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/cm² radiation (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 immunocompetence, and thymic involution (3). Moreover, in rabbits abnormalities of the lens (4) testis and epididymes (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 referred 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/cm² radiation during 26 and 52 days and all animals were sacrificed under ether anesthesia to detect and compare the renal changes induced directly by irradiation. Mean total body specific absorption 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 1a).

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).](image)
Discussion

The results of the present study indicated that rats exposed to 2.65 mW/cm² 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 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).
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