodes recordings.

In Fig. 4(b), after few minutes of thalamus stimulation, the patient have about (50%) higher energy at 12 Hz, which characterizes alpha wave; there is some increasing activity with about (20%) at the frequency of 20 Hz. These waves

characterize the conscious state of the brain at Fp_2 site, the rest of the electrodes show no significant changes of the energy level.

Fig. 4(c) after another few minutes of stimulation, we observe that the brain generates waveforms at various frequencies; it may not be synchronized or harmonic activity, but it is certainly higher energy than the before stimulation.

4. Results

The study shows that almost all patients had experienced changing in the energy and brain activity under electrical stimulation.

About half of them showed raise in energy (about 40%) at higher frequencies range, where alpha and beta waves are observed.

It seems to be true that, speech, motor cortex, and thought processing centers are more sensitive and much affected by the electrical stimulation than other parts of the brain. These results coincide with the results mentioned in the study of median nerve stimulation [9], where was reported that the stimulation improves speech, increases cerebral activity, and improves motor and emotional responses. However the percentage and numbers of patients in thalamus stimulation is higher than those in the median nerve stimulation

The other half had also showed changing in energy, but it was not very clear or acute.

Only one patient showed no respond to the stimulation.

Short stimulation periods interrupted by short resting period during one stimulating session seam to add a good stimulating effect on the brain activity.

In some cases the stimulation had the effect of suppressing the brain activity at low frequency and redistributing it over the whole gamma of frequencies.

5. Conclusions

Deep electrical stimulation of the brain appears to be promising method in helping coma patients to recover as was demonstrated here that the stimulation works in increasing the energy of brain activities. It seams that, if we just can find a good combination of stimulating waveform, and frequency, we may be able to awaken up the patient from coma. However electrical stimulation does not have the exact same effect on all coma patients.

Applying magnetic stimulation on the active and sensible centers in the cortex after applying the electrical stimulation of the thalamus may be helpful and subject for a future study.

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