Original Article

Evaluating Temperature Changes of Brain Tissue Due to Induced Heating of Cell Phone Waves

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Abstract

Background: Worries have recently been increased in the absorption of radiofrequency waves and their destructing effects on human health by increasing use of cell phones (mobile phones). This study performed to determine the thermal changes due to mobile phone radio frequency waves in gray and white brain tissue. **Methods:** This study is an empirical study, where the thermal changes of electromagnetic waves resulted from cell phones (900 MHZ, specific absorption rate for head 1.18 w/kg) on the 15 brain tissue of a cow were analyzed in a compartment with three different thickness of 2 mm, 12 mm, and 22 mm, for 15 min. The Lutron thermometer (model: MT-917) with 0.01°C precision was used for measuring the tissue temperature. For each thickness was measured three times. Data analysis is done by Lutron and MATLAB software packages. **Results:** In confronting of the tissue with the cell phone, the temperature was increased by 0.53°C in the 2 mm thickness that is the gray matter of the brain, increased by 0.99°C in the 12 mm thickness, and also increased by 0.92°C in the 22 mm thickness. Brain temperature showed higher rates than the base temperature after 15 min of confrontation with cell phone waves in all the three thicknesses. **Conclusions:** Cell phone radiated radio frequency waves were effective on increasing brain tissue temperature, and this temperature increase has cumulative effect on the tissue, being higher, for some time after the confrontation than the time with no confrontation.

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

Introduction

Cell phones (mobile phones) have currently been transformed into an inseparable part in the life of human beings. Cell phones have many advantages, including communicating with the family, friends, and even business, playing games, and listening to music. Along with advantages that they have, cell phones have various disadvantages which are confrontation with the metals such as arsenic, lead, lithium used in cell phones manufacturing and focused on the determination of the toxic metal content of liquid crystal displays presented in various electrical and electronic equipment waste included mobile phones, all of which are toxic. Confronting with radiofrequency radiation in cell phones can also be indicated that could be effective on human health, leading to cancer diseases.[1] Currently, 96.6% of the world population are using cell phones. Seventy-four percent of the population in India, 100% in the USA, 170% in Finland, and 8.3% in South Korea use cell phones.[2] It is predicted that the number of smartphones in the world increase to 2380 million devices by 2017.[3] Cellular phones operate in the range of microwaves, using electromagnetic and radiofrequency radiations. Electromagnetic radiations cause biological changes, both directly and indirectly.[4] Biological effects for confronting with radiofrequency waves from cell phones are different in biological systems, including organic interactions, tissues, cellular and molecular levels. It is logical to presume that biological damages can be started in a molecule and in macromolecular level.[5] Placing the cell phone near ear and head leads to confrontation of tissues and structures around the ear and head with radiofrequency waves. Peripheral and central neural systems that coordinate the body vital functions are also affected by these waves. The studies done on animal and human models have shown significant results for increasing headaches, changing the sleeping pattern, and changes in the cycle of neural cells.[6] Reports from various studies have shown that the people holding the mobile phone near their ear canal and head are

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30% more exposed to brain tumors in comparison.[7] Despite their small body sizes, cell phones are altered into a complicated device with high rates of efficiency. The concentration of temperature in a peculiar section of it has been transformed into a problem in this device.[8] In a study by Anderson and Rowley on the effect of increasing skin temperature due to confronting with cell phone radiofrequency waves, it was shown that skin temperature increases by 2.3°C–4.5°C with regard to the frequency in the cell phones. Increasing the skin temperature was reported to be 0.01°C due to the direct effect of cell phone radiofrequency waves.[9] Absorption of radiofrequency energy by the tissues increases their temperatures, causing serious harms to human health, including cataract disease, skin burns, and testicular decline. Some experimental studies and also studies on the live tissues show the thermal effect of radiofrequency waves on blood vessels occlusion in brain, chromosomal changes, immune system, activities of neurotransmitters, brain tumors, and also the rate of cellular mutation.[10] The people, who stated that they were sensitive against radiofrequency waves, often have the experience of cognitive disorders, believing that they suffer from headaches due to confrontation with radiofrequency waves. They consider it as a sign of being exposed to radio-frequency waves. Headache is an important warning sign, indicating that body temperature has increased, and it is presumed that in exposure to radiofrequency waves, the tissues biological temperatures, body temperature, and other vital physiological signs, such as blood pressure and heartbeat, to be altered.[11] Very low increase in temperature of hypothalamus by 0.2°C–0.3°C, when exposed to cell phone radiofrequency waves, leads to behavioral changes in regulating the temperature.[12] Rapid ever-increasing growth of communication industries, general application of mobile phones, and general worries from the effects cell phone waves, especially since it is placed near the head and ear canal during communicating with it, caused this study to be done with the aim to determine the thermal changes of cellular phones radiofrequency waves in the grey and white matters of the brain.

Methods

The present study was an empirical study. Due to the similarities to human brain tissues, 15 cow brains were used which brain after slaughter was transferred to laboratory by a cool box. Tissue temperature during slaughter was 38.5°C which it had to be equivalent to laboratory temperature and sampling box. This temperature is the base temperature which is shown in the graph. Tissue was selected to be analyzed. Its weight was about 432 g that was immediately bought after slaughter and transferred to the laboratory.

Laboratory equipment

A compartment with the height of 40 cm, length of 80 cm, and width of 30 cm was designed and made by plexiglass to increase the measuring precision and reducing errors due to temperature, humidity, and ventilation systems during the measurements, and the brain tissue was placed in it so that it was separated from contacts with environmental conditions, and its door was closed after the required adjustments. Lutron thermometer (model: MT-917) with the precision range of ±0.01 was used for measuring the tissue temperature. The thermometer has five measuring probes, and the probe "PT100" was used for the current study. This probe is used for measuring depths and thicknesses, and its temperature range was +199.99 and its material is of platinum. Lutron thermometer can measure both in "Fahrenheit" and "Celsius" grades. However, "Celsius" unit was used for this study. The thermometer was connected to a computer system by a cable (USB-01) [Figure 2]. The temperature range of this USB cable was between 0°C and 50°C, having efficiency in humidity under 80%. Temperature changes of the thermometer were recorded by installing Lutron software. Thus, the collected data were analyzed by this method.

Preparation and confrontation

The brain tissue was placed on a plate in the compartment that was separated from the compartment bottom. Then, regarding the measurement of the gray and white matters of the brain, the "PT100" probe was placed in 2 mm, 12 mm, and 22 mm thicknesses of the tissue. The first thickness was related to the gray matter of the brain with 2 mm thickness. A smartphone was used to analyze the thermal effect of cell phones radiofrequency waves, which was placed on a stand, 4 mm away from the brain tissue and on its left, exactly like the time that a person is communicating with a cell phone. After adjustments, the thermometer was turned on and connected to a computer system by a USB cable, and the related software was started [Figure 3]. For holding heat balance between the tissue and the inner environment of the compartment and reducing errors, a contact was made between the tissue and the cell phone. The brain tissue had no confrontation with the cell phone radiofrequency waves, which took 2–3 h during the balancing period. After balancing of the compartment temperature and the tissue, the tissue temperature before confronting with the cell phone was considered as the base temperature. Then, the contact was held between the tissue and the cell phone, exactly as a person was communicating with a cell phone. The confrontation time was considered to be 15 min. By ending the confrontation time, the contact was cutoff. The tissue was kept in the compartment for 15 min in the next stage for its temperature to be reduced without exposures and the presence of radiofrequency waves. In all the previous stages, during and after exposure to cell phone radiofrequency waves, the thermometer was connected to the computer system, and the temperature changes were recorded by the software. This experiment was also done for 12 mm and 22 mm thicknesses in the brain tissue (white matter of the brain). Finally, the temperature changes relative to the obtained time were transferred to

MATLAB software (2012 version, MathWorks company), and the graph related to each thickness was obtained.

Results

To determine the thermal changes of radio frequency waves of cell phones on the brain tissue, brain tissue of a cow was analyzed for different thicknesses of 2 mm, 12 mm, and 22 mm, during contacting with a mobile phone.

It was required to balance the tissue and compartment temperatures for measuring the temperatures in different considered thicknesses of the brain tissue. This temperature was equal to 18.38 ˚C for the three thicknesses and after unification of the compartment temperature with the brain tissue temperature, which was considered as the base temperature (tissue temperature before confronting with the cell phone).

Since the thermometer recorded temperature changes once every 5 s, and the base temperature was 18.38°C, after contact between the tissue and the cellular phone in 15 min, the temperature of the brain gray matter increased up to 18.91°C by the 2 mm thickness of the tissue (brain grey matter), and the brain tissue showed an increase of 0.53°C in comparison with the time before confronting with the cell phone. Temperature changes of the gray tissue of the brain relative to time are shown in Figure 1.

After the contact and confrontation of the tissue with a cell phone for 15 min, the tissue temperature reached to 19.37°C from 18.38°C in 12 mm thickness of the tissue, and the brain tissue had a temperature increase of 0.99°C in comparison with the time before confrontation of the tissue with a cell phone.

Moreover, the base temperature of the brain tissue at the thickness of 22 mm was equal to 18.38°C after the contact and confrontation of the tissue and the cell phone for 15 min, temperature raised to 19.3°C, showing an increase of 0.92°C in comparison with the time before the confrontation. The tissue temperature changes in 12, 22 mm thickness are shown in Figure 1.

The duration of the tissue exposure to cell phone was 15 minutes, and 0.01°C increase in confrontation with the cell phone was observed in thicknesses of 12 mm and 22 mm (white matter of the brain) after 5 s and in 2 mm thickness (gray matter of the brain) after 10 s. In fact, the white matter had the temperature increase faster than the gray matter. Moreover, by the increase in the tissue thickness, the times that they reached maximum temperatures were less, such that 22 mm thickness and 2 mm thickness reached reached after 7 min and 9 min and 25 s, respectively, to maximum temperature increases, i.e., 19.3°C and 18.91°C, and the maximum temperature increases were fixed in 15 min of confronting with the cell phone. On the other hand, the time for maximum temperature reduction after stopping the exposure in higher

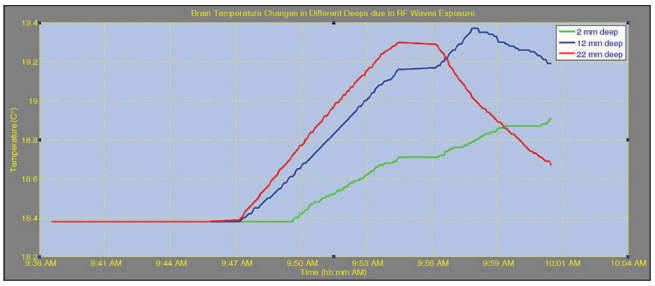

Figure 1: Brain temperature changes in different deeps due to radiofrequency waves exposure

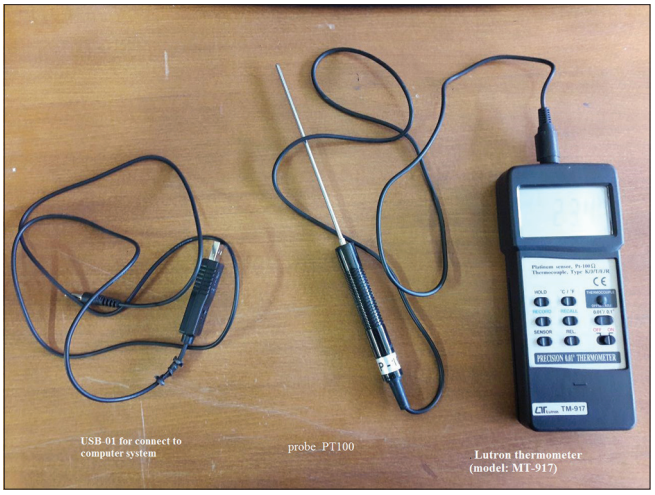

Figure 2: The Lutron thermometer (model: MT-917), probe "PT100, and USB cable for connected to computer system

Figure 3: Exposure setup

thicknesses was less, such that maximum temperature reduction was observed in 22 mm, 12 mm, and 2 mm thicknesses after 5 min 5 s, 8 min 13 s, and 14 min, respectively, and the temperature reduction was fixed until the end of 15 min after stopping the confrontation. In general, the time that in 2 mm thickness of the brain tissue (gray matter of the brain), temperature showed an increase by 0.53°C, and in other words, in 2 mm thickness,

the slope in the relevant figure showed a mild increasing trend, while in higher thicknesses (12 mm and 22 mm) (the white matter of the brain), the temperature increase was equal to 0.99°C and 0.92°C, respectively, and the slope in the figure in these thicknesses increased with higher rates. In fact, higher temperature increases were observed in 12 mm and 22 mm thicknesses. Figure 1 shows the comparison between increasing temperatures in the three different thicknesses of the brain tissue.

Brain tissue temperatures in the three mentioned thicknesses were evaluated for the 15 min period after stopping the confrontation with the cell phone. The results showed that the base temperature in 2 mm, 12 mm, and 22 mm thicknesses (the tissue temperatures before the exposures) was equal to 18.38°C, and 15 min after stopping the required confrontation, the temperature rates were 18.58°C, 18.74°C, and 19.01°C, respectively. In other words, the temperature of the brain tissue decreased in all the three thicknesses relative to the exposure time. However, it was higher in comparison with the base temperature, such that the tissue temperatures in 2 mm, 12 mm, and 22 mm thicknesses were 0.33°C, 0.63°C, and 0.29°C higher than the base temperature, respectively.

Discussion

The present study has analyzed the thermal changes of cell phones radiofrequency waves on the gray and white matters of the brain tissue.

Results have shown that confrontation of the brain tissue for 15 min with a cell phone increases its temperature. In fact, temperature increases were observed for all the three thicknesses (2 mm, 12 mm, and 22 mm) during confrontation and relative to the base temperature (brain tissue temperature before confrontation), and this increase in the temperature was 0.53°C, 0.99°C, and 0.92°C for the mentioned thicknesses (2 mm, 12 mm, 22 mm), respectively.

Rusnani *et al*. reported that in 15 min and 30 min confrontation with a cell phone, the temperature increases in the head and ear members of users, and this temperature in this parts increases by increasing the time of conversation by the cell phone. They showed that temperature by confrontation of the head with a cell phone for 15–30 min increased by 0.3°C–2.9°C.[13]

Tahvanainen *et al*. stated that in confronting with radio frequency waves of cell phones for 35 min, the ear canal temperatures of users increased 1.5°C.[14]

One of the important effects of absorbing radio frequency waves of cell phones is increasing the temperature of body tissues, such that increasing 4.5°C in the brain is reported in a study due to confronting with a cell phone for 30 min.[15]

In this study, the temperatures of brain tissue in different thicknesses of 2 mm, 12 mm, and 22 mm for 15 min confrontation with a cell phone show reductions in comparison with the tissue temperature during the confrontation. However, despite temperature reductions, the temperatures of the brain tissue in the three thicknesses and after confronting with a cell phone are higher in comparison with the base temperature, with the rates of 0.33°C, 0.63°C, and 0.29°C, respectively. In other words, not only temperature increase was observed during confrontation with the cell phone, in the brain tissue, but also this increase was cumulative even after the confrontation, and the temperature was higher for some time after the confrontation with the cell phone relative to the time before the confrontation.

Since the cell phone antenna is located near the head and an ear of the user, most probably the brain is confronted extensively to radiofrequency waves.[4] In fact, by increasing the brain temperature, the brain blood circulation is increased and lateral thermal adjustment reactions are activated. Measuring automatic responses of the brain and evaluation of brain blood flow are used as indirect evidence from blood circulation interactions and regulating temperature during confrontation with radiofrequency waves. Thus, repeating the exposure to cell phones will increase the tissue temperature during the confrontation and leads to high temperature of the tissue, even for a while after confrontation, which provides improper effects on the brain health.[16]

Tissue temperature in the thicknesses of 12 mm and 22 mm of the brain showed a higher increase, which indicates the effects of the brain tissue layers on the thermal balance in the considered thickness. This result shows that with more layers of the tissue, the accumulated heat in the tissue will be higher. Hence, it is possible that the effects due to using the cell phone are more in the deep tissues. On the other hand, it is possible that the deep tissues (white matter of the brain) have higher sensitivity in confronting with cell phone waves, and the sensitivity emerges by higher absorption of energy and thus, higher increase of temperature. These results can primarily be due to the differences in the fluid materials of the tissue layers, such that more fluid in the gray matter than the white matter can generally produce higher heating capacity. This phenomenon causes the gray matter to have less increase of temperature in a unit time, reaching a lower temperature by the end of the experiment. On the other hand, the difference in temperature increase can be due to the important point that the induced heating in the tissue does not necessarily have direct and linear relation with the depth of the tissue, and it is a function from physical variables of electromagnetic waves, including frequency, field flux, and intensity. Wessapan *et al*. showed in their study that due to confronting with the cell phone, the rate of the generated heat in the brain tissue is more than the skin since brain is a tissue with high metabolism in heat generation. Hence, temperature is higher in the brain tissue as compared to other tissues with low metabolism

in heat generation. High blood supply of the skin tissue plays an important role for keeping the tissue temperature in low condition, while supplying blood to the brain tissue is lower as compared to skin, causing the brain tissue temperature to rise.[12] In a study on forty mobile phone users, it was reported that 35 users complained about skull problems such as tingling and feeling pins and needles on ear sections, and frontal and posterior parts of the brain.[17]

Maximum temperature additive changes in human brain occur in the frequency of 900 MHZ to over 1800 MHZ. On the other hand, electromagnetic waves resulted from cell phones in 900 MHZ permeate to the confronted tissue, and the energy resulted from these waves is taken by the tissue. Although the transmitting device of the cell phone transmits a little force, the users' bodies absorb this force from the transmitting device antenna, and the highest rate of exposure to radiofrequency waves is concentrated in the users' heads. According to some studies, it is determined that the absorbed energy by the users is transformed into heat inside the biological tissues, affecting the tissues through the generated heat.[18]

Conclusions

It can be concluded that the radiated radio frequency waves from cell phones are effective on increasing the temperature of brain tissue, and the increase is cumulative in the tissue, (tissue temperature after exposure was different with its base temperature before exposure) such that the temperature remains higher, even for some time after the confrontation, as compared to the time with no confrontations.

The time of increasing temperature in the white matter is lower as compared to the gray matter. Despite the advantages of cell phones that have led to increasing the number of users, their harmful effects on people are inevitable, and the related effects emerge by the passage of time and increasing use of the cell phones. This should be considered by the people who continuously use mobile phones as a communicating device.

It is proposed to analyze the effects of radio-frequency waves of cell phones for different using times and considering different models.

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Conflicts of interest

There are no conflicts of interest.

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