Ultrastructural effects of ultraviolet C radiation on the stratum basale of mole rats epidermis

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ABSTRACT

The ultrastructure of the epidermis of mole rats (Spalax leucodon) was studied after irradiation with ultraviolet (UV) light (λmax = 254 nm; 0.00147 J cm⁻² s⁻¹; for periods of 52, 112 and 168 h) by using transmission electron microscope (TEM). After irradiation, Vacuolation in cytoplasm and mitochondria, and wrinkled nucleus were found in the stratum basal cells. Also, pathological aggregations of tonofilaments are formed in the desmosomes in these cells. These findings clearly demonstrated the harmful effects of ultraviolet C radiation on the stratum basale. The degree of pathological changes occurred depending on exposure time and radiation dosage applied.

1. Introduction

Ultraviolet (UV) radiation is part of the spectrum of electromagnetic radiation emitted by the sun. It is divided into 3 categories of different wavelength: UVA (400–320 nm), UVB (320–290 nm) and UVC (290–200 nm) and has long been known to cause adverse effects to organisms (Dong et al., 2007; Stolarski, 1988; WHO, 1994).

UVA rays cause light brown tan in a short time; the subsequent darkening is due to melanin, which accumulates in the skin. UVB rays cause a delay but long-term tan mostly results in melanin synthesis in the skin. It causes serious sunburn, associated with intensified erythema and edema, ache, and blister formation in less than one day of exposure. UVC rays, which have sterilization and biocidal properties, are especially harmful for eyes. Usually, they cannot reach the earth surface due to absorption in the ozone layer (Stolarski, 1988; WHO, 1994).

UVC radiation has harmful effects on living beings. Majority of this radiation is filtered by the ozone (O₃) layer. The different reasons, such as the usage of chlorofluorocarbon...
(CFC) gases, the thickness of this layer have been reduced in recent years. It is estimated that skin cancer, cataract and immune deficiency syndrome cases will be increased in near future (Armstrong & Kricker, 2001; De Gruijil, 1999; Mayer, 1992; McKenzie, Bjorn, Bais, & Ilyas, 2003). The radiation will probably affect the epidermis of mammals. All these negative effects justify the studies on the relation between the UV rays and epidermis.

Though, plenty of data has been gathered concerning the effects of radiations on epidermis of some animals (Applegate, Stuart, & Ley, 1985; Gange & Rosen, 1986; Bivik et al., 2006; McMillan et al. 2008), but similar studies done with UVC radiation on the stratum basale of epidermis have not been encountered. For this reason, our purpose was to determine the effects of UVC radiation on mole rats stratum basale by the electron microscope.

Although the living organisms on earth are directly exposed to UV radiation coming from the sun, the underground-dwelling mammal species like mole rats are not under such affects. In this study, mole rats were selected for this study as these animals live in underground galleries and have no UV exposure in their habitat. That’s why, they were exposed to artificially produced UVC radiation in lab and epithelial cells changes were compared to control group.

2. Materials and methods

Thirteen adult mole rats (Spalax leucodon) of both sexes, weighing 180–200 g were used in this study. All rats were caught within the rural areas of Ankara, Çankırı and Kırıkkale in Turkey. They were kept at the laboratory for 10 days at a stable temperature (20 ± 2 °C) in order to obtain adaptation of the new environment. The rats were housed individually in special cages called terrarium and a constant UVC dosage was applied. All animals were fed with carrot, potato, plant roots and no special diet was given.

A “Mazda TG” ultraviolet lamp in 30 W powers and in 90 cm length was placed to the upper cover of the terrarium. The intensity of the UV emitted from the lamp was measured to be 254 nm in wavelength and the energy in one second was found to be 0.0014 J/cm². Sunlight period was taken into account and rats exposed to artificial UVC radiation for 8 h daily (between 08.00 and 17.00 h). A feeding interval was given at midday for 1 h. A timer was used to standardize UV exposure times. Animals were divided in to four groups. Group I was separated as a control. Group II was exposed for 52 h (7 days), Group III was exposed 112 h (14 days) and Group IV was exposed for 168 h (21 days) of UVC radiation. Experiment groups, exposure times and total dosage were enlisted in Table 1.

At the end of radiation periods of 52, 112 and 168 h, the animals were sacrificed under ether anesthesia to detect and compare the dermal changes induced directly by irradiation. At sacrifice, dermal tissues were rapidly removed and bisected.

For electron microscopy, tissues of 1 mm³ were fixed in glutaraldehyde (3%) and phosphate buffered saline (pH 7.2) at 4 °C for 3 h, and post-fixed with 1% osmium tetroxide for 1 h. Osmium tetroxide was washed away with the same buffered. Ethyl alcohol was used for dehydration and specimens were embedded in Araldite CY-212. Thin sections were double stained with saturated uranyl acetate (20 min) and lead citrate (10 min). Jeol JEM 100 CX-II electron microscope was used for the examination of the specimens.

All experiments were carried out in accordance with the Ankara University guidelines for the care of experimental animals. Also, guiding principles for experimental procedures found in Declaration of Helsinki of the World Medical Association regarding animal experimentation were followed in the study.

3. Results

3.1. Ultrastructural results of the control group

The epidermis of mole rats were distinguished as four layers starting from dermis as follows: Stratum basale, stratum spinosum, stratum granulosum and stratum corneum (Fig. 1).

3.2. Effects of UV radiation on the stratum basale of dermis for 52, 112 and 168 h

After an exposure of 52 h, the lipid droplets in the cytoplasm of basal cells increased, vacuole formation started in mitochondria and there became a large increase in the volume of nucleolus (Fig. 2). Desmosomes lost their typical appearance

![Fig. 1 – General appearance of the epidermis of mole rats. SC: Stratum corneum; SG: Stratum granulosum; SS: Stratum spinosum; SB, Stratum basale; D: Dermis. X3.900.](image-url)
and tonofilaments in the structure of desmosome became a round mass with granules (Fig. 3).

After 112 h radiation exposure, these changes increased a lot in basal cells. Intercellular gaps were occurred between the basal cells and increased. Vacuolation increased in the cells, the basal lamina was destroyed and pseudopodes were occurred in the intercellular gaps (Fig. 4).

At the end of 168 h of irradiation, vacuolization increased in the basal cell cells. Deformation in the nucleus was happened. There were not any changes in mitochondria and dermis. Vacuolation in the cytoplasm and mitochondria were increased, some vacuoles became larger and reached the nuclear membrane. Also big vacuoles were occurred in the spinous cells. Also, there was seen a deformation in the dermis layer (Fig. 5).

4. Discussion and conclusion

In this study, it was aimed to investigate the effects of UVC radiation on mole rats epidermis. Even though the harmful effects of UVC radiation, which is one of the main components of the radiation from the sun, is more than UVA and UVB radiation, the environmental effects of this kind of radiation have been studied less. These studies are especially dealt with the effects of radiation on the skin and blood values of living organisms (Broucek & Kovalcik, 1989; Gange & Rosen, 1986; Lundgren, Cavalcanti, & Sampaio, 2008; Verma et al., 2011).

The harmful effects of UV radiation on living organisms occur indirectly. Free radicals are released as a result of radiolysis of water molecules when they are exposed to radiation.
and these radicals lead to changes in the structures and functions of various molecules by interacting with them (Jagetia & Reddy, 2005; McMillan et al., 2008). The deformation in the cells could depend on the dosage and the period exposure of the radiation applied (Denham, Hauer-Jensen, & Peters, 2001; Mansoub & Sarvestani, 2011; Weiss et al., 1990).

After the irradiation of mole rats for 52, 112 and 168 h, there became considerable fine structural changes in the stratum basale of mole rats. These appeared as transparency in cytoplasm, formation of some vacuoles in different sizes, increase in the vacuoles in the cytoplasm, distortion and vacuolization in the mitochondria, dilatation in GER and distortion in nucleus double of membrane.

After the irradiation of 52, 112 and 168 h, the major changes occurred in the stratum basale of mole rats, generally appeared in cytoplasm, mitochondria and nucleus. Although the effects of UV have been studied on the epidermis of human, mice and guinea pig up to now (Brody, 1959; Epstein, Fukuyama, & Epstein, 1971; Johnston, Oikarinen, Lowe, Clark, & Uitto, 1984; McMillan et al., 2008), some further different changes in the epidermis have been seen. The typical appearances of desmosomes have disappeared in the basale and spinous cells of the epidermis of mole rats (Hibbs & Clark, 1959; Schwartz, LeRoux, Schaller, & Neurand, 1979). Since these changes caused both intercellular relationships and tonofilaments concentration in the cytoplasm, they might affect the inner cellular skeleton. The lipid droplets in the basal cells have increased and vacuolation were seen in the mitochondria. The nucleolus volume in the basal cells increased significantly. It is obvious that these changes occurring in the nucleus and mitochondria will affect the cell structure and functions.

The increase in the rate of keratohyalin and the vacuoles formed in the cytoplasm by the effect of the UV radiation are among the remarkable changes. The fact that the keratohyalin granules in the granular cells are condensed in the part where UV comes from shows that these cells help to protect the cells beneath them (Garmyn, Yaar, Boileau, Backendorf, & Gilchrest, 1992; Moysan, Clement-Lacroix, Dubertret, & Morliere, 1990).

These changes in the stratum basale by the effect of the UV radiation are similar to the pathologic findings of Nix, Nordquist, Scott, and Everett (1964) and the studies on human and guinea pig epidermis (Raknerud, Hovig, & Iversen, 1971). The changes occurring here by the effect of the UV are an expected results.

As a result, these findings clearly demonstrated the harmful effects of ultraviolet C radiation on the stratum basale. The pathological changes occurred depending on exposure time and radiation dosage applied.

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Conflict of interest

None.
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