Biological effects of electric field on histopathological study, electrical properties and kidney function of albino rats

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ABSTRACT

The present study was to investigate the effects of electric field (EF) of strength 50 Hz – 3 kV/m on the histopathology, dielectric properties and kidney function tests in albino rats. Forty eight albino rats were equally divided into three groups (16 each) namely A, B and C. Animals of group A used as control group which did not receive any treatment. Animals of group B was divided into two subgroups namely B1 and B2 which were discretely exposed to 50 Hz, 3 kV/m electric field for a period of 15 day (8 h/day, 5 days/week). Group B2 were left to survive and housed at normal environmental conditions similar to control group A for a period of 15 days post exposed. Animals of group C were divided into two subgroups namely C1 and C2 which were discretely exposed to the EF for a period of 30 days (8 h/day, 5 days/week). Group C2 were left to survive and housed at normal environmental conditions similar to control group A for a period of 15 days post exposed. At the end of exposure, fresh samples of kidney and blood were collected from all groups for experimental investigations. The dielectric constant (έ) and electrical conductivity (σ) were measured in frequency range 42 Hz up to 5 MHz to investigate any possible-related changes in kidney structure through studying histopathological examination. Also, the kidney function was studied through analysis of urea and creatinine after exposure to EF. These biochemical parameters have been evaluated in the blood serum of rats. The results show high significant changes in the values of έ and σ of kidney tissues for all groups exposed to EF as compared with the control group. The exposure of rats to EF can induce significant increase in the levels of kidney profile creatinine and urea. These variations were recovered during two weeks after stopping exposure but they did not return to its original control values before exposure. On microscopic level; kidney histological section showed abnormal configuration of renal tubules RT, congested blood vessel and degenerated renal tubules arrow, necrosis N, glomerular shrinkage GS, and increase in space between glomerulus and Bowman's capsule.

Keywords: Electric field, histopathology, kidney function, dielectric constant, electrical conductivity.

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INTRODUCTION

Life on earth has evolved amidst a broad band of electromagnetic frequencies, which originate from the universe (Lotfi, 2011) and the environmental, artificial, microwave devices, wireless communication devices, wireless computers and surgical instruments have been increased dramatically by more than trillion times. Nowadays, exposure to non-ionizing electromagnetic fields (EMFs) has increased due to mobile handset and base station antenna. Electromagnetic waves penetrate the animal body and act on all organs altering the cell membrane potential and the distribution of ions and dipoles. These alterations may influence the biochemical processes in the cell (Lee et al., 2004). EMFs produce energy which affects the tissues (Hirata et al., 2002;
Human beings are unavoidably exposed to ambient EMFs generated from various electrical devices and from power transmission lines. All of the electronic equipment’s that we use in our daily life without thinking how much creates EMF (Ongel et al., 2009). The increasing use of the electric technology, electromagnetic fields especially the extremely low frequency electromagnetic fields (ELF-EMF) have become a part of the modern life. These fields are produced by all electric devices, including high energy sources like power lines and microwaves, but also found in low energy devices such as cell phones (Van Deventer et al., 2005).

The principle that electric fields can provoke biological effects has been known since the middle of the 19 century. Currently, the biological possessions of ELF-EMFs have attracted attention of many researchers to not only establish the basic mechanisms of its interaction to living systems but also its potential of practical applications (Martirosyan et al., 2013). The influence of EMFs on biological systems has been attracting interests of more and more scientists during the past two decades. A great deal of research has been conducted and convincing evidence indicates that exposure to ELF-EMF can induce the alterations in living systems (Zhang et al., 2005). Several studies have been performed to verify direct effects exerted by ELF-EMF on cell functions. In recent years histological and physiological studies have increased in the evaluation of the effects of EMFs on human health (Lotfi, 2011; Ozguner et al., 2002; Al-Glaib et al., 2007; Zare et al., 2007; Wang et al., 2008; Hashem and El-Shakawy, 2009). It was reported that extremely low frequency EMF induced tissue damage in different organs of the experimental animals (Fiorani et al., 1997; Khaki et al., 2006).

EMF hazarded was considered one of the most dangerous types of pollution (Cakir et al., 2009; Alghamdi and El-Ghazaly, 2012) due to EMFs which affected the functions of cells of the body (Al-Rajhi, 2006). The results of different studies on animals and humans dealing with the biological effects of exposure to ELF-EMFs have consistently been both positive and negative (Fiorani et al., 1997; Varshney et al., 2012). In literature, various theories were described concerning the effect of EMF on living organisms through induction, resonance, and radical mechanisms (Sieroń, 2000; Bachanek et al., 2010) affecting cell signal transmission, structure of biological membranes and ion transport, processes of replication and transcription of nucleic acids and synthesis of proteins, and cell proliferation processes (Sieroń, 2000; Bachanek et al., 2010). The present study investigates the histopathological effects of permissible dose of EMFs on the kidney of albino rats. In exposed rat group to 50 Hz horizontal electric field for 8 hours/day for 8 weeks, many histological alterations such as focal tubular atrophy, necrosis and degeneration of the seminiferous epithelium were observed in the testes (Erpeki et al., 2007). Zare et al. (2007) clarified that the exposed group of guinea pigs to 50 Hz electric field for 2 h daily for 5 days cause cytoplasmic vacuolations of the hepatocytes. Furthermore, swelling in the epithelial cells of renal tubules and subsequently cell necrosis were observed with glomerular dilatation. And also, atrophy of the seminiferous tubules was detected (Zare et al., 2007).

It was reported that ELF-EMFs induced tissue damage in different organs of the experimental animals (Zare et al., 2007; Khayyat and Abou-Zaid, 2009). Also, exposure to MF adversely affects spermatogenesis, Sertoli and Leydig cells of experimental animals (Forgács et al., 2004; Aydin et al., 2007). Recently, the histological and physiological studies have increased in the evaluation of the effects of EMFs on human health (Zare et al., 2007; Hashem and El-Sharkawy, 2009).

EMFs penetrate the human body and act on all organs altering the cell membrane potential and the distribution of ions and dipoles. These alterations may influence biochemical processes in the cell, thus, changing both biochemical parameters and enzyme activities of serum (Kula, 1991; Lotfi, 2011).

Creatinine is a chemical waste molecule that is generated from muscle metabolism. Creatinine is produced from creatine, a molecule of major importance for energy production in muscles. Approximately 2% of the body’s creatine is converted to creatinine every day. Creatinine is transported through the bloodstream to the kidneys. The kidneys filter out most of the creatinine and dispose of it in the urine. Although it is a waste, creatinine serves a vital diagnostic function. Creatinine has been found to be a fairly reliable indicator of kidney function. As the kidneys become impaired the creatinine will rise. Abnormally high levels of creatinine thus warn of possible malfunction or failure of the kidneys (Price et al., 2005; Patel et al., 2013).

The aim of our work is to investigate the effects of electric field (EF) of strength 50Hz-3kV/m on possible histological changes, dielectric properties and kidney function tests in albino rats.

MATERIALS AND METHODS

Experimental animals and study design

Animals kept in the same conditions for 2 weeks for adaptation. Experiments were performed on forty eight Albino rats weighing from 170 to 200 g. Animals presenting any symptoms of illness were excluded from the study. All testing was performed between 9:00 a.m. and 4:00 p.m. Rats were fed on standard diets and water and were housed in plastic cages under standard conditions. The experimental animals were equally divided into three groups (16 each) namely A, B and C. Animals of group A were used as control group which did not receive any treatment and housed at normal
environmental conditions. The temperature inside the lab varied between 22 and 25°C, lighting condition are natural light from large windows during the day and complete darkness during the night. Animals of group B was divided into two subgroups namely B1 and B2 which were discretely exposed to 50 Hz, 3 kV/m electric field for a period of 15 days (8 h/day, 5 days/week). Animals of group B2 were left to survive and housed at normal environmental conditions similar to control group A for a period of 15 days post exposed. Animals of group C were divided into two subgroups namely C1 and C2 which were discretely exposed to the electric field for a period of 30 days (8 h/day, 5 days/week). Animals of group C2 were left to survive and housed at normal environmental conditions similar to control group A for a period of 15 days post exposed. The device admit the rates to be under influence of an alternating electric field of 3 kV/m. it is constructed of a plastic cuboid and its dimensions are 80 cm length, 20 cm width and 20 cm height. The two inner parallel sides of the cuboid were covered by two isolated copper plates which were made of two PCB sheets. Figure 1 revealed the schematic diagram for exposure facility system. The copper sheets were electrically connected with a power supply. The power supply consists of a variac and step up transformer. The alternating potential difference across the two plates was adapted to be 600 volts.

**Dielectric and conductivity measurements**

The dielectric measurements were carried out for the kidney samples in the frequency range 42 Hz to 5 MHz using a loss Factor Meter type HIOKI 3532 LCR Hi TESTER; version 1.02, Japan and cell types (PW 950/60) manufactured by Philips. Animals were sacrificed then the kidney was immediately excised and placed between a pair of 1 cm diameter black platinum circular electrodes for dielectric measurements. The sample between the electrodes was maintained at constant pressure, and the distance between the electrodes was measured through the use of a micrometer by measuring the diameter of kidney tissue which represents the distance between the two electrodes, while the kidney sample was filling the whole volume between the electrodes. During measurements, the sample between the electrodes was kept at a constant pressure and temperature of 24 ± 0.1°C. The capacitance (C) of the tissue was measured at each frequency and the resistance (R) was recorded. Each run was repeated three times. The relative permittivity (ε) of the sample was calculated for each frequency using the relation (Ahmed et al., 2014; Sahar et al., 2015):

$$\varepsilon' = \frac{Cd}{\varepsilon_0 A}$$

Where A is the area of electrode, d the distance between the two electrodes, ε₀ is the permittivity of free space and ε is the dielectric constant. The dielectric loss ε" is calculated from the relation (Ahmed et al., 2014; Sahar et al., 2015):

$$\varepsilon'' = \frac{\varepsilon'}{2 \pi f R C}$$

Where f is the applied frequency in Hertz, R and C are the resistance and capacitance of the sample at resonance and δ is the loss angle. The electric conductivity σ is given by Ahmed et al. (2014) and Sahar et al. (2015):

$$\sigma = 2 \pi f \varepsilon'' \varepsilon_0$$

**Histopathological examination for kidney**

Specimens of kidney tissues were taken from all groups and prepared for the histological and histopathological sections following Bancroft and Stevens (2006). Kidney tissue was fixed in 10% buffered formalin (10 ml formalin in 30 ml normal saline or sterilized distilled water) embedded in paraffin blocks and sectioned. The tissues were subsequently dehydrated in upgraded concentrations of alcohol (70% alcohol) cleansed in xylene. Several sections of 3 to 6 µm thickness were cut, dried with blotting paper (Chauhan, 2004), using
microtome then embedded in paraffin and sections stained with Hematoxylin and Eosin (H&E) (Al-Nakeeb, 2011; Al-Qudah, 2012). The slides were then evaluated for pathological changes under light microscope (100x). Photographs were taken using Kodak digital 10.3 mega pixels camera (Sagan, 1992).

RESULTS AND DISCUSSION

Kidneys are the major excretory organs and about 20 to 25% of the total amount of circulating toxins, including mycotoxins, reach them (Harriet, 2003). The demands of kidneys for nutrients and oxygen are high because of their extensive functional load. Approximately one-third of the total blood volume is filtered through kidneys and at the same time, 98 to 99% of systemic water and sodium chloride are reabsorbed.

In the present work, ELF-EMFs was chosen because it has been encountered in many work places, medical practice and new technologies in use nowadays (Juutilainen, 1991). The exposure of rats to electric fields can induce significant increase in the levels of kidney profile creatinine and decreased in urea as shown in Figure 2 for all groups as compared with control group A. Urea is the major nitrogen-contain in metabolic product of protein catabolism. The significant reduction in serum urea concentration throughout the experimental period may be attributed to impairment of the urea cycle leading to reduced production of the metabolic product. The exposure of rats to electromagnetic radiations can induce significant increase in the levels of creatinine (Figure 2a) and decreased in the levels of urea (Figure 2b) for all exposure groups as compared with control. Creatinine is the final metabolite of creatine conversion and a major marker of kidney function.

The dielectric relaxation spectroscopy study showed a dielectric dispersion in the frequency region from 42 kHz to 5 MHz for both control and exposed groups to 50 Hz–3 kV/m electric field. In this frequency range (β-dispersion) the relaxation mechanism is due to the counter ion molecules and proteins at the cellular membrane. Figures 3, 4 and 5 illustrate the variation of the relative permittivity (ε'), the dielectric loss ε'' and the electric conductivity (σ) for the kidney from groups A, B (B₁ and B₂) and C (C₁ and C₂), respectively, as measured in the range of (42 kHz–5 MHz) to 50 Hz–3 kV/m electric field. The data indicated that there was a pronounced decrease in the dielectric loss for the sample except for group B₂ it attained a higher value than the control value as shown in Figure 4. The data also indicated that there was a pronounced decrease in conductivity of kidney tissue suspension with frequency for all groups as compared with control group as shown in Figure 5. It can also be noticed that the conductivity of group B₂ nearly the same as detected for group C₁ and the conductivity of group B₁ nearly the same as detected for group C₂.

Examination of H&E sections of renal cortex of control rats showed renal corpuscles with normal glomerulus and capsular space surrounded by Bowman's capsule. Histological examinations of the kidney from the control group showed a normal appearance of glomeruli, renal tubules, and interstitial tissue (Figure 6), but the kidney of rats exposed to electric field for 15 days showing abnormal configuration of renal tubules RT, congested blood vessel and degenerated renal tubules, necrosis N and glomerular shrinkage GS, and increase in space between glomerulus and Bowman's capsule (c) also appears abnormal configuration of renal tubules arrow (Figure 7). Kidney sections for group B₂, C₁ reveals shrunken glomeruli, abnormal configuration of renal tubules and increase in space between glomerulus and Bowman's capsule, degenerated and lobulated glomeruli and abnormal configuration of renal tubules (Figure 8, 9, 10).

The results of our study indicated that long term
Figure 3. The variation of permittivity with frequency of the kidney tissue suspension after exposure to electric field and recovery values after two weeks.

Figure 4. The variation of dielectric loss with frequency of the kidney tissue suspension after exposure to electric field and recovery values after two weeks.

Figure 5. The variation of conductivity with frequency of the kidney tissue suspension after exposure to electric field and recovery values after two weeks post exposed.
exposure to EF radiation increases serum creatinine level in male rats. The studies show that urea and creatinine significantly increase following increase in the duration of exposure (Moussa, 2009). The adverse effects of waves have been shown on many tissues (Watson et al., 2014). The mobile phones emitting 900-MHz electromagnetic radiation may be mainly absorbed by kidneys because they are often carried in belts (Oktem et al., 2005), according to which, may influence serum creatinine level. Exposure to the electromagnetic radiation emitted is able to induce renal tissue damage (Al-Glaib et al., 2007). The damage to such tissues may have a part in increasing of serum levels of creatinine. There is association between cell phone radiation and cellular damage (Grundler et al., 1992), which in turn, may result in increased serum levels of creatinine.

**CONCLUSION**

In conclusion, the results demonstrated that:

1. Our findings show that long term exposure to electromagnetic radiations can increase serum creatinine level, according to which, may impose damaging health effects on body function.
2. It is necessary to review the dose limits recommended by the ICRP-60 for radiation workers based on the present findings.

3. This study suggests that, the activities of kidney
function induce significant increase in the levels of kidney profile creatinine and urea; conductivity may decrease by exposure to electric field generated during magnetic resonance imaging or nuclear magnetic resonance procedures.

4. The decrease in conductivity due to field exposure and the recovery groups not returned to the control value during the recovery period this is an indicator that there is no improvement in the kidney state.

5. It is recommended not to allow buildings close or down to power-lines and a special protocol for buildings permission should be done in a way that exposures to such fields are omitted.

6. Similar to ionizing radiation rules, special precautions and some governmental recommendations should be done to be followed by workers in the electric power station.

REFERENCES


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