THALAMUS ELECTRICAL STIMULATION ON VEGETATIVE COMA PATIENTS

B. Zabach*, M. Ungureanu*, S. Pasca*, J. Ciurea**

* Politehnica University/Department of Medical Electronics and Informatics, Bucharest, Romania
** Bagdazar Hospital/ Department of Neurosurgery, Bucharest, Romania

bareaa75@yahoo.com, mickyungureanu@yahoo.com,
sever.pasca@elmed.pub.ro, ciureaj@yahoo.com

Abstract: Coma is a deep state of unconsciousness. During it the patients are alive, but unable to react to their environment. It can be caused by head trauma, which usually follows accidents and head injuries, or undergoing and hidden illness, like the cases of nervous system alcoholic intoxication, which causes some chemical changes in the brain activity, and make them to be different from the normal awake or sleeping persons. In this study, The EEG signals were recorded before and after the application of the electrical stimulation for a group of coma patients in the vegetative state. EEG records are then analyzed to discover the effect of the electrical stimulation on the brain activities. Half of the patients show a higher energy level of the brain activity, in comparison to the other half of patients who show a lower energy level, but it is still higher than the brain activity level before the stimulation.

Introduction

Sometimes, some coma patients may enter what is known as a persistent vegetative state, this happens when patients lose all cognitive neurological functions. This lost in the cognitive brain part leaves them unable to respond to their environment. But they are still able to breathe or make sudden movements. These patients may even appear to be awake and normal, while they are not. By using the Explorator 16-E program in our experiment, we can graphically analyze the EEG recordings, which are made before and after the application of electrical stimuli on patients in the vegetative state. The changes in the brain activities are very valuable to estimate the changes on the consciousness level of the patient's brain.

There are many causes of coma or other unconsciousness conditions. Some are reversible, others are not. Some of them are called focal processes - localized abnormalities that affect one part of the brain, like tumors or a blockage in blood vessels. Others are described with the term diffuse processes that affect large parts of the brain [12], like toxins problems, which change the balance of elements concentration in the blood, and eventually affect some body functions, and the nervous system.

The coma can be a direct result of head trauma like brain injury or brain damage, when the post-injury swelling in the brain tissue increases the intracranial pressure, and applies pressure forces on the blood vessels, decreasing by that the blood pressure and blood alimentation to the brain. Sometimes the sever injuries can end up with death. Coma also happens as a symptom for 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 the coma attacks.

Materials and Methods

The *consciousness* is considered to represent the reciprocal interaction and successful functioning of two neural components. The first component is the *Ascending Reticular Activating System* it is the nerve pathways in the brain concerned with the level of consciousness, from the state of sleep, drowsiness, and relaxation to full alertness and attention. The second component is the *Cerebral Cortex*, which is responsible for intellectual faculties and higher mental functions. Researchers believe that a continuous neurotransmission, of chemical signals from the brainstem to the cerebral hemispheres of the brain, is important physiological processes to keep a person conscious and aware of their environment. Abnormalities that interrupt it can lead to coma.

Usually there are dedicated terms that describe different situations of coma as in the following [11].

Persistent vegetative state: brainstem circuits maintain vital functions but awareness or consciousness is absent.

Delirium: impaired consciousness with confusion, agitation and hallucinations.

Stupor: the patient is unconscious with decreased activity, most patient respond to strong repeated stimulation.

Akinetic mutism: in this condition, the vital body functions are reserved, the patient experiences sequential phases of wakeness and sleepness, but he do nothing, often due to bilateral, inferior (orbital) frontal lobe lesions.

Locked in syndrome (coma vigile): not a form of coma, consciousness is preserved, but patient's motor function is sufficiently impaired to prevent outward expression of thought and behavior. Due to extensive or transverse high brainstem lesions.

ISSN: 1727-1983

The Brain Metabolism

A study related to the vegetative coma investigation [4] has analyzed the brain metabolism, which is defined as The sum of chemical changes that occur within the tissues of an organism consisting of anabolism and catabolism, the buildup and breakdown of molecules used by the body. It was detected by Positron emission tomography (PET), showed that global brain metabolism in vegetative coma patients is reduced to 40 - 50% of normal values for waking persons, while it is reduced by only 10% than the values of deeply sleeping persons. Trans-synaptic degeneration could be responsible for this progressive loss of metabolic functioning over time. At present there is no established correlation between brain metabolism depression and patient outcome.

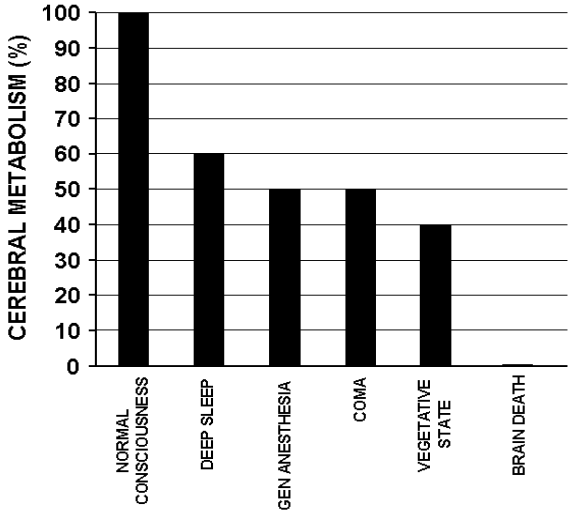

Figure 1: Cerebral metabolism in different unconscious states [4].

In the vegetative state the relative preservation of metabolism is in the brainstem, basal forebrain, and posterior hypothalamus. This allows the maintenance of vegetative functions like ventilatory control, and cranial nerve reflexes. And that makes the hypothalamus a good area to apply the stimulation.

Experimental description

The experiments of electrical stimulation for coma patients were conducted by Dr. Jean Ciurea, at the Bagdazar Hospital in Bucharest.

The scope of the experiment is to reactivate the patient brain and to bring him back to consciousness.

It was believed that the thalamus and hypothalamus are important and vital zones in the brain, not known exactly how, but these areas in the brain seams to be involved approximately in all brain activities.

The aim of this paper is to study the changes of the EEG registration of patient's brain activity, and to notice the modifications that might be caused by the applied stimulation.

EEG signals were recorded by a brain mapping digital system having 16 channels, developed by Genesys general system S.R.L.

EEG signals are processed using the explorator 16-E program, developed by Dr. Nicolaie Rusca at Genesys General System S.R.L.

The appearance of *alpha* or *beta* waves are Expected in the records, and since they are distinguished by the frequency, the FFT *fast Fourier transformation* is used in this experiment.

Here is a quick review for the most known waves of the brain activity and their frequencies [19].

Delta: They have less than 4Hz and occur in deep sleep.

Theta: Their activity has a frequency of 3.5 to 7.5 Hz and is classed as "slow" activity, It is abnormal theta waves to appear in the EEG records of awake adults

Alpha: these waves are between 7.5Hz and 13Hz. They will peak around 10Hz. Good healthy alpha production promotes mental resourcefulness, aids in the ability to mentally coordinate.

Beta: they have a frequency of 14Hz and greater. They reflect desynchronized active brain tissue. And they are usually seen on both sides in symmetrical distribution. and may be absent or reduced in areas of cortical damage.

At the stimulator output two waveforms of stimulation pulses as illustrated in the following figure can be obtained.

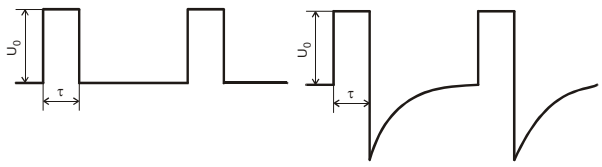

Figure 2: Shows the waveforms obtained at the stimulator output [7].

The second waveform is much more preferred, because of the negative part of the signal, which comes after the positive part, it helps the tissue to rest and repolarizes.

The whole stimulation periods vary from 30 minutes to 6 hours, according to the protocol to apply the stimulation. A train of pulses last for 1 second, followed by a pause period of 5 seconds is applied, the pulses have the frequency range of 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.

Here is the analyses of the brain activity changes for two patients.

ISSN: 1727-1983

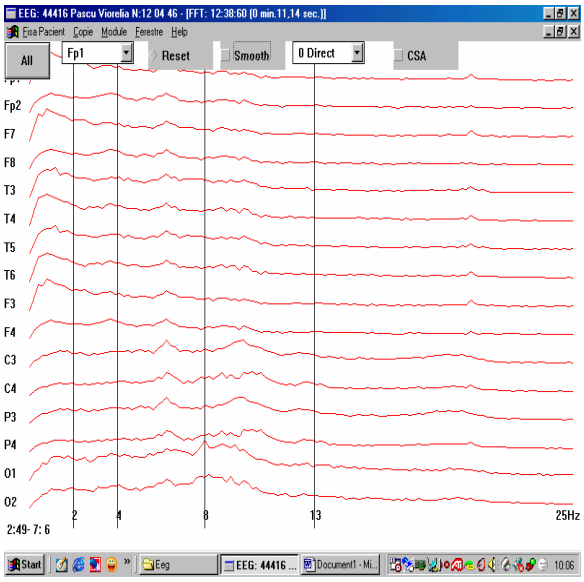

Figure 3: before the stimulation, we can see the activation at low frequencies they are rather delta and theta wave, which describe and indicate the unconsciousness, there is also insignificant appearance of activities at 8 Hz, for coma patient before applying the stimulation

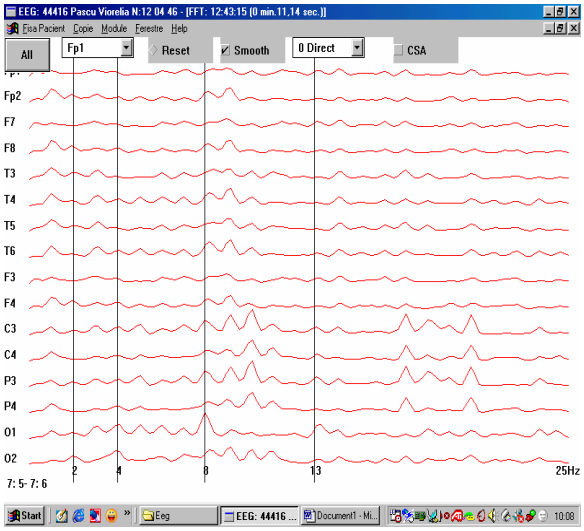

Figure 4: after applying the stimulation, the patient have higher activity at 12 Hz, which charactarize alpha waves, there is some activity between 12-20 Hz frequency range at C3, C4, P3, P4, these waves characterize the state of attention, the low frequency waves are suppressed, in addition to the energy is much better distributed.

Following now, is the registration of the next patient, while the analyses where made for the sites T5, C4, because they were the most active sites of the cortex, and the program allows us for the comparssion reasons to present the analyses of each electrode apart or with other selected electrodes.

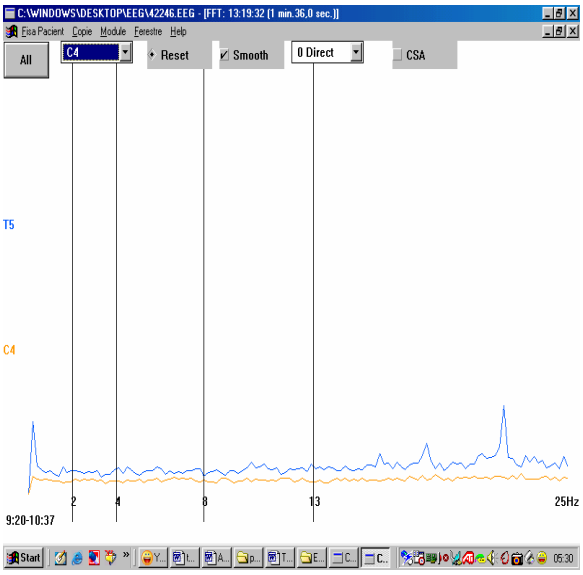

Figure 5: before the stimulation the patient shows no activity at C4 site, while at T5 there is some activity at low and high frequency, but not in the range between 8-13Hz, this site is responsible for, language, speech, and words recognition and hearing.

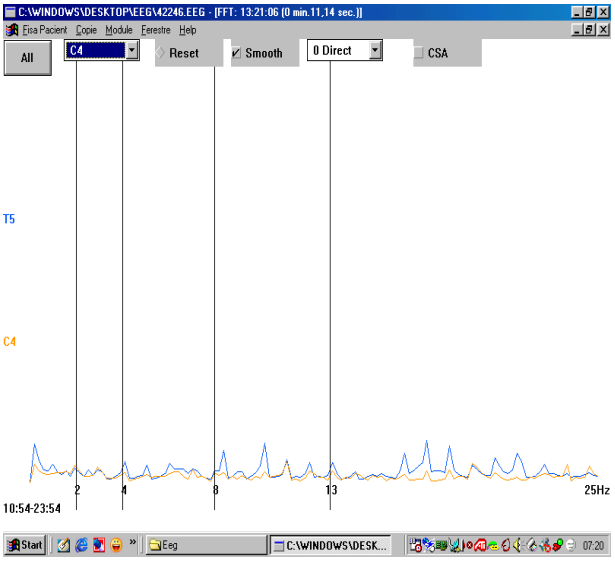

Figure 5: There are clear higher activities at C4 site, the activities are at delta and theta waves, and a strong activity now clearly appears at the 8-13Hz range at T5 site.

ISSN: 1727-1983

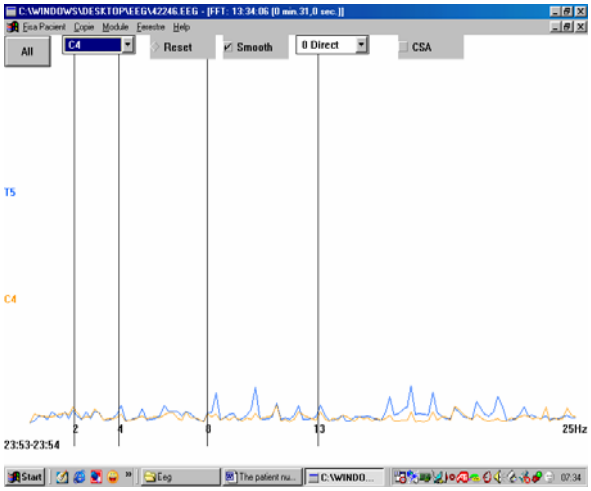

Figure 5: after second stimulating the signals are more concentrated at high frequencies, at the same time the low frequency signal is suppressed.

Results

In our study almost all patients have showed a higher energy level of brain activities compared with level of the activities before the stimulation. Some patients showed a higher energy level of activity, in comparison to the other half of patients, who showed a lower energy level, but still higher than the brain activity level before the stimulation. Only one patient showed no response to the stimulation.

It also seems to be true that, speech, motor cortex, and thought processing centers are more sensible and much affected by the electrical stimulation than other parts.

The Electrical stimulation appears to be a promising method, but it doesn't has the same effect on all vegetative coma patents, and it can't be used for all cases of coma.

Discussion

Some cases of coma patients do wake up after stimulation, but there is always a big question mark over the efficiency of this method. Some physicians believe that the electrical stimulation is a reason of recovery, directly or indirectly. Others don't appreciate the method, considering that the brain healed itself and the patient waked up.

Further studies can reveal that, the real effect of the stimulation at the molecular and chemical level under the condition of persistent coma could be measured, when the right conditions to measure the brain metabolism just after applying the electrical stimulation, or even during it, are settled. Based on it, it can be understood how the coma alters the normal and typical response of the neural tissue, to the electrical stimulation. In case that the optimal combination between the waveform and the frequency of the stimulation is found, we may be able to bring back the patient from coma. The continuity of the stimulation applied on patients is an important factor in our opinion and we will investigate its importance and influence.

Conclusions

This study leads us to think that, if we just find an optimal combination between the waveform and the frequency of the stimulation signal, then we may be able to bring back the patient from coma. The continuity and the repetition of the stimulation applied on patients are important factors that need to be investigated in future study. Using a system, which has the ability to alter and change the waveform and the frequency of the stimulation signal, can help, to overcome the problem of nervous tissue adaptation, which occurs in the cases of long stimulation.

We also can apply multiple stimulations, respecting the neural connection order, to amplify the effect of the first stimulation. For example, the electrical stimulation is applied at the beginning to the thalamus area, followed by magnetic stimulation of the thought processing center area.

References

[1] SINELNICOV D. R. (1990): 'Atlas of Human Anatomy', Mir Publisher, Moscow, Vol.III ISBN 5-03-000325-8, 5-03-000322-3.

[2] HARRISON M. L. (1998): 'The Pocket Medical Dictionary', CBS Publisher and Distributors.

[3] GENESYS GENERAL SYSTEM S.R.L. (2001): Utilization Manual, 'Exploratory 16-E, EEG Digital Mapping System ', Manual De Utilizare, 'Explorator 16-E, Sistem Digital De Mapping EEG Cu Canale'

[4] SCHIFF D. N., RIBARY U., MORENO RODRIGUEZ D., BEATTIE B., KRONBERG E., BLASBERG R., GIACINO J., MCCAGG C., FINS J. J., LLINAS R., PLUM F. (June 2002): 'Residual cerebral activity and behavioural fragments can remain in the persistently vegetative brain', Brain, Vol. 125, No. 6, 1210-1234,

[5] PHILIP P. V., PRKER A., SCOTT N. R. (February 1998): 'Adaptive Stimulus Artifact Reduction in Noncortical Somatosensory Evoked Potential Studies', IEEE Transaction on Biomedical Engineering, Vol. 45, No. 2.

[6] ADAMS ET AL. (Feb 1995): 'Principles of Neurology', Fortschr Neural Psychiatry, 6th Ed, P348, 63(2): 59-67.

[7] CIUREA J., CONSTANTINOVICI AL., SIMOCA I., PERIN R., MIRCEA D., PASCA S. (1998): 'Brain Electrical Stimulation Therapy in Patients With Prolonged Consciousness Disturbances - Pilot Study', Romanian Neurosurgery, Romanian Academy, New Serie VII, No. 1-2, January-December , pp. 119-126.

[8] CIUREA J., PASCA S., SZTOJANOV I. (1996): 'New System for Prolonged Coma Treatment by Electrical Stimulation', 'Sistem pentru tratamentul comei prelungite prin stimulare electrica',

ISSN: 1727-1983

Professional Realizations in Electronical Domain volume, ICSITE, Bucharest 17-18 October , pp. M13-M17.

[9] STRUNGARU R., PASCA S. (1986): 'Electrical Stimulation of The Tissues', 'Stimularea electrica a tesuturilor', Bulletin I.P.B., Electronical Serie, Volume XLVIII, pp. 43-49.

[10] BCM, http://www.bcm.edu/neurol/jankovic/educ_dbs.htm

[11] NN/LM, http://www-medlib.med.utah.edu/neuronet/coma/filloux.html

[12] Neurology Channel, http://www.neurologychannel.com

[13] Science Direct, http://www.sciencedirect.com

[14] NorthwesternUniversity, http://clifton.mech.northwestern.edu/~me381/project/neurostim.pdf

[15] Brown Medical School-Department of Neurology, http://www.brown.edu/Departments/Clinical_Neurosciences/

[16] Estrella Mountain Community College, http://www.estrellamountain.edu/index.asp

[17] The Lufkin Hyperbaric Center, http://www.lufkinhbo.com/index.html

[18] Medical Dictionary Online, http://www.online-medical-dictionary.org/copyright.asp

[19] Clinical Neurophysiology, http://www.neurophys.com/

ISSN: 1727-1983