Original Article

Mobile Phone Distance from Head and Temperature Changes of Radio Frequency Waves on Brain Tissue

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Abstract

Background: Analyzing the possible negative effects of using cell phones on the users' health is an important and vital affair due to rapid growth and extensive use of these devices on human communications and interactions. The aim of this study was to determine the effect of increasing the distance of cell phones to brain tissue on the temperature of the central and gray matters of brain due to the heat generated by radio frequency waves. **Methods:** This study was an experimental study. A cow's brain tissue was analyzed in a compartment with three thicknesses of 2, 12, and 22 mm, in the distances of 4 mm and 4 cm from a cell phone for 15 min. Lutron thermometer was used to measure the tissue temperature, and the data analysis were done by Lutron and MATLAB software packages. **Results:** The tissue temperature was increased while confronting with a cell phone in distances of 4 mm and 4 cm in all the three thicknesses of 2, 12, and 22 mm. The tissue temperature was higher after removing the confrontation at 4 mm distance as compared to the distance of 4 cm. **Conclusions:** During confrontation and after that with the cell phone, reducing the distance of brain tissue and the cell phone increased the tissue temperature intensely. In fact, by increasing the cell phone distance from brain tissue, the thermal effect of radiofrequency waves was reduced.

Keywords: *Brain tissue, cell phone distance, radiofrequency waves, temperature*

Introduction

It is just to say that we live in a modern world with advanced technology. Requiring access to information and communications everywhere has created a new world.[1] A device such as a cell phone has been used extensively due to having supreme communicative technology, but a cell phone is the main source of electromagnetic waves, which can influence human tissues.[2] The World Health Organization has reported dispersion of radiofrequency waves as one of the most polluting sources, which are hazardous for human beings.[3] Cell phones are considered as an important invention that has changed communication ways in this modern world.[4] However, using cell phones has had irregular growing rate in recent years.[5] This rapid increase of using cell phones has provided worries about radiated radiofrequency waves from them. One of the effects of radiofrequency waves resulted from cell phones is increasing the temperature of body tissues.[6] Using cell phones near the head has provided general worries about damaging effects on the central nervous system both in children and in adults.[7] Brain is specifically confronting with radiofrequency waves during conversation with the phone.[8] In a study, after a 30-min confrontation of a cell phone with brain tissue, the brain temperature increased by 4.5°C.[6] Cell phone users often complain about warming of their ears due to having contact with cell phones. This temperature increase may be due to radiofrequency and electromagnetic waves absorbed by the user's head.[9] Since the cell phone antenna is placed near the ear and head during contacts, the head is necessarily facing radio frequency waves, and this has caused anxieties in this regard.[10] Lindholm *et al*. stated that the temperature of ear canals in users increased up to 1.5°C in confronting with the radiofrequency waves of cell phones for 35 min.[7] A research (2001) reported that skin temperature during confrontation with a cell phone increases by 0.01°C.[11] Another study has shown that negligible increase of temperature (about 0.2°C–0.3°C) in hypothalamus leads to behavioral change in regulating the body temperature.[12]

Since during contacts, cell phones are placed near the ear and head and also because the sensitivity of brain tissue

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to changing of the temperature, the aim of this study was determining the effect of cell phone distance on the temperature of central and gray matters of brain due to the heat generated by radiofrequency waves.

Methods

This study was an experimental study. A cow's brain tissue without the brain covered with cranium was used to evaluate the effect of cell phone distance with the tissue. The brain was transferred by heat insulating box to the laboratory immediately after slaughtering the cow.

Laboratory equipment

To promote the measurement accuracy and reducing errors due to temperature, humidity, and ventilation systems during the measurement, a compartment with height of 40 cm, length of 80 cm, and width of 30 cm of Plexiglas material was designed and made, where the tissue is placed in it, not to have any contacts with the laboratory environmental conditions. The compartment door was closed after the required adjustments. Lutron thermometer (Model: MT-917) with precision of +0.1 was used for measuring the tissue temperature. The thermometer had 5 probes for measurements and the probe "TP100") was used for the current study. This probe is applied for measuring different depths and thicknesses with temperature range −199.99°C to +199.99°C, and it was made of platinum. Lutron thermometer could measure in both Fahrenheit and Celsius units, and Celsius unit was used for this study. The thermometer was connected by a cable (Model: USB-01) to a computer. The temperature range of this cable was between 0°C and 50°C and could be applied in humidity under 80%. The temperature changes were measured and recorded in momentary basis after installing Lutron software (Lutron Electronic, Taiwan).

Preparation and confrontation

Brain tissue was placed in the compartment. Then, probe "TP100" was placed in thicknesses of 2, 12, and 22 mm of the tissue for measuring the temperature of the gray and white matters of the brain, where the precise thicknesses were determined by a digital caliper. The first case was related to the gray matter of the brain with the thickness of 2 mm. A smart cell phone was used to investigate the thermal effect of the cell phone radio frequency, placed on a pod in 4 mm distance on the left of the brain tissue, as if a person is talking on a cell phone. After adjustments, the thermometer was turned on and connected by the USB cable to the computer, and the related software was operated.

The temperature balance between the environment inside the compartment and the tissue for reducing the errors regarding the contact between the tissue and the cell phone was not fulfilled at the beginning, until the temperature of the tissue and the compartment became similar, and the thermometer showed a fixed temperature, such that after 15 min of tissue temperature stabilization, the stabled temperature was recorded, and this temperature was called the base temperature (tissue temperature before confronting with the cell phone). Then, the contact was made between the tissue and the cell phone, as if a person was talking on the phone. The confrontation time was considered 15 min. After finishing the confrontation time, the contact was cut off. For the next stage, the tissue was kept in the compartment for 15 min for its temperature to be reduced without confrontation and the presence of radiofrequency waves. In all the stages, before, during, and after confrontation with the radiofrequency waves of the cell phone, the thermometer was connected to the computer system, and the temperature variations of the tissue were recorded by the software. After each test, the brain tissue was not used and requires no maintenance. This study was done at 4 mm and 4 cm distances between the cell phone and the brain tissue, for the thicknesses of 2, 12, and 22 mm. The following equation was used to calculate the specific absorption electric:

$$SAR = \sigma E^2/\rho$$

SAR: Specific absorption rate, σ: Guided tissue of the head, E: Root average electrical energy, ρ: The mass density of the head. The amount of electrical energy in this mobile phone (900 MHz) was 1.18 v/m. Field finally, the temperature variations relative to the time were transferred to MATLAB 2012 software (2012 version, MathWorks company), and the related graphs for each thickness were drawn.

Results

A cow's brain tissue was used to evaluate the effect of cell phone distance with the tissue on the temperature increase of the brain due to radiofrequency waves, at three different depths of 2, 12, and 22 mm and in 4 mm and 4 cm distances, before, during, and after the considered confrontations.

The base temperature was 17.94°C at the depth of 2 mm (gray matter of the brain) in both 4 mm and 4 cm distances, but after 15 min of confrontation, the tissue temperature for the distance of 4 mm reached to 18.23°C and reached 18.13°C for the distance of 4 cm. According to Figure 1, the temperature of the gray matter of brain for the distance of 4 mm increased by 0.29°C, and for the distance of 4 cm, it increased by 0.19°C. Figure 1 shows the temperature changes for the mentioned distances.

The base temperature was 18.85°C at the depth of 12 mm (white matter of the brain) in both 4 mm and 4 cm distances, after 15 min of confrontation. After confrontation of the brain tissue and the cell phone, the tissue temperatures for the distances of 4 mm and 4 cm increased to 19.16°C, and 18.90°C, respectively. In fact, it showed an increase of 0.31°C compared to the base temperature for the distance of 4 mm, and the increase relative to the

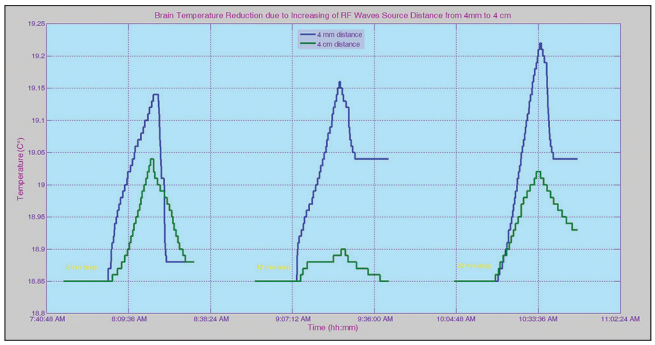

Figure 1: Comparison of temperature increase in brain tissue, during confrontations with a cell phone for the distances of 4 mm and 4 cm: (A2) 2-mm thickness and the distance of 4 cm; (A12) 12-mm thickness and the distance of 4 cm; (A22) 22-mm thickness and the distance of 4 cm; (B2) 2-mm thickness and the distance of 4 mm; (B12) 12-mm thickness and the distance of 4 mm; (B22) 22-mm thickness and the distance of 4 cm

base temperature was only 0.05°C for the distance of 4 cm. Figure 1 shows the temperature changes in the considered distances in the depth of 12 mm.

Tissue temperature at the depth of 22 mm (white matter of brain) was 19.83°C and 19.63°C for the distances of 4 mm and 4 cm, respectively, during 15 min of confrontation with cell phone contacts. The base temperature in this depth was 19.46°C, indicating the increase in temperature by 0.37°C and 0.17°C for the distances of 4 mm and 4 cm, respectively. Figure 1 shows the temperature changes in the considered distances in the depth of 22 mm.

At the time of confronting with the cell phone, temperature increase in the tissue for the distance of 4 mm at the three thicknesses of 2, 12, and 22 mm was higher than that for the distance of 4 cm. According to Figure 1, the gradients of B2, B12, and B22 curves (for thicknesses of 2, 12, and 22 mm, respectively) were higher for the distance of 4 mm than the gradients of the curves A2, A12, and A22 (for thicknesses of 2, 12, and 22 mm, respectively) for the distance of 4 cm. In other words, the gradients of the curves for the three thicknesses increased with higher speed for the distance of 4 mm. In particular, the increase in gradient was quite apparent for the distance of 4 mm in the thicknesses of 12 mm and 22 mm (B12 and B22) in the brain white matter.

Brain tissue temperatures for the distances of 4 mm and 4 cm away from a cell phone were evaluated for the three considered thicknesses, for 15 min after disconnecting the confrontation aspect. Brain tissue temperatures reduced for the distances of 4 mm and 4 cm as compared to the time when confrontation occurred for the three considered thicknesses, but they were higher in comparison with the base temperature. In other words, after the disconnecting confrontation of the brain tissue and the cell phone, the tissue temperature did not return to the base temperature after 15 min, and this temperature was higher than the base temperature, even after disconnecting the confrontation purpose. The higher rate referred to the 4 mm distance as compared to the distance of 4 cm. For instance at the thickness of 22 mm, the temperatures were 0.22°C and 0.08°C higher than the base temperature for the distances of 4 mm and 4 cm, respectively. The tissue temperature after the confrontation became equal to the base temperature for the distance of 4 cm, in the thickness of 12 mm while it was 0.19°C higher than the base temperature for the 4 mm distance. The rates of increasing tissue temperatures relative to the base temperature, after the confrontation, at the thicknesses of 2, 12, and 22 mm from the tissue surface, for 4 mm and 4 cm distances.

Discussion

The present study evaluated the effect of increasing the distance of cell phones to brain tissue on the temperature of the central and gray matters of brain, due to the heat generated by radio frequency waves. In practice, the probe was placed for 30 min in an empty box with the cell phone and we have not seen a rise in temperature after half an hour. According to the obtained results, confronting brain tissues and cell phones for 15 min led in increasing temperature in the tissue. In fact, increasing the temperatures was observed in the three considered tissue thickness of 2, 12, and 22 mm as compared to the base temperature, during the confrontation. Rusnani *et al*. reported that in 15 and 20 min of confrontation with cell phones, the temperatures are increased in the head and ears of the users, and this rate is further increased by increasing the contact time. They showed that confronting head with cell phones for 15–30 min increased the temperatures in that part by 0.3°C–2.9°C.[9] Tissue temperatures at the distance of 4 mm had higher increases than the distance of 4 cm, by the confrontation of brain tissue and cell phones, for the three considered tissue depths of 2, 12, and 22 mm. For instance, brain tissue had temperature increases of 0.31°C and 0.05°C at the depth of 12 mm, for the distances of 4 mm and 4 cm, respectively. Not only the brain tissue temperature for the distance of 4 mm was higher than that for the distance of 4 cm but also the gradient of temperature increase was higher for the distance of 4 mm than that for the distance of 4 cm. Hossain *et al*. reported that by increasing the distance of the head from the cell phone antenna, the rate of SAR is decreased.[13] In analyzing the internal functioning of cell phones and the relation between the distance of cell phone antenna from the human body and SAR, Kivekas *et al*. reported that the easiest way for reducing the SAR is increasing the distance of users from cell phone antennas.[14] The rates of brain tissue temperatures at the thicknesses of 2, 12, and 22 mm showed reductions after 15 min from finishing the confrontation with the cell phone as compared to the tissue temperature during the confrontation, but despite the temperature reduction, the temperatures of brain tissue for the three considered thicknesses were high in comparison to the base temperature for the distances of 4 mm and

4 cm, after confrontation with the cell phone. In other words, not only temperature increase was observed in the brain tissue during the confrontation with the cell phone but also increasing the temperature even had an accumulation status and it was high for some time after the confrontation with the cell phone, as compared to previous situations. The rate of tissue temperature after the confrontation with the cell phone was higher for the distance of 4 mm as compared to that for 4 cm distance. The important point is that the temperature showed increases in all the stages of investigations, before and after the confrontations with the cell phone, and also by increasing the depths and thicknesses of the brain tissue. The results showed that the more the layers of the tissue, the accumulated temperature in the tissue would be higher. Hence, it is possible that the effects created due to using cell phones are more intensive in deeper tissues. On the other hand, it is possible that deep tissues (white matter of the brain) have higher sensitivity in confrontation with cell phones, and the sensitivity emerges by higher absorption of energy, and hence increasing the temperature. The results of the present study showed that in the cases of during and after the confrontation with the cell phone, the lower distance of the brain tissue and cell phone increases the tissue temperature. In other words, by increasing the distance of brain tissue and the cell phone, the thermal effects of radiofrequency waves of the mobile phone was reduced. The distance of brain tissue to the cell phone had inverse relations with the increasing rate of tissue temperature, and by increasing the distance, less amount of increase in the brain tissue temperature was observed. Hirata *et al*. stated that there are some effective factors on the absorption rate of electromagnetic waves, among which are the size of the confronting tissue, electrical properties of the tissue, and the distance between the electromagnetic wave source and human body.[15]

Most of the hazardous biologic effects about the cell phone waves on humans are considered to be due to the effects of temperature increase, such that some of the cell phone waves are transferred to human body as heat by current activated hyperpolarization induced by the electric field and vibration of polar molecules, in going through an environment.[16] Wessapan *et al*. showed in their studies that due to confrontation with cell phones, the generated heat in brain tissue is greater than that in the skin since brain is a tissue with high rate of metabolic aspect in generating heat. Hence, temperature is higher in brain tissue as compared to other tissues with low metabolic aspects in generating heat.[12]

By increasing the temperature of the brain, the blood circulation is rapidly increased, and the thermal self-adjusting reactions are activated. Measuring heart automatic responses and evaluation of brain blood flow are used as the indirect evidences of the interactions of blood circulation and adjusting the temperature during confrontation with radio frequency waves. Thus, repeating confrontations with cell phones increasing the tissue temperature during confrontation, and high temperature of the brain tissue even after some time from the confrontation would make undesirable effects on brain health after a passage of time.[7] In the studies by Beason *et al*., about the electromagnetic effects on brain, they showed that the similar waves to the cell phone telecommunication system could lead in 52% of case in increasing brain neuron activities, and in 17% of the cases reduce brain neuron activities.[17] The results obtained from some epidemiologic studies show that even with lower densities than the permissible limits, cell phone waves can cause signs and symptoms such as a headache, feeling of high temperature in ears, weakness of memory, and fatigue.[18] In a study regarding the effects of waves due to radiation generated by cell phones on vital signs in users, Mortazavi and Atefi obtained significant relations between using cell phones and disorders in paying attention, learning, and concentration in users.[19] Negative effects of waves resulted from cell phones on the brain activities, and capabilities are confirmed in some studies.[19-21] Saikhedkar *et al*. studied about the effects of radiation of cell phone waves on the structure and performance of brain in rats. They showed that cell phone waves could increase anxiety and amount of learning in rats.[22] It was reported in a study that cell phone waves provide considerable changes in the density of dopamine, norepinephrine, and serotonin in hippocampus, hypothalamus, cerebellum, and medulla in the brains of mature mice. This change in the rate of the densities of neural intermediates can be effective in creating anxiety and problems regarding memory and learning.[23]

Conclusions

Brain tissue temperature in 4 mm distance from a cell phone was not only higher than the base temperature but also from the 4 cm distance from the cell phone, but the temperature was higher for the 4 mm distance by increasing the tissue thickness. In fact, the temperature had accumulating status in gray and white matters of the brain in the distance of 4 mm, even after confrontation aspect, and increasing the temperature was higher in greater thicknesses, which include the white matter of the brain. On the other hand, the distance of brain tissue with the cell phone had clear and definite effects in increasing the tissue temperature, such that by increasing the distance, the tissue temperature showed a reduction. The distance of brain and cell phones was considered in this study as an important parameter in reducing the thermal effects due to cell phone waves.

The temperature difference could be related on one side to heterogeneity of brain tissue during movement from the brain membrane to its depth, which is due to changing of gray matter of brain to white matter. The gray matter has higher rate of water and less fat and in comparison, the white matter has higher amount of fat. From another point

of view, the differences in building and temperature in various depths could be related to the aspect of generating optimum induced temperature in different depths, with regards to different variables such as frequency of waves and the direction of radiations, all of which should be considered in the future studies.

This study shows that the temperature of brain tissue is increased after contacts with electromagnetic waves generated by cell phones. However, this increased temperature could create problems in brain functions, similar to the increased temperature due to hyperthermia that is emerged as fever or heatstroke. The more important point according to the authors of this study is using the index of tissue temperature as an index due to contacts with electromagnetic fields since the certain point is that electromagnetic waves have different effects on live tissues, in physical, electrophysiological, or electrochemical forms, which are because of the mutual effects of these waves on matters and are inevitable. The fact that the effects of these waves, or in a more precise term, the contacts with the waves could be observed and recorded is an introductory for predicting the mentioned effects and the probable effects due to them.

Ethical considerations

The protocol of this study was approved by the Medical Committee of Isfahan University of Medical Sciences at IR.MUI.REC.1394.3.1047.

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Conflicts of interest

There are no conflicts of interest.

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