

**UNIVERSITY OF PÉCS**

Biological Doctoral School  
Comparative Neurobiology Programme

**Effects on the central nervous system of the exposure to  
electromagnetic fields applied in mobile phone systems**

**PhD Thesis**

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## 1. Introduction

During the last decades the electromagnetic (EM) pollution in the environment was increased very intensively. Therefore all research related to the biological effects on biological systems became the focus of interest. The number of personal communication terminals using radiofrequency (RF) and microwave radiation has increased considerably leading an increase of the exposure to radiofrequency radiation (RF) of general public. In the past few years the explosive growth of mobile communications has brought up several environmental and health problems in the field of non-ionizing electromagnetic radiation. The quantitative evaluation of the phenomena concerning the functions of central nervous system (CNS) is needed in order to clarify the mechanisms affected by electromagnetic field. According to the statements of World Health Organisation (WHO) the general usage and fast spreading of mobile phones may lead to a new public health questions appeared since the large number of population even with relatively low risks.

In our animal and human experiments the studies were performed in order to investigate the possible effects of human exposure to RF, especially to the exposure emitted by mobile phones. Within the animal studies in acute experiments on rats a number of physiological modalities were recorded in polygraphic measurements before, during and after RF exposure. Also in animal studies the response of the central nervous system was observed by quantitative electroencephalogram (EEG) and Visual Evoked Potential (VEP) measures on freely moving rats. In order to examine the possible acute effects of radiofrequency (RF) exposure emitted by GSM cellular phones human studies on healthy volunteers were also carried out. Cerebral circulation, EEG and ECG were recorded and within the analyzing procedure the exposed and non-exposed hemisphere were compared. In our recent human study within an EU research project Auditory Brainstem Response (ABR) was recorded before and immediately after exposure to RF pulsed field emitted by a commercial mobile phone.

The results of current investigations may provide scientific explanations of the potential health risks of the exposure to RF due to mobile phone use and support the development of a health based scientific guidelines and standardisation.

In present essay the scientific results obtained during the last 15 years were summarised in the time and logical order. The studies were performed in a wide ranging collaboration work including the former thesis of my doctoral degree work. Nevertheless all studies elaborated here may be classified as the neurobiological effects of exposure to RF with special regard to mobile phone exposure.

## 2. Aims

The main aims of present study were to investigate the possible acute effects of RF exposure on central nervous system quantitatively in animal and human models and also to evaluate the results in the point of view of radiation hygiene. In particular the specific aim was to investigate the acute effects of RF exposure generated by mobile phones since a short time RF exposure is occurred close to the human head using the mobile phone by the people. Within the human and animal investigation we made an effort to provide similar RF exposure than emitted by mobile phones. Therefore the designing of exposure systems - that were developed first time in Hungary by the author's group - and the relevant studies of dosimetry take place a specific importance within the investigations.

Further aims were to follow the examined neurophysiological process with appropriate real-time recordings, therefore proper electrophysiological methods were selected within the studies. The selected electrophysiological methodologies were also meet the requirements of both human and animal studies with relevant standardized medical diagnostic process. Within the above general aims we have the following specific aims:

- To design RF exposure systems for animal studies as well as to develop the appropriate RF dosimetry methods for both whole body and localised exposure to the head.
- To design an appropriate exposure system and RF dosimetry for human studies.
- To measure the level of RF dose and investigate the changes of brain tissue temperature due to the RF radiation.
- To investigate the effects on central nervous system of continuous wave (CW) and modulated whole body and brain localised RF exposure in animal model with polygraphic recording and processing including brain electrical activity and cerebral circulation.
- To perform human studies on the investigation of the acute effects of the RF exposure from mobile phones on the brain electrical activity and cerebral circulation.
- To investigate the potential effects of acute exposure generated by mobile phone on human hearing sensory system.

In summary all studies may support the assessment of risk to the users and the general public from exposure to RF radiation from mobile and other devices supporting the development of appropriate safety standards.

### 3. Methods and tools

#### 3.1 Exposure system and dosimetry

The whole body animal irradiation was performed in RF anechoic room. The brain localised irradiation of rat were performed in a TE-cell waveguide system. In order to quantify the Specific Absorption Rate (SAR) in the exposed animals a polyacrilamide phantom rat model was used.

For human experiments commercially available GSM handy-phones were used. The level of output power and the switching on/off the cellular-phones were controlled by computer interface. The output peak power of the handy device was 2 W at 900 MHz and 1 W at 1800 MHz respectively.

#### 3.2 Polygraphic recordings within animal studies

On F1-hybrid male rats, standard electrophysiological procedure was performed. In acute experiments the following electrophysiological modalities were recorded simultaneously: electroencephalogram (EEG), rheoencephalogram (REG), DC brain tissue impedance, brain tissue and rectal temperature, ECG. On the polygraphic recordings off-line signal and data processing were made on personal computer. The power spectrum of EEG was processed by Fast-Fourier transformation (FFT) and the standard EEG frequency bands were also evaluated with calculation of the pulse wave minimum/maximum time from the REG waveforms and its delay to the ECG R peak.

#### 3.3 Spontaneous EEG and Visual Evoked Potential (VEP)

Standard electrophysiological procedure was performed on F1-hybrid male rats. The electrodes were placed over the visual cortex below the skull on the *dura mater*. Bipolar and monopolar EEG were recorded simultaneously. The Visual Evoked Potential (VEP) was performed on freely moving animals by using flash lamp stimuli. The VEP responses (N=40) were averaged and between the light stimuli resting EEG Power Spectrum was analysed by FFT processing.

#### 3.4 Investigation of human EEG and cerebral circulation (REG) before and after mobile phone exposure

Within the study the following polygraphic modalities were recorded: REG, tissue impedance measurement on the skull at 125 kHz, EEG, EKG. The recordings of exposed and non-exposed hemisphere were compared in all variations of the output data. The disturbances of cerebral circulation and changes in REG were evaluated by analysing the disturbances took the form of pulse wave distortion, peak delay, or asymmetry of pulse amplitude of REG and the power spectrum of the EEG. In electrically shielded area the subjects with half-laying position were exposed to common GSM handy-phone with computer controlled switch on/off process that were not able to perceive by the examined

subjects. The level of anxiety and blood pressure were also measured before and after the recording protocol.

### 3.5 Investigations on the Auditory Brainstem Response (ABR) after mobile phone exposure

Standard ABR potentials were recorded and 2048 responses were averaged and evaluated on twenty healthy volunteers. The amplitudes and latencies of waves V of the ABR were measured. The cochlear microphone (CM) potential was defined from 0.5 ms to 1 ms window of the averaged ABR waveform. The eligible subjects were selected by standard subjective audiometer with randomised threshold evaluation. In electrically and noisily shielded area the subjects on half-laying position were exposed to common GSM handy-phone.

## 4. Results and discussion

### 4.1 Thermal effects of RF exposure

- a) The brain temperature of rats were increased after  $100 \text{ W/m}^2$  whole body exposure with 2,3 W/kg whole body and 8,3 W/kg brain averaged specific absorption rate (SAR) respectively.
- b) The brain temperature during RF exposure to local brain was increased above 16,8 W/kg SAR. In accordance with the obtained data the SARs beyond the above limit were considered as thermal dose.

### 4.2 Effects of exposure to RF thermal and non-thermal radiation on the polygraphic recordings on rats

- a) The power of EEG delta band and the total power of EEG were increased by thermal level of RF exposure simultaneously with increasing of the REG amplitude and heart rate.
- b) No changes in the EEG power spectrum were occurred by non-thermal level of continuous wave RF exposure simultaneously with decreasing than increasing of the REG amplitude. No changes were found in the DC impedance but slight decrease in the heart rate during the exposure.
- c) The non-thermal amplitude modulation of 16 Hz with 8,4 W/kg SAR was associated with increase the power of EEG beta band but changes in the REG amplitude were not observed.

### Evaluation and conclusions

- a) Significant changes in the polygraphic modalities due to the whole body RF exposure were occurred above the thermal level only.
- b) In case of localised head exposure to RF detectable and significant changes were observed predominantly during the exposure that suggest an acute transient effects in the polygraphic modalities.
- c) On the basis of the experimental results the polygraphic modalities were transformed into different direction due to the thermal or non-thermal level of RF radiation. Slight changes in cerebral blood flow and brain electrical activity were observed after modulated RF radiation. These

transient alterations did not exceed the range of normal physiological variations, although various compensating factors with different speeds may be involved depending on the local or whole body exposure.

#### 4.3 Spontaneous EEG and Visual Evoked Potential (VEP)

- a) No changes were observed in the early (P0, N1) nor late (P2, N3) latency times of VEP after 30 min, 30 W/m<sup>2</sup> (brain SAR 0,31 +/- 0,11 W/kg) GSM modulated RF exposure of rats.
- b) The frequency bands of EEG Power Spectrum were changed in the 5th minute after the exposure then after the 20th minutes were restored back to the baseline.

##### Evaluation and conclusions

- a) The visual pathway was not affected due to the RF radiation following the acute GSM modulated RF exposure.
- b) All changes in the spontaneous resting EEG spectral components were reversible that may more intensive during the exposure.

#### 4.4 Human polygraphic recording during mobile phone exposure

- a) We found changes in the level of anxiety and blood pressure which represent the importance of the measurement of anxiety and stress before and after the recording procedure and protocol.
- b) No changes were occurred in the REG amplitude during the exposure, nor in the peak frequency of the EEG alpha band. The EEG peak power was not changed during the mobile phone exposure.
- c) Slight decreasing was occurred in the total power of EEG alpha band during the first exposure period while we observed a slight increase of power in the fast EEG frequency bands.

##### Evaluation and conclusions

- a) The deviation from the normal spectral distribution of the EEG recording with closed eyes may evaluate as the deterioration of the resting physiological state. These deviation was disappeared during the second exposition period that may lead to some compensation mechanisms in the brain.
- b) Based on the evidence of increasing the EEG activity we assume that the possible thermal effects of the mobile phone exposure may lead to an activation of metabolic processes.
- c) Although at certain period of exposure some changes appeared as significant but there was no clear tendency with the presence of exposure.
- d) These transient alterations did not exceed the range of normal physiological regulation therefore may not consider as adverse health effects.

#### 4.4 Investigations on the Auditory Brainstem Response (ABR) after mobile phone exposure

- a) No statistical changes were occurred in the mean latencies of ABR wave V before and after mobile phone exposure for the three stimulus condition. We found no significant effects of genuine/sham EMF exposure in any of the stimulus conditions.
- b) No alteration in the latency of CM potential was observed due to the mobile phone exposure in two stimulus (rarefaction, pressure) conditions (CM recording with alternating stimulus is not available).

#### Evaluation and conclusions

- a) No effects on the hearing system were assumed due to the acute exposure to RF generated by mobile phones according to our investigations on ABR and results obtained from otoacoustic studies by other laboratories.
- b) Nevertheless the results from epidemiological studies suggest a remarkable correlation between the mobile phone usage on the risk of acoustic neuroma. Therefore the investigation of acute and effects on the hearing sensory system may take place an important role on the evaluation of public health in the future.

### **5. Considerations related to public and environmental health**

The man made electromagnetic fields (EMF) and radiation became a significant environmental pollutant in the developed countries nowadays, therefore it is necessary to deal with its potential effects on environmental health. This is extremely important since the international bodies intend to harmonize the EMF health based standards and exposure limits based on the results of scientific investigations. At the same time the scientific research on the effects of EMF exposure is always under very fast development. Because of the lack of adequate knowledge the “precautionary approach” was raised by the European Council. The standardisation process is also difficult since the technological and industrial development were ahead the considerations of environmental health issues. Since in the exposure to EMF radiation is not avoidable in our civilisation therefore the application and development of health based standards may lead to several difficulties. The public exposure to EMF will be increased considering the new and emerging technologies coming in the near future.

Nevertheless the main aim in the development of health based EMF standards and guidelines is to provide a good harmonisation of interest within the economy sociology and public health, yield to the point of view of health without being an obstacle to the spreading of emerging technology. Furthermore exposure limits in standards and guidelines that are acceptable by the community as well as the limitation of risks of the potential adverse health effects also have to be assured.

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