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Effect of Low-Intensity Microwave Radiation on Rat Kidney: An Ultrastructural Study*

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Abstract: Exposure to low-intensity microwave radiation for prolonged periods is known to be a potential factor inducing visceral damage. There are several studies in the literature demonstrating the harmful effects of such radiation on the kidney of laboratory animals. Our aim was to determine the effect of low intensity microwave radiation on rat kidney at the light and electron microscopic level.

Animals (28 rats) in the experiment group were exposed to 2.65 mW/cm^2 radition (9450 MHz) for 1 h per day during 26 and 52 days respectively and tissue samples of these animals were examined and compared with those of the control group.

At the light microscopic level most significant changes were observed in the 52.0-days exposure group. In the renal tubular epithelium there was extensive apical vesiculation almost totally obliterating the lumen. Cytoplasmic vacuolization of the epithelial cells was not prominent in the 26.0-day group but also became most significant in the 52.0-day group. Degenerative changes in the kidney glomeruli were also most prominent in the 52.0-day group at light and electron microscopic levels. At the ultrastructural level renal tubular epithelium and glomeruli reflected features of early necrotic changes gradually increasing as the exposure period increased. Glomerular sclerosis was the end stage of these degenerative changes as clearly outlined at the ultrastructural level.

Our findings clearly demonstrate the harmful effects of low-intensity microwave radiation on kidney parenchyma in an exposure-period dependent manner.

Key Words: Low-intensity microwave radiation, kidney, rat.

Introduction

The application of nonionizing electromagnetic radiation both in industry and in medicine has increased greatly in the last few years. However, there is an increasing number of reports indicating that biological side effects of high intensity ionizing and nonionizing radiation may be noxious to mammals, including humans (1,2). It has been shown that high-intensity radiation exposure induces in mice a state of peripheral lymphopenia, considerable suppression of cell-mediated immunocompetance, and thymic involution (3). Moreover, in rabbits abnormalities of the lens (4) testis and epidydimes (5-6) and in rats embryonic development alterations (7) have been reported following radiofrequency irradiation. Altered immune reactions such as in the nervous system, testis and lens, have also been observed in several mammalian species in response to microwave fields (8,9). However, the effect of low-intensity MW (microwave) radiation on the biological system is not known exactly and there are contradictory reports in relation to the effect of low-intensity MW radiation on rats and humans. The effects of electromagnetic radiation on the kidney have not been thoroughly investigated. However, ionizing electromagnetic radiation induced a nonimmunologically mediated nephritis, which has been widely documented in both humans and animals (2). This nephritis is currently refered to as “radiation nephritis”. Our aim was to determine the effect of low-intensity microwave radiation on rat kidney at the light and electron microscopic level.

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Materials and Methods

Animals and exposure devices: Twenty-eight male adult Spraque-Dawley rats ranging in weight from 250 to 350 g were used in the experiments. Twenty-one rats were exposed to microwave radiation (9450 MHz) and seven rats were used as unexposed controls. All animals were maintained on standard rat diet pellets and water ad libitum and were housed in individual metal cages. The animals, in the experiment group, according to the following schedule, were exposed 60 min each day to 2.65 mW/cm^2 radiation during 26 and 52 days and all animals were sacrificied under ether anesthesia to detect and compare the renal changes induced directly by irradiation. Mean total body specific absorbtion rate (SAR) was 1.80 W/kg. SAR was measured by the calorimetric method (10).

Morphological techniques: At sacrifice, both kidneys were rapidly removed and bisected. One half of each kidney was fixed in Bouin's solution and embedded in paraffin. Five micrometer sections were stained with Methylene blue-Azure II. For electron microscopy, small fragments of tissue were excised from the half and immediately fixed in buffered osmium tetroxide, dehydrated in graded ethanol, and embedded in vestopal (9). One-micrometer-thick sections of the plastic embedded tissue were stained with an alkaline solution of toluidine blue and examined under a light microscope to select areas for ultrastructural studies. Eight hundred-Angstrom thick sections were stained with lead citrate-uranyl acetate and examined under a Jeol electron microscope.

Results

Results of light microscopy: Semi-thin section of the kidney of a rat belonging to group. No significant structural change was detected at the light microscopic level (Figure 1 a).

At the end of the irradiation period, by light microscopy, most significant changes were observed in the 52.0-days exposure group. In the renal tubular epithelium there was extensive apical vesiculation almost totally obliterating the lumen. Cytoplasmic vacuolization of epithelial cells was not prominent in the 26.0-day group but also became most significant in the 52.0-day group. Degenerative changes in the kidney glomeruli were also prominent in the 52.0-day group at light microscopic levels (Figure 1b).

Results of electron microscopy: The kidneys of control animals were normal by electron microscopy (Fig. 2a). Degenerative changes in the kidney glomeruli were prominent in the 52.0-day group at the electron microscopic level. Renal tubular epithelium and glomeruli reflect features of early necrotic changes gradually increasing as the exposure period increased. Glomerular sclerosis was the end stage of these degenerative changes as clearly shown at the ultrastructural level (Figure 2b). In addition to extensive vesiculation, membrane-bound organelles like mitochondria and endoplasmic reticulum cisternae underwent structural changes as shown in (Figure 3).

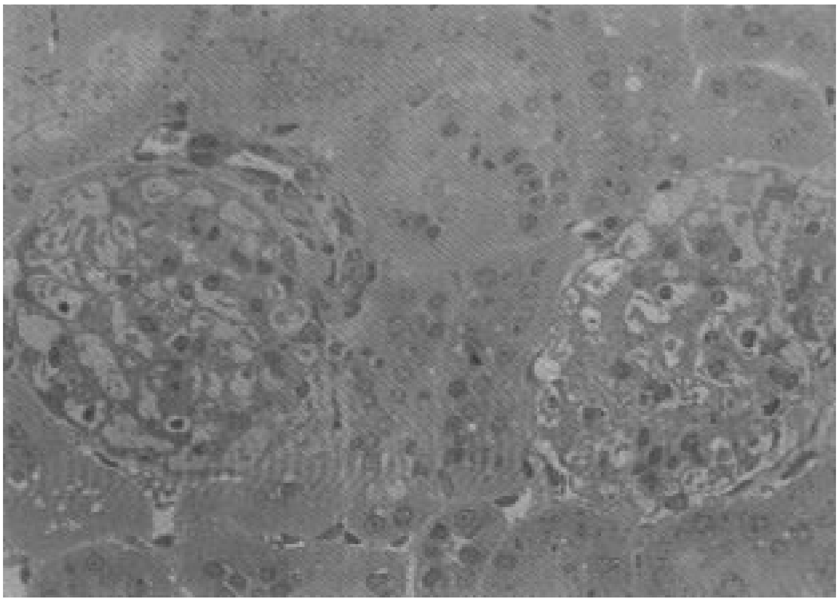

Figure 1a. Semi-thin section of the kidney of a rat belonging to control group. No significant structural change was detected at the light microscopic level (Methylene blue- Azure II stained, original magnification X40).

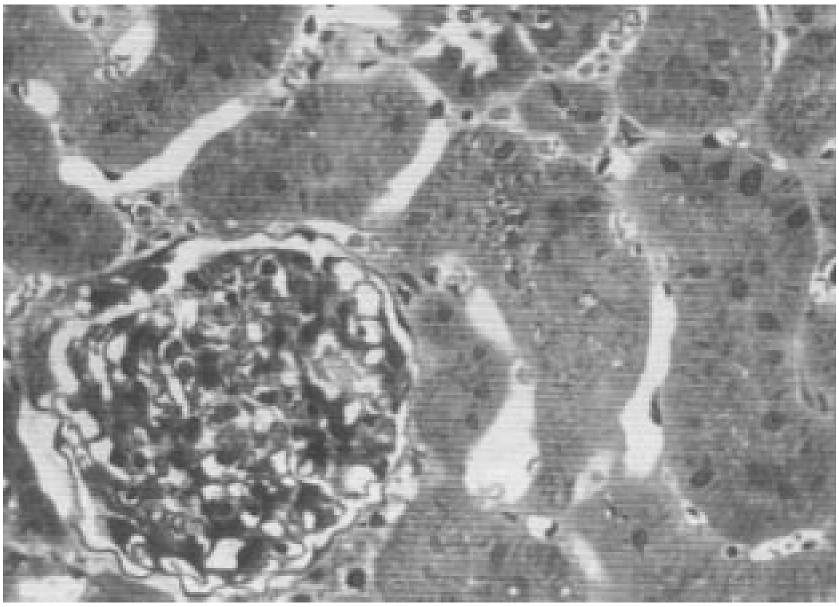

Figure 1b. Semi-thin section from 52.0-day low-intensity microwave radiation exposed group. Vacuolization of renal tubular epithelium and degenerative changes in the kidney glomeruli are prominent in this group (Methylene blue- Azure II stained, original magnification X40).

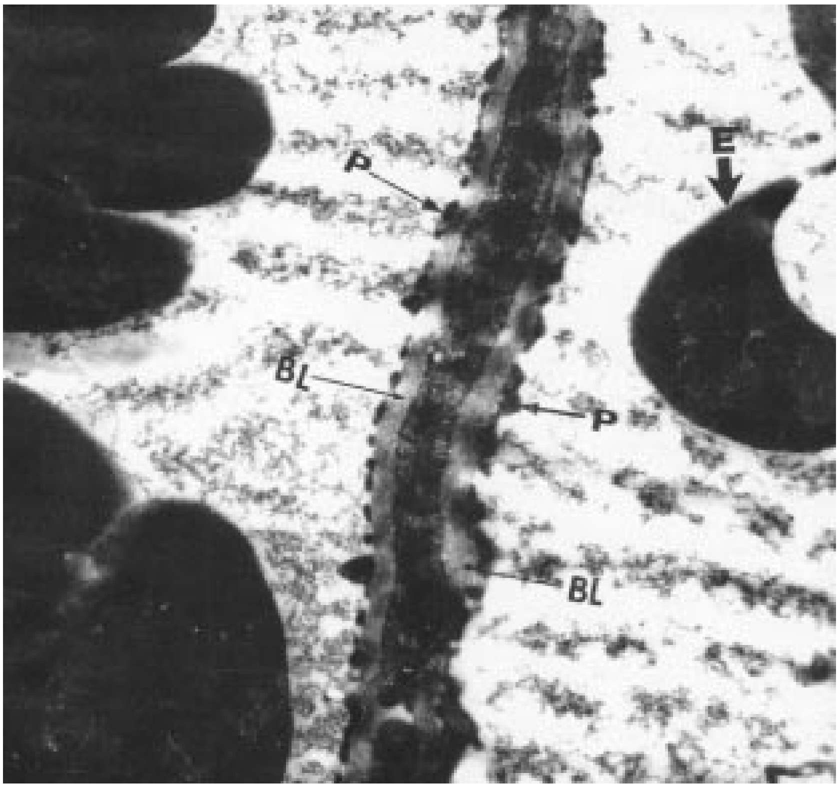

Figure 2a. Electron micrograph of kidney glomerulus of a rat from the control group. Glomerular filtration barrier and podocytes appear to be quite normal. BL: Basal lamina, E: Erythrocytes, arrows: Pedicels secondary processes of podocytes (Lead citrate-uranyl acetate stained X6200).

Discussion

The results of the present study indicated that rats exposed to 2.65 mW/cm^2 radiation develop renal lesions. Initially under the conditions of our experiments, both glomeruli and tubules seemed to be sensitive to the radiation damage, thereafter, the tubules largely returned to normal, probably because of active regenerative processes (12), whereas the glomeruli lesions persisted and evolved toward membranous changes. However, these results are based on multiple doses of radiation at

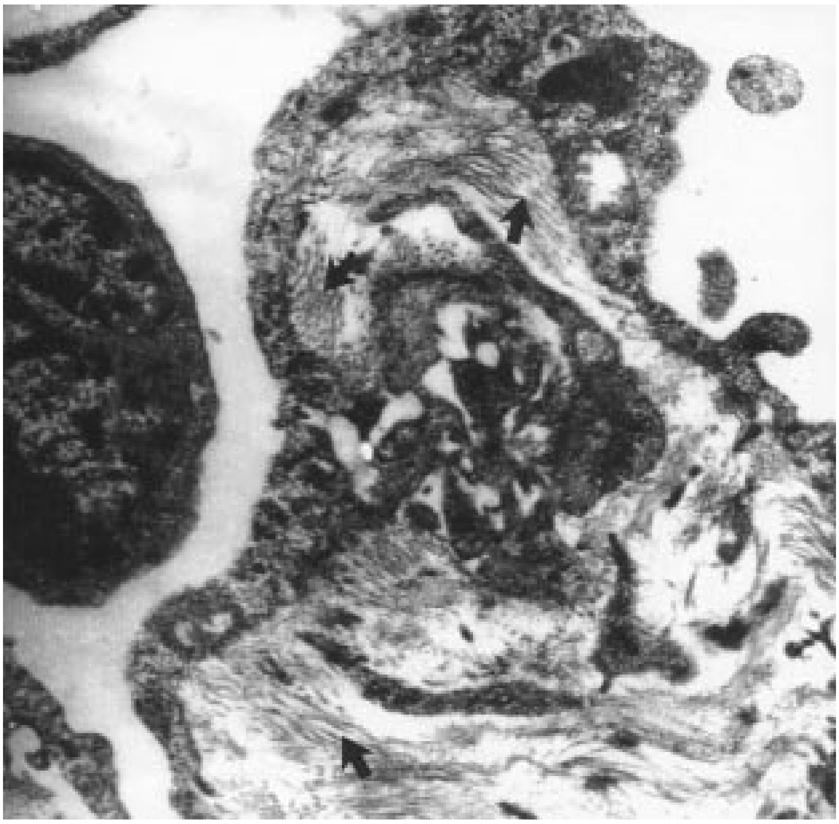

Figure 2b. A section from the glomerulus of a rat from the 52.0-day low-intensity microwave radiation exposed experimental group. Glomerular sclerosis was evident as clearly detected by the extensive increase in collagen fiber bundles (arrows) (Lead citrate-uranyl acetate stained X11200).

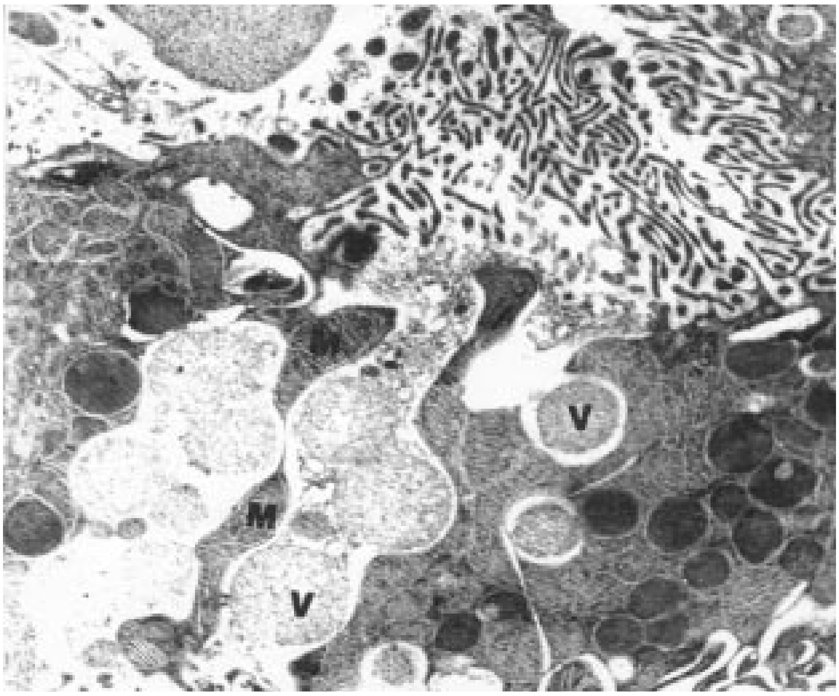

Figure 3. Microphotograph demonstrating the apical compartment of a proximal convoluted tubule of rat kidney belonging to the 52.0-day experimental group. In addition to extensive vesiculation, membrane bound organelles like mitochondria and endoplasmic reticulum cisternae underwent early necrotic changes. V: vesicles, M: mitochondria *: endoplasmic reticulum cisternae (Lead citrate-uranyl acetate stained X11200).

certain values of intensity and different results may be obtained at different doses and conditions of irradiation and in different animal species which may show different genetic susceptibility to this radiation.

Several clinical and experimental studies (13) have described pathological findings in kidneys damaged by X-irradiation and the mode of their progression, which does not seem to be sustained by immunological mechanisms (14). Although these two types of radiation nephritis evolve differently i.e., toward glomerulosclerosis and interstitial fibrosis in ionizing radiation nephritis and toward glomerular membranous changes associated with immune deposits in nonionizing radiation nephritis, there are striking similarities between the early ultrastructural lesions observed in radiofrequency radiation nephritis and those described in experimental X-ray nephritis (13), such as tubular cell degeneration and necrosis.

Accini et al (15), reported that a variety of lesions as well as early regenerative features were detected in the tubulus. They were represented by degenerative changes of the epithelial cells such as cytoplasmic vacuolization and desquamation of the epithelial cells with collapse of the tubulus. In other research (16), sclerosis of the glomeruli has been described as recognizable under light microscopy and electron microscopic examination. The glomerular changes, degeneration and necrosis of the epithelial cells in both the proximal and distal convoluted segment have been found. The results of our study (Figs 2a, 2b, and 3) have supported the two studies mentioned above.

In conclusion, our findings clearly demonstrate the harmful effects of low-intensity microwave radiation on kidney paranchyma in an exposure-period dependent manner.

References

1. Roberts NJ, Michaelson SM, and Lu ST. The biological effect of radiofrequency radiation: critical review and recommendations, Int. J. Radiol Biol. 50: 379-420, 1986.
2. Williams MV. The cellular basis of renal injury by radiation, Brit. S: Cancer 53 : 257, 1986.
3. Liburdy RP. Radiofrequency radiation alters the immune system: Modulation of T and B lymphocyte levels and cell-mediated immunocompetence by hyperthermic radiation, Radiat. Res. 77: 34-46, 1979.
4. Favino A, Galloth C, Fenconi MT, Tartara A, Grobci A, Delluosmo C, Guıdoleh A and Zennero G. Experimental findings in chronic exposure of rabbits to 10 MHz radiofrequencies, G. Italy Med. lab. 4: 25-29, 1982.
5. Labbate N, De Leo R and Sborgia G. Experimental results in rabbits exposed to 100 MHz Radiofrequencies, G. Italy. Med. lab. 4 : 31-38, 1982.
6. Akdağ M.Z, Çelik M.S, Ketani A, Nergiz Y, Deniz M and Daşdağ S. Effect of chronic low-intensity microwave radiation on sperm count, sperm morphology, and testicular and epididymal tissues of rats, Electro and Magnetobiology. 18:133-145, 1999.
7. Dietzel F. Effect of electro magnetic radiation on implantation and intrauterine development of the rat: Biological effects of nonionizing radiation, Ann. N.Y. Acod Sci. 247: 367-376, 1975.
8. Smialowicz R, Rogers R, Garner M, Kuebk R and Rowe D. Complement receptor positive spleen cells in microwave, 2450 MHz irradiated mice. J. Microwave Power 16:73-77, 1981.
9. Yang HK, Caim CA, Lockwood J and Tompkines WAF. Effects of microwave exposure on the hamster immune system. Naturel killer cell activity. Bioelectromagnetics 4: 123-139, 1983.
10. Durney CH, Iskender MF, Massoudi H, Allen BS, Stewart J, Mitchell BS and John C. Radiofrequency Radiation Dosimetry Handbook 3rd Ed. Report SAM-TR-80-32, USAF School of Aerospace Medicine, Brooks Air Force Base,Texas, 1980: 28-32.
11. Sam F, Stanley R, Alex CS. Gradwoh'l clinical laboratory methods and diagnosis, 1: 1970, 935-960.
12. Marino AA and Becker RO. Biological effects of extremely low frequency electric and magnetic fields, a review. Physiol. Chem. Phys, 9:131-147, 1977.
13. Madrazo AA and Chrug J. Radiation nephritis. Chronic changes following moderate doses of radiation, Lab. invest. 34: 283-290, 1976.
14. Kean WF, Crosson JT, Staley NA, Anderson WR and Stearo FI. Radiation-induced renal diseases. A clinicopathologic study. Am. J. Med. 60: 127-137, 1976.
15. Accini L, De Martino C and Mariutti G. Effects of radiofrequency radiation on rabbit kidney: A morphological and immunological study. Experimental and Molecular Pathology 49: 22-37, 1989.
16. Madrazo AA, Szuki Y and Chubu J. Radiation nephritis II chronic changes after high doses of radiation Am. J. Pathol. 61: 37-56, 1970.