EXPERIMENTAL AND SIMULATION STUDY OF ELECTROMAGNETIC RADIATION (EMR) EFFECT ON HUMAN THYROID TISSUE

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Abstract. This study aims to investigate the effects of non-ionizing radiation emitted from mobile phone base station on some target group of children. Their thyroid-stimulating hormone (TSH) has been investigated taking into account the children were provided with possible protective olive oil supplement. The target group was composed of 120 children (6–12 years) and it was divided into three sets. The first group served as control group. The second group was exposed to electromagnetic field (EMF) alone, the third group was exposed to EMF and given 2.5 mL/day olive oil supplementation for 5 weeks. The second and the third groups lived nearby mobile phone base station (100–150 m) for more than 5 years. The thyroid-stimulating hormone (TSH) was assumed. EMF exposure caused decrease in TSH. Furthermore, this work presents a simulation study of electric fields, magnetic fields, power density and specific absorption rate (*SAR*) distribution in human thyroid tissue. Concerning numerical modeling, the power absorption and specific absorption rate in a thyroid tissue are generally computed using FDTD methods. Results show that electromagnetic radiation (EMR) from mobile phone penetrates the thyroid tissues and attenuates rapidly to reach zero at the inner of the tissue. The absorbent power and *SAR* show a maximum at the interface.

Key words: simulation, life tissue, cellular phone radiation, thyroid-stimulating hormone.

INTRODUCTION

According to the widespread use of mobile phones and the interactions of electromagnetic field produced from mobile phones with the environment and with tissues of human beings are still under discussion and many research teams are investigating if there are any clear effects on human health, as there is still a great controversy regarding the possibility of induction of any significant physiological effects in humans by microwave radiations emitted by mobile phones. The biological effects of radiofrequency (RF) exposures from various national and international expert groups had been reported [8]. The effects of electromagnetic

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fields induced by the Global System Mobile (GSM) communications on the thyroid-stimulating hormone in humans had been evaluated [7]. Agustiño *et al.* studied if non-ionizing radiation at 2.45 GHz may modify the expression of genes that codify heat shock proteins (HSP) in the thyroid gland [1]. They used the enzyme-linked immunosorbent assay (ELISA) technique and studied levels of HSP-90 and HSP-70. The results demonstrated that the thyroid gland is sensitive to 2.45 GHz RF and non-thermal mechanisms cause a transitory decrease in the values of HSP-90 and HSP-70, which determine cellular stress levels in the thyroid gland. Santin *et al.* investigated the possible histopathological effects of pulse modulated radiofrequency fields on the thyroid gland, using light microscopy, electron microscopy and immunohistochemical methods [6]. The aim of other researches [11–12] was to review the evidences of indirect effects on thyroid function and growth regulation, and its mechanisms. The genomic effects of electric field on normal and abnormal thyroid tissue were also reviewed, as well as no genomic, distinct molecular pathways. Simulation of human body models is used for biomedical research in many papers, where it is advantage to replace life human body layer by the numerical model. Biological effects of EMF are one of the areas as the numerical models with many advantages had been used [10]. On the other side, a lot of researches deal with different possibilities of numerical modeling of electromagnetic field effects on the human body which calculated the specific absorption rate distribution in human body.

In this work, we investigated the effects of radiation emitted from mobile phone base station on a target group of 30 children in control group, and 50 + 40 = 90 children in the experimental ones, healthy children volunteers who had agreed to participate in this study. Their thyroid-stimulating hormone has been investigated taking into account the children were provided with possible protective olive oil supplementation. We present also a simulation study of electric and magnetic fields, power density and specific absorption rate distribution in human thyroid tissue. Concerning numerical modeling, the power absorption and specific absorption rate in a thyroid tissue are effectively computed using FDTD methods.

MATERIALS AND METHODS

A total of 120 volunteer children (aging 6–12 years) participated in the experiment. They were divided into three groups: the first group (30 children) served as control group who lived outside the area of radiation, and two experimental groups, who lived, for more than 5 years, in an area nearby mobile phone base station (100–150 m). So, the children were exposed to non-ionizing radiation emitted from mobile base station in Khan Younis county in Gaza Strip, Palestine, with a power in the range of 1.4–4.7 mW/cm^2, which is used in their country and measured during the experiment using a power meter. The electric field is in the range of 60–130 V/m. The antenna received the signal from the mobile base station in the area. The mobile system used in Gaza is GSM (Global System for Mobile) whose frequency equals 900 MHz. The second group (50 children) was exposed to EMF alone, and the last group (40 children) was exposed to EMF and given 2.5 mL/day orally olive oil all over the experimental periods (5 weeks). Blood samples of 3 mL were collected. The level of TSH was measured by ELISA kits from Dia Metra, Italy [10]. Extra-virgin olive oil was taken from olive tree in Gaza which is healthy and cheap.

DATA ANALYSIS

Data were analyzed using SPSS program for windows (Statistical Package for the Social Sciences Inc. Chicago, Illinois). Mean values were compared by independent sample t-test. Significance is taken as follows: $P > 0.05$ is non-significant, $P \leq 0.05$ is significant, $P < 0.001$ is highly significant.

SIMULATION MODEL

Suppose that electromagnetic radiation with different frequencies is incident vertically upon the interface thyroid tissue [2–5]. Dielectric properties for thyroid tissue at frequency 900 MHz, shown in Table 1, were calculated by online program, Dielectric Properties of Body Tissues, from the Italian National Research Council [13].

Table 1

Dielectric properties for thyroid tissue at frequency 900 MHz

Tissue name	Conductivity σ (S/m) at 900 MHz	Relative permittivity at 900 MHz	Penetration depth (m)	Density ρ (kg/m^3)
Air	0	1	1	1.229
Thyroid	1.0385	59.684	0.040066	1100

Electromagnetic radiation research may be modeled as boundary value problems control by partial differential equations subject to initial boundary values. The spatial domain of the boundary value problem may be complicated in general. The study of a heterogeneous model for human tissue is a difficult theoretical task. Maxwell's equations are the basic equations to simulate human life tissue by FDTD method. There have been used special models and techniques, each valid only in a limited range of frequencies or other parameters. A combination of techniques has been used to obtain specific absorption rate for different models as a function of frequency and time. The permittivity and conductivity of thyroid tissue are different according to changing frequency. The electric field is assumed to propagate in the z direction with polarization at the x direction [2–5]. In addition, we assume that the fields do not vary in the x–y plane. The dielectric properties of the body tissue, in general, are conceded in the complex permittivity formula as:

$$\varepsilon_r^*(\omega) = \varepsilon_r - j\frac{\sigma}{\omega\varepsilon_0}, \tag{1}$$

where ε_r is the relative permittivity for human tissue and changes according to different frequencies, ε_0 is the permittivity of free space, ε_r^* is the complex permittivity, σ is the conductivity of the tissue and ω is the angular frequency.

According to the theoretical details described in references [4, 5], in this study we chose a thyroid tissue as a model and the final equations of electric and magnetic fields in the thyroid tissue are evaluated as:

$$\tilde{E}_x^{m+1/2}(\kappa) = \frac{1-\dfrac{\Delta t\cdot\sigma_{th}}{2\varepsilon_0\varepsilon_{rth}}}{1+\dfrac{\Delta t\cdot\sigma_{th}}{2\varepsilon_0\varepsilon_{rth}}}\tilde{E}_x^{m-1/2}(\kappa) - \frac{1/2}{\varepsilon_{rth}\left(1+\dfrac{\Delta t\cdot\sigma_{th}}{2\varepsilon_0\varepsilon_{rth}}\right)}[H_y^m(\kappa+1/2) - H_y^m(\kappa-1/2)] \tag{2}$$

$$H_y^{m+1}(\kappa+1/2) = H_y^m(\kappa+1/2) - \frac{1}{\sqrt{\varepsilon_0\mu}}\frac{\Delta t}{\Delta z}[\tilde{E}_x^{m+1/2}(\kappa+1) - \tilde{E}_x^{m+1/2}(\kappa)] \tag{3}$$

where *E* is the electric field, *H* is the magnetic field, ω is the angular frequency, ε_{rth} is the real relative part of the permittivity thyroid tissue, σ_{th} is the conductivity of thyroid tissue, *m* is the time index and κ is the spatial index, with indexes times $t = m\Delta t$ and positions $z = \kappa\Delta z$. The time index is written as a superscript, and the spatial index is within brackets. It has been assumed that $\mu_1 = \mu_0$, where μ_0 is vacuum permeability and μ_1 is the permeability of tissue. The free space is assumed for the exterior of the model with wave number $k_0 = \omega\sqrt{\varepsilon_0\mu_0}$.

RESULTS AND DISCUSSION

Experimentally, the effect of electromagnetic field and the role of olive oil as protective agent on thyroid-stimulating hormone in children tissue is summarized in Table 2. Electromagnetic field exposure caused a decrease in TSH. TSH level in children tissue decreased by 28.8%, compared to the control level. The treatment of children subjected to electromagnetic field by olive oil improved the decreasing rate to 1.66%, compared to the control level. In general, according to this study, the thyroid-stimulating hormone which was subjected to electromagnetic field exposure shows a decreasing in TSH in children who have been living nearby the base station for five years.

Table 2

Thyroid-stimulating hormone in children tissue exposed to electromagnetic field and therapeutic action of olive oil

Parameter	Control $N = 30$	Electromagnetic field $N = 50$	Electromagnetic field + olive oil $N = 40$
TSH (mIU/L)	2.5±0.2	1.78±0.08	2.46±0.16
% change		–28.8	–1.66
P value		< 0.01	> 0.05

In the simulation model in this study, we supposed a theoretical model in one dimensional finite difference model for predicting electric and magnetic fields in human life tissues, such as thyroid tissue, undergoing microwave heating. For cell phone radiation, the simulated radiation source is a continuous waveform of 900 MHz. The values of electrical parameters, relative permittivity and electric conductivity for this frequency, are presented in brief in Table 1 [13]. The specific absorption rate and power density are evaluated for the human thyroid tissue using FDTD method, as follows [4]:

$$SAR = \frac{\sigma E^2}{2\rho} \quad \text{and} \quad P = \frac{\sigma E^2}{2} \tag{4}$$

where E is the electrical field intensity, σ is the electrical conductivity of the tissue, P is the power density and ρ is the mass density.

Simulations were run for global system mobile radiation of the human thyroid. FDTD method was implemented to compute the distribution of electric and magnetic fields, specific absorption rate and power density in thyroid tissue.

Figure 1 represents the electric field in thyroid tissue; after 150 time steps, the electric field is maximum and decreases exponentially towards the inner tissue. The magnetic field penetrated in the thyroid tissue from mobile radiation is illustrated in Figure 2. It shows that the amplitude of the magnetic field at the first peak is maximum compared to the second and the third peak; it means that the effect of magnetic field decreases fast in the inner tissue. Specific absorption rate in thyroid tissue is represented in Figure 3. We notice that the specific absorption rate value is increased in the inner tissue. In Figure 4, we represented the results of simulation of power density *vs* time steps. The maximum peak of power density is high and decreases exponentially. The power density is directly proportional with the density of the tissue, according to equation (4). Figure 5 shows the conductivity *versus* frequency in the thyroid tissue. The conductivity increases by increasing frequency in a low frequency range, but it is almost constant in a high frequency range.

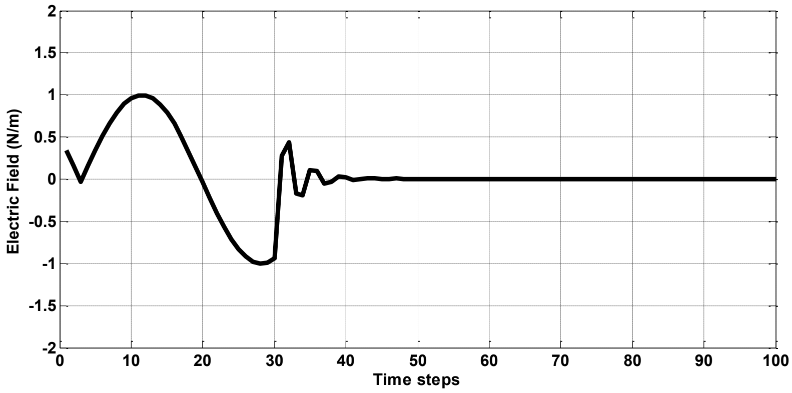

Fig. 1. Electric field strength in the thyroid tissue at a frequency of 900 MHz.

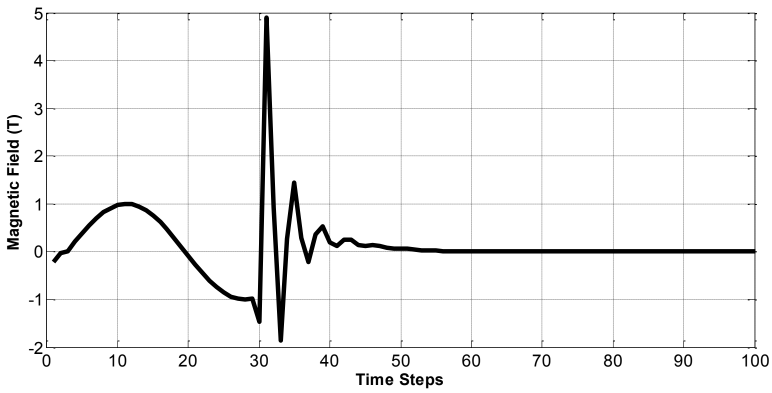

Fig. 2. Magnetic field strength in the thyroid tissue at a frequency of 900 MHz.

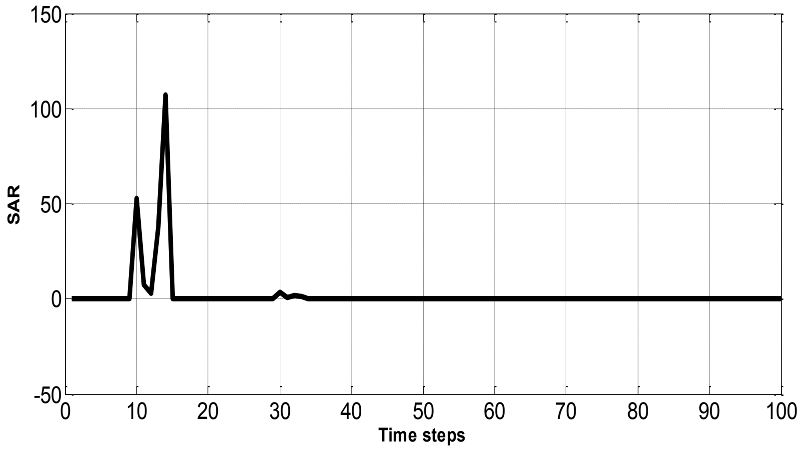

Fig. 3. Specific absorption rate in the thyroid tissue at a frequency of 900 MHz.

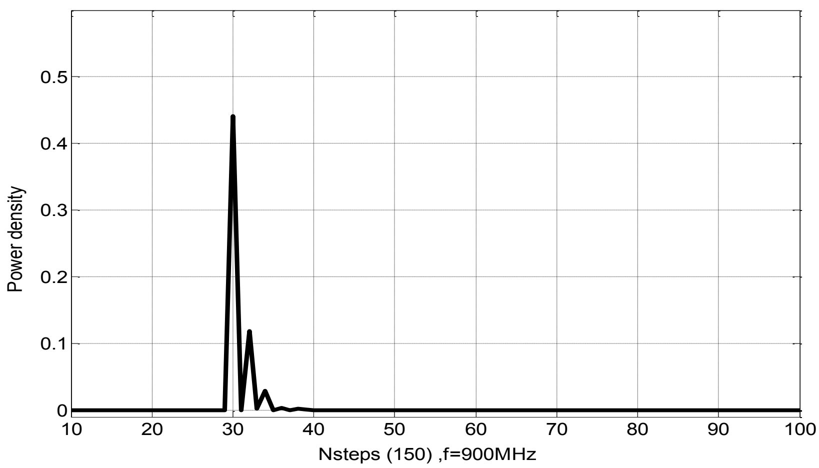

Fig. 4. Power density in the thyroid tissue at a frequency of 900 MHz.

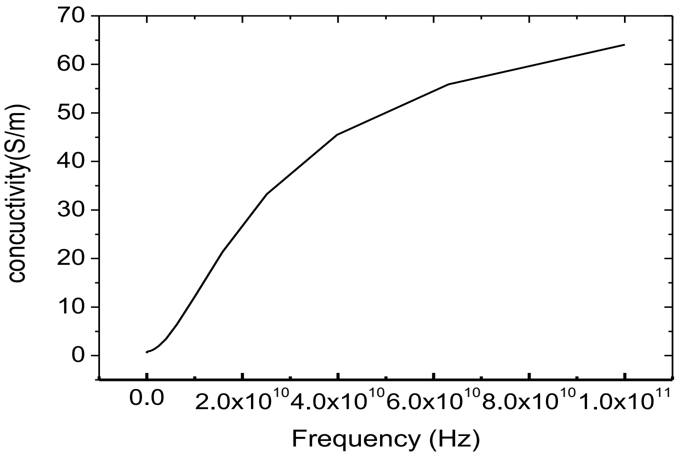

Fig. 5. Conductivity *versus* frequency in the thyroid tissue.

CONCLUSION

The response of human thyroid tissue, representing simplified model life tissue, to irradiation by plane waves produced by mobile phone, with a frequency of 900 MHz, has been investigated. Experimentally, exposure of human thyroid tissues to electromagnetic radiation leads to a decrease in TSH; by treatment with olive oil the TSH hormone is increasing after it decrease by the effect of radiation.

FDTD is used to study the distribution of the electromagnetic fields, the absorbed power, and the *SAR* distribution in the thyroid tissues. It is found that the fields penetrate the interface of tissue and are attenuated rapidly till they reach zero at the inner layer. Specific absorption rate has a maximum value at the interface of tissue. According to the results from the graphs, one can notice that the effect on the tissue of a 900 MHz radiation of the Global System Mobile is more significant at the first time steps. The dielectric properties for tissue are different according to the changes in frequency.

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