Case Report

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EXPOSURE OF MICE TO 900 - 1900 MHZ RADIATIONS FROM CELL PHONE RESULTING IN MICROSCOPIC CHANGES IN THE KIDNEY

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ABSTRACT

Objective: The study was to evaluate possible effects of chronic exposure to 900 - 1900 MHz radiations emitted from 2G cell phone on kidney of mice at the histological level.

Methods: Mice were exposed to 2G ultra-high frequency radiation, 48 minutes per day for a period of 30 to 180 days. The amount of electromagnetic field (EMF) exposed was measured by radiation frequency meter. The sham control mice were subject to similar conditions without 2G exposure. Six animals each were sacrificed at the end of 30, 60, 90,120,150 and 180 days of exposure in the experimental group after 24 hours of last exposure. Same numbers of control animals were sacrificed on similar period. Both kidneys were harvested and processed for histomorphometric study. Kidneys size, weight and volume were measured and analysed. Kidney sections were analysed under the light microscope and structural changes were studied.

Results: In 2G exposed group the kidney weight and volume was significantly reduced in the first month. Kidney weight alone was significantly increased in the fifth month. Glomerulus showed dilated capillaries and increased urinary space. Proximal convoluted tubule showed wider lumen with reduced cell size. Brush border interrupted at places and vacuolated cytoplasm and pyknotic nuclei. Wider lumen with decreased cell size and marked basal striations were found in the distal convoluted tubule.

Conclusion: Chronic exposure to ultra-high frequency radiation from 2G cell phone could cause microscopic changes in glomerulus, proximal and distal convoluted tubules of the kidney.

Key Words: Ultra-high frequency radiation, 2G cell phone, mice kidney, glomerulus, kidney tubules.

INTRODUCTION

Rapid development in telephone technology has made communication faster and easier. However, increased use of mobile phones by all classes of humanity, it has become imperative to assess the exposure damage to the biological models (animals or humans). Electromagnetic fields (EMFs) emitted from mobile phones and towers are a big public concern today. Most of the cellular phones operate within the ultra-high frequency bandwidth of 900-2200 MHz's. Ultra high frequency (UHF) electromagnetic radiation or radiofrequency radiation (RFR) with a frequency range of 300- 3000 MHz is "non-ionizing". The present inquest is regarding this form of radiation either to incriminate it as potentially hazardous or absolve it as absolutely harmless.

The second generation cell phone (2G) network operates in the 900-1900 MHz frequency for GSM (Global System for Mobile Communications). Mobile phone in operation emits a pulsed radiofrequency electromagnetic field (RF-EMF). Most of the energy is absorbed into user's body particularly in the head region which can produce heat stress and non-thermal stress in the form of releasing free radicals, alter the enzyme reaction and there by compromises immune system. Specific absorption rate (SAR) is a unit of Watt per kilogram to measure the amount of electromagnetic radiation absorbed by body tissue whilst using a mobile phone. The higher the SAR the more radiation is absorbed. International Commission on Non-Ionising Radiation Protection (ICNIRP Guidelines 1998) recommendations set a SAR limit of 2.0 W/Kg in 10 grams of tissue. Whole body average SAR

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of 0.4W/Kg is widely adopted in most guidelines as the basic restriction based on the threshold of the observed effects due to whole-body heating to cause significant elevation of core temperature (>1°C). Public fear of possible unrevealed effects of exposure below guideline levels is still increasing[1].

Earlier reports have shown that exposure of mobile phone radiation induced damage to tissues which ranges from those at the molecular level manifested as an increase in single and double strand DNA breakages[2], increased risk of acoustic neuroma associated with mobile phone use of at least ten years duration[3], genotoxic effects in human peripheral blood leukocytes[4], keeping a cell phone on or close to the waist can decrease sperm concentration[5], non-thermal DNA breakage by mobile phone radiation in human fibroblasts, decrease in sperm motility and viability after direct exposure of the semen to cell phone radiation[6], reduction of Purkinje cell number in the adult female rat cerebellum[7], long- term exposure to mobile phone radiation lead to reduction in serum testosterone levels[8], and short – term memory in mice is affected by mobile phone radiation[9]. Similarly the authors found that short term exposure of mobile phone radiation induced damage to kidney[10, 11,12,13,14].

In contrary to above findings some researchers reported no adverse biological effects of exposure to non-ionizing radiation emitted from the cell phone, these includes no double stranded DNA breaks or effects on chromatin of rat brain[15], no effect on mouse embryonic lens development[16], psychomotor performance was not influenced by brief repeated exposures to mobile phones[17] and the lack of histological changes on rat testis[18].

The present study was carried out because of the contradictory findings on effects of exposure to non-ionizing radiation emitted from the 2G cell phone on kidney.

MATERIALS AND METHODS

Our study was approved by the Institutional Animal Ethics Committee of Mahatma Gandhi Medical College and Research Institute, Puducherry. Seventy two neonatal albino mice (one day old) of both sexes were obtained from the King Institute of Preventive Medicine and Research, animal section, Guindy, Chennai. New born mice were kept with the mother for twenty one days followed by randomly divided into two independent groups and housed in mice cages at the temperature of 22 ± 1°C and 60% relative humidity. Animals were housed in the central animal house and provided with adequate ventilation, twelve hours of illumination alternated with twelve hours of darkness. During the study, all the animals were received appropriate animal care and were fed with laboratory diet and water ad libitum.

Thirty six mice were exposed to 900-1900 MHz frequency radiation emitted from 2G cell phone and thirty six mice were sham control. The roof of the mice cage was designed to hang the 2G cell phone from the distance of five centimetres from the floor which allow the mice to move freely and to avoid direct thermal injury to mice. 2G mobile phone in non-vibrating, silent, do not disturb (DND) and auto answer activated mode was kept hanging inside the mice cages. EMF was emitted from a standard 2G handset with frequency bandwidth of 900-1900 MHz and power of 2W/Kg. The highest specific absorption rate (SAR) value for this standard handset was 1.69 W/Kg (10gm) and this SAR value was within the limit of the International Commission of Non-Ionizing Radiation Protection (ICNIRP) recommendation. The mobile phone which was kept inside the mouse's cage was rung upon from other cell phone for every half an hour, each call lasting for two minutes. Exposure time was forty eight minutes per day for twelve hours periods (from 8.00AM to 8.00PM) and total duration of exposure was thirty to hundred and eighty days. RF meter was kept inside the mice cage in switch on mode to measure the amount of radiation exposed (Fig.1). The sham control group of thirty six mice were kept under similar conditions without 2G exposure. 2G cell phone and RF meter were kept in switch off mode.

We measured weights of the mice before sacrificing them in both groups. Six mice each were sacrificed at the end of thirty, sixty, ninety, hundred and twenty, hundred and fifty, hundred and eighty days of exposure in the experimental group after 24 hours of last exposure. Equal numbers of control mice were sacrificed on similar time points. Mice were sacrificed under anaesthesia and their both kidneys were dissected out. Kidney weight and volume were measured. Weight measured by Denver's digital weighing machine (0.001gm) and volume measured by the water displacement method. After the morphometric analysis, the kidney specimens were immediately fixed in 4% formalin solutions for twenty four hours then tissues were processed and embedded in paraffin. Tissues were sectioned at five microns, stained with Haematoxylin & Eosin and Periodic Acid Schiff (PAS). Kidney sections from random slide, random sections and random field were analysed under the light microscope and structural changes were studied.

STATISTICAL ANALYSIS

We applied non-parametric Mann Whitney U test for comparing the morphometric data and the t test for comparing histomorphometric data of kidney. P value <0.05 was considered statistically significant.

RESULTS

Morphometric study: The mean kidney weight and volume were significantly reduced in the first month 2G exposed mice in comparison to control mice (P value <0.004 and <0.001 respectively). No significant changes were observed in the second, third, fourth and sixth month. Kidney weight alone was significantly increased in the fifth month 2G exposed mice (P value <0.002). Animal weight did not vary in two groups statistically. (Table 1)

Microscopic appearance a) Glomerulus (G): In comparison to the sham control group, the size of the glomerulus of 2G exposed kidneys showed dilated capillaries and increased urinary space (US) which was filled with filtrate. (Fig. 2). 2G exposed kidneys showed glomerular diameter was significantly larger in all months except the third month (P value <0.001). Glomerular urinary space was significantly larger in second, third, fourth and sixth months of 2G exposed mice in comparison to control mice (P value <0.001) (Table 2).

b) Proximal convoluted tubules (PCT): In the experimental mice of one to six months, brush border of the proximal convoluted tubules showed disrupted appearance due to loss of the brush border in the lining epithelium. The lumen of PCT was widened. The cuboidal cell lining of the tubules had round dark nuclei; pyknotic and vesicular nuclei were found in some cells. The cytoplasm was acidophilic, vacuolated and foamy appearances were found in many cells (Fig. 2). Diameter of PCT was significantly less in third and sixth months of 2G exposed kidneys (P value ≤ 0.001) (Table 2). However the diameter of PCT was significantly high in second, fourth and fifth months of 2G exposed kidney (P value ≤ 0.005) (Table 2). No significant difference in the first month. Height of the cuboidal cells lining the PCT was significantly low in the first month 2G exposed mice in comparison to control mice (P value < 0.001) (Table 2). However, height of the cuboidal cells lining the PCT was significantly high in second, fourth and sixth month (P value < 0.001) (Table 2). In the third and fifth month, no significant difference was observed in the height of cuboidal cells lining PCT.

c) Distal convoluted tubules (DCT): The distal convoluted tubules of experimental group showed indistinct brush border and discontinuity at some places with wider lumen. Cytoplasm appeared normal, flattened nuclei towards lumen and marked basal striations (Fig. 2). Diameter of DCT was significantly less in fifth and sixth months of 2G exposed kidney (P value < 0.001) (Table 2). However, the diameter of DCT was significantly high in second and fourth months of 2G exposed kidney (P value < 0.001) (Table 2). No significant difference in the first and third month. Height of the cuboidal cells lining the DCT was significantly low in the first, second, third and fifth month 2G exposed mice in comparison to control mice (P value < 0.001) (Table 2). In the fourth and sixth month, no significant difference was observed in the height of cuboidal cells lining DCT (Table 2).

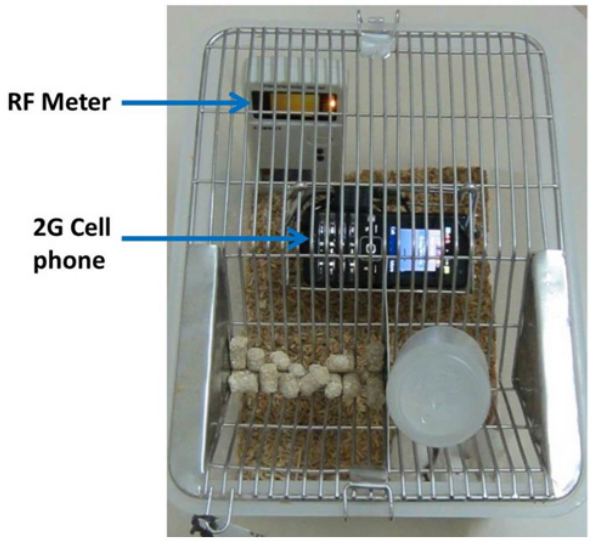

Figure 1: Experimental design

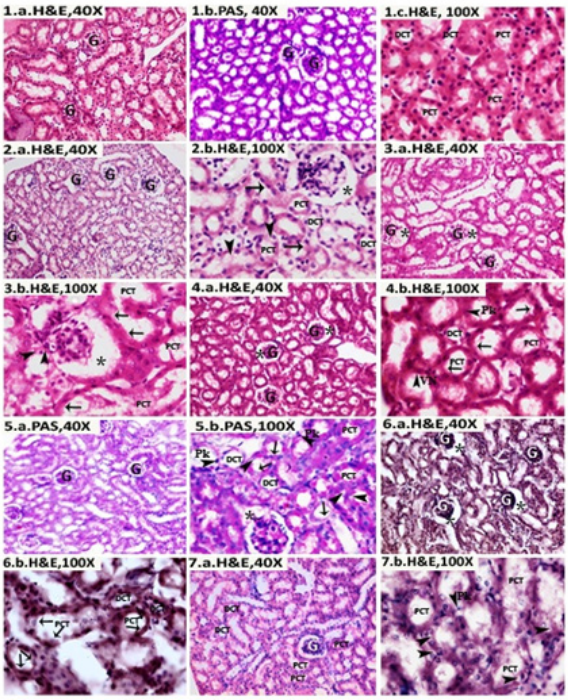

Figure 2: 1a, 1b & 1c. Kidney sections of control mice, 2a & 2b. Kidney sections of 30 days 2G exposed, 3a & 3b. Sections of 60 days 2G exposed, 4a & 4b. 90 days 2G exposed, 5a & 5b. 120 days 2G exposed, 6a & 6b. 150 days 2G exposed, 7a & 7b. 40X -400 times magnification, 100X-1000 times magnification. G-glomerulus, PCT-proximal convoluted tubule, DCT-distal convoluted tubule,
*- increased urinary space, Arrow-discontimuous brush border, Arrow head-cytoplasmic vacuolation, Pk-pyknotic & VN-vesicular nuclei.

Table: 1. Morphometric parameters of mice kidney: 2G exposed versus control

	Mean animal weight (gm)			Mean kidney weight (gm)			Mean kidney volume (ml)		
Months	Control	2G	P value for mean difference	Control	2G	P value for mean difference	Control	2G	P value for mean difference
1	11.98±2.98	8.47 ± 1.43	>0.05	0.25±0.29	0.09±0	0.004*	0.2±0	0.1±0	0.001*
2	20.83±4.99	20 ± 3.78	>0.05	0.17±0.04	0.2±0.04	>0.05	0.2±0	0.2±0	>0.05
3	24.03±2.43	20.8 ± 6.63	>0.05	0.23±0.07	0.21±0.09	>0.05	0.25±0.05	0.25±0.05	>0.05
4	25.5±6.05	25.65 ± 0.79	>0.05	0.25±0.05	0.25±0.01	>0.05	0.25±0.05	0.21±0.04	>0.05
5	29.1±3.04	30.62 ± 2.34	>0.05	0.23±0.03	0.3±0	0.002*	0.2±0	0.25±0.05	>0.05
6	28.21±3.97	29.25 ± 2.64	>0.05	0.27±0.098	0.27±0.06	>0.05	0.3±0.11	0.25±0.05	>0.05

* P value is statistically significant (<0.05)

Table 2: Histomorphometric parameters of mice kidney: 2G exposed versus control

	GD (mm)			GUS (mm)			PCTD (mm)			PCTCHT (mm)			DCTD (mm)			DCTCHT (mm)		
Months	Control	2G	P value	Control	2G	P value	Control	2G	P value	Control	2G	P value	Control	2G	P value	Control	2G	P value
1	0.048 ± 0.007	0.057 ± 0.006	<0.001*	0.011 ± 0.004	0.011 ± 0.002	0.925	0.027 ± 0.003	0.026 ± 0.004	0.193	0.022 ± 0.002	0.018 ± 0.002	<0.001*	0.025 ± 0.032	0.021 ± 0.003	0.235	0.010 ± 0.001	0.007 ± 0.001	<0.001*
2	0.043 ± 0.003	0.069 ± 0.005	<0.001*	0.010 ± 0.003	0.020 ± 0.003	<0.001*	0.031 ± 0.004	0.037 ± 0.004	<0.001*	0.025 ± 0.002	0.029 ± 0.003	<0.001*	0.022 ± 0.004	0.024 ± 0.002	0.005 *	0.011 ± 0.008	0.007 ± 0.001	0.001 *
3	0.065 ± 0.008	0.064 ± 0.004	0.474	0.015 ± 0.004	0.021 ± 0.002	<0.001*	0.034 ± 0.008	0.030 ± 0.003	<0.001*	0.025 ± 0.021	0.024 ± 0.004	0.670	0.019 ± 0.002	0.020 ± 0.002	0.363	0.011 ± 0.003	0.007 ± 0.001	<0.001*
4	0.042 ± 0.003	0.060 ± 0.003	<0.001*	0.007 ± 0.003	0.016 ± 0.003	<0.001*	0.030 ± 0.004	0.039 ± 0.002	<0.001*	0.018 ± 0.004	0.028 ± 0.002	<0.001*	0.024 ± 0.004	0.028 ± 0.005	<0.001 *	0.011 ± 0.003	0.011 ± 0.004	0.978
5	0.055 ± 0.010	0.074 ± 0.007	<0.001*	0.020 ± 0.004	0.020 ± 0.002	0.904	0.029 ± 0.003	0.031 ± 0.003	0.005 *	0.024 ± 0.002	0.024 ± 0.003	0.607	0.029 ± 0.003	0.027 ± 0.003	<0.001*	0.011 ± 0.002	0.008 ± 0.001	<0.001*
6	0.050 ± 0.004	0.066 ± 0.007	<0.001*	0.012 ± 0.004	0.018 ± 0.003	<0.001*	0.030 ± 0.003	0.028 ± 0.003	0.001 *	0.023 ± 0.003	0.025 ± 0.003	0.015 *	0.026 ± 0.002	0.022 ± 0.002	<0.001*	0.015 ± 0.003	0.140 ± 1.032	0.350

GD – glomerular diameter, GUS-glomerular urinary space, PCTD-proximal convoluted tubule diameter, PCTCHT- proximal convoluted tubule cell height, DCTD-distal convoluted tubule diameter, DCTCHT- distal convoluted tubule cell height. * P value is statistically significant (<0.05)

DISCUSSION

The present study was done to investigate the effects of chronic exposure of 2G cell phone radiation on kidney of mice at the histological level. Following chronic exposure of 2G cell phone radiations to mice, the kidney weight and volume was significantly reduced in the first month. Kidney weight alone was significantly increased in the fifth month. Glomerulus showed dilated capillaries and increased urinary space. Proximal convoluted tubule showed wider lumen with reduced cell size. Brush border interrupted at places and vacuolated cytoplasm and pyknotic nuclei. Wider lumen with reduced cell size and marked basal striations were found in the distal convoluted tubule.

Previous studies showed that the degrees of damage to kidneys were increased with the time of exposure to EMF. In the past studies, Al-Glaib B et al (2008)[10] reported, mobile phone radiation exposed to mice one hour per day for ten days showed some glomeruli were atrophied, more mononuclear leukocytic infiltration between the renal tubules, dilatation and vacuolation of some tubules. In our study glomeruli were dilated and urinary space increased. Lumen of the renal tubules were wide due to reduced height of the cells lining the tubules and disruption of the brush border of cells lining the PCT. Cytoplasmic vacuolation and vesicular pyknotic nucleus were found in PCT and no leukocytic infiltration was observed between the tubules.

Laila K et al (2010)[11] exposed 900 MHz radiations to rats one hour per day for 4 weeks and found atrophy of few glomeruli and extravasation of blood cells between kidney tubules. In our study, we found glomeruli were dilated and no extravasation of blood cells between the tubules. Findings from Latifa Ishaq Khayyat study (2011) [12] was when mice were exposed to EMF eight hours for three days and twelve days, most of the glomeruli were atrophied, epithelial cells of the renal tubules showed cytoplasmic vacuolation with pyknotic nuclei. They also found congested and dilated renal veins and intertubular inflammation. These findings were more severe and pronounced in the animals exposed EMF eight hours for twelve days. To compare with our study, glomeruli were dilated due to dilated capillaries and epithelial cells lining the PCT and DCT showed cytoplasmic vacuolation with pyknotic nuclei. We also found that lumen of PCT & DCT were wide due to reduced height of the cells lining the tubules and loss of brush border in PCT.

It was previously reported by N Hanafi et al (2012)[13] that kidney of infant mice exposed to mobile phone radiation forty five minutes per day for one month showed atrophied glomeruli and bleeding infiltrations within convoluted tubules with the presence of obstruction of some convoluted tubules. In our study, we did not find atrophied glomeruli or bleeding infiltration. Ingole IV & Ghosh SK (2006)[14] reported that 900 MHz frequency cell phone radiation exposed to chick embryo of six, eight and ten days old with varying period of four, five and six hours exposure resulted in narrowed Bowman's space of renal corpuscles and some of the cells lining the affected tubules showed cytoplasmic vacuolation, disruption of luminal border and pyknotic nuclei. Similar changes were observed extensively in sections of eight and ten days old embryos. In the present study, we found glomeruli were dilated and urinary space (Bowman's space) increased. The cells lining the PCT showed discontinuous brush border, cytoplasmic vacuolation and vesicular pyknotic nucleus. Robert E. Anderson, Morgan Berthrong and Louis F. Fajardo (2009)[19] stated that early radiation injury to the kidney was vasodilatation and increased glomerular filtration rate. Delayed radiation injury was leading to cortical atrophy and interstitial fibrosis. In our study, we found glomerular capillary dilatation and increased urinary space after chronic exposure to 2G cell phone radiation.

CONCLUSION

Chronic exposure of 900 – 1900 MHz radiations emitted from 2G cell phone induced microscopic changes in the kidney of mice. The EMF exposed kidney showed dilated glomerular capillaries and increased urinary or Bowman's space. PCT had wider lumen with reduced cell size. Brush border interrupted at places, vacuolated cytoplasm and pyknotic nuclei. It was suggestive of features of early radiation injury.

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