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The Effect of Ionizing Radiation on Health Professionals Working in The Radiology Department

Adem KESKİN[1*], Recai ACİ[2], Murat ARI[3]
[1] Department of Biochemistry (Medicine), Institute of Health Sciences, Aydın Adnan Menderes University/Aydın, Turkey, ademkeskin78@gmail.com (https://orcid.org/0000-0003-1921-2583)
[2] Department of Medical Biochemistry, Samsun Training and Research Hospital, Health Science University/Samsun, Turkey, recaiaci35@gmail.com (https://orcid.org/0000-0002-1517-3356)
[3] Söke Vocational School of Health Services, Aydın Adnan Menderes University/Aydın, Turkey, muratari60@gmail.com (https://orcid.org/0000-0002-1504-7050)

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*Corresponding author

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Abstract

This study was designed on the effects of radiation on healthcare professionals working in environments with radiation in the healthcare field. Healthcare workers working in radiation areas are exposed to low doses of radiation. The organ most affected by this exposure is the thyroid. There is an important correlation between thyroid stimulating hormone levels and exposure to radiation for 5 years. People exposed to radiation may develop DNA damage and the DNA repair system may be affected. It can be said that health workers working in the fields of radiation are at risk for some types of cancer depending on the dose they are exposed to. Interventional radiology and nuclear medicine workers are most affected by these harmful effects. In order to be protected from these health problems or to experience less health problems, health workers working in the fields of radiation should apply all kinds of protection methods. These prevention methods should be evaluated both individually and in terms of the patient. In addition, other health professionals should make use of the radiation environment, which is an indispensable element in health, as little as possible. Exposure to radiation during diagnosis or treatment can cause delays in the healing process.

Keywords: Ionizing radiation, radiation workers, DNA, cancer, and thyroid

1. Introduction

The energy that can remove electrons from atoms and thus cause ionization is defined as ionizing radiation. X-rays based on photons, electron beam technology based on electrons and Ɣ radiation technology based on photons are the three major ionizing radiation technologies (Pillai & Shayanfar, 2017). Electromagnetic radiation consisting of photons emitted from the nucleus of a radioactive isotope is gamma rays. While cobalt-60 is the isotope source in most environments, Ɣ-rays are also produced from cesium (Cs)-137 in some cases. It is electron beam technology based on high energy electrons produced from normal electricity. Electromagnetic radiation consisting of photons is x-rays. The generation of X-ray photons is produced using energetic electrons from accelerators that are allowed to strike an extremely dense metal such as tantalum (Ta) or tungsten (W) (Pillai & Shayanfar, 2017).

Depending on the dose, ionizing radiation causes oxidative damage to proteins, DNA and lipids, and various damage to tissues and normal cells (Azzam et al., 2012). Ionizing radiation affects living organisms by indirect and direct methods. The direct effect is the damages that occur as a consequence of interactions among energetic electrons or photons and molecules within an organism, while the indirect effect is the damages that occur as a consequence of interactions with water radiolysis products (Miller, 2006). The direct effect, such as the DNA ionization, results in the phosphodiester bonds cleavage along the backbone of DNA. While single stranded breaks are usually repairable, large double stranded breaks are extremely difficult for an organism to repair and overcome. (Tahergorabi et al., 2012). Indirect action such as radiolysis of cellular water content produces a wide variety of highly reactive however short lived free radical species such as hydrogen peroxide, hydrated protons and electrons, and hydroxyl radicals. Although hydroxyl radicals are extremely short lived, they can give rise to important damage to molecules in their immediate surroundings. (Mavragani, et al., 2019). In addition, superoxide radicals produced by the radiolysis of water accumulate in the cell and cause serious damage to proteins such as enzymes with iron sulfur clusters. (Popović-Bijelić et al., 2016). In addition, cysteine and methionine have been found to be particularly sensitive to ionizing radiation (Reisz et al., 2014).

This study was designed on the effect of ionizing radiation on health professionals working in the radiology department. Studies in this field were selected from scientific databases such as Institute for Scientific Information-Web of Science, Scopus, Science Direct, PubMed and Google Scholar. Keywords used to find related studies were ionizing radiation, radiation workers, DNA, cancer, and thyroid.

2. Monitoring of individual radiation dose

Dosimetric monitoring should be performed in medical radiation environments to limit exposure to ionizing radiation and reduce subsequent health risks. The annual average effective doses in all units of medical radiation environments range from 0.44 to 8.20 mSv. In diagnostic radiology, annual dosimeter intervals were found to be between 0.07 and 4.37 mSv. The mean annual dosimeter intervals for radiotherapy and nuclear medicine, which are other medical radiation environments, were found to be between 6.30 and 0.56 mSv. Data for research/teaching and industrial radiation environments range from 0.38 to 19.40 mSv (Gbetchedji et al., 2020).

In a study of Chinese radiation workpeople exposed to low-dose radiation, the average of the annual cumulative dose was found to be highest in interventional radiation workpeople. The rate of detection of lens opacity in these workers was found to be 37%. The chromosomal abnormality rate was found to be highest in radiology workpeople with over 20 years of service. The annual cumulative dose of these healthcare workers is 2.04 mSv, and the 3-month follow-up dose is up to 1.62 mSv. Chromosomes with two centromeres have also been identified. Manual packaging and drug delivery I-131 has been detected in the thyroids of nuclear medicine personnel. Thyroid I-131 detection rate was higher in the hand-packaged and administered group than in the auto-administered group. (Liu et al., 2022)

In a study evaluating 7-year individual doses of 1156 radiation workers, comparisons were made according to medical radiation environments (diagnostic radiology, radiotherapy, nuclear medicine, interventional radiology). It was stated that the individual dose levels of radiation workers in most hospitals were low, and it was significant to focus on interventional radiology workpeople and nuclear medicine workpeople (Zhu et al., 2018).

3. Tissue and organ damage

4308 radiation workers were included in a study examining the thyroid functions and impact factors of radiation health workers. In the related study, abnormal thyroid gland was detected in 14.3% of radiation healthcare workers. In addition, abnormal thyroid nodule, which is the main symptom of thyroid gland abnormality, was detected in 5.1% of radiation health care workers and abnormal thyroid stimulating hormone (TSH) level in 7.1% of radiation health care workers. Abnormal thyroid nodules, T3 and TSH rates were found to be higher in female radiation healthcare professionals than in male radiation healthcare professionals. In addition, it was stated that the abnormal thyroid nodules rate, T4 and T3 levels increased as the age of the working increased. It has been concluded that ionizing radiation can give rise to thyroid damage in radiation healthcare workpeople. Therefore, more attention should be paid to radiation protection management to protect the healthcare of radiation workpeople (Yang et al., 2022). In another study examining the thyroid functions of healthcare workers exposed to ionizing radiation, serum TSH levels were found to be elevated in 7.1% of healthcare workers without free T4 or free T3 changes. An important correlation was found between the dosimetric values and TSH levels of the healthcare workers in the previous year and the duration of exposure to radiation in the last 5 years. It has also been reported that there is a greater risk of developing subclinical hypothyroidism depending on radiation doses (Luna-Sánchez et al., 2019). On the other hand, a study evaluating 20 years of data found that incidence rates of thyroid cancer among healthcare radiation workpeople were slightly higher than in the general citizens. However, there was no important evidence that this increase was related with vocational radiation dose (Lee et al., 2019). Additionally, in the study conducted with radiology technicians, no changes were detected in radiation exposure and blood count parameters (Machi et al., 2022).

A study on radiation in gastroenterology states that radiation is used daily in therapeutic interventional procedures and different gastrointestinal diagnostic and imaging, and that radiotherapy is one of the basic therapy methods in the treatment of gastrointestinal malignancies. On the other hand, it is stated that radiation can give rise to organ dysfunction, fibrosis, malignancy and inflammation. The risk of malignancy has been stated to be slightly higher in patients who are repeatedly exposed to radiation for diagnostic imaging and treatment procedures. In addition, it was stated that healthcare workers who perform fluoroscopy have a high risk of malignancy and cataract formation (Ahmed & Ahmed, 2022). In the study of Şafak et al., it is stated that exposure to ionizing radiation together with radiotherapy affects many organs in the neck and head and may give rise to early and late side effects (Şafak et al., 2022). A recent study reported that radiation treatment is an effective cancer therapy, but it is common for it to damage healthy tissue. Additionally, it has been reported that different dose dependent and tissue specific endothelial and epithelial responses to radiation occur in many organs of breast cancer patients receiving radiation therapy (McNamara.et al., 2023).

4. DNA damage

Chronic exposure to low dose ionizing radiation in radiation healthcare settings has been shown to induce a DNA damage response in exposed individuals and may be mutagenic in healthcare workpeople with a family history of cancer (Gaetani et al., 2018). DNA methylation levels can be affected by the duration of occupational low dose radiation exposure. Radiation effects on DNA methylation changes can be associated with chromosomal aberrations (Lee et al., 2015). On the other hand, in a study conducted with radiology technicians, it was stated that the ionizing radiation used by radiology workpeople for imaging purposes could damage DNA enough to activate the MutS repair system. The expression trend of this system is higher in radiology technicians exposed to ionizing radiation for longer periods of time (Machi et al., 2022). Total RNA measured in healthcare workpeople exposed to ionizing radiation has the potential to predict the risk of exposure to ionizing radiation. In addition, the total time of working in the field of tomography importantly changes the free nucleic acids level (Kılınç et al., 2022).

A study on DNA damage clustering and chromatin breaks after ionizing radiation reported that there is increasing evidence that charged particle radiation therapy using low and high linear energy transfer ionizing radiation causes clustered DNA double-strand breaks (Mladenova et al., 2022). In the study of Zhou et al., it was stated that DNA damage caused by ionizing radiation plays a significant role in the development and pathogenesis of radiation-induced liver disease, also known as radiation hepatitis (Zhou et al., 2023). In the study of Zhang et al., it was stated that radiation induced DNA damage is a significant process that changes cell mechanics. Moreover, this relationship has been experimentally confirmed by inhibiting the process of radiation-induced DNA damage. It has also been shown that radiation reduces H3K9me3 staining intensity but has no impact on F-actin (Zhang et al., 2022). In a study conducted with people exposed to radiation due to cardiac catheterization, it was reported that DNA damage increased in the patients' peripheral mononuclear cells, but this increase was not seen in healthcare personnel who performed cardiac catheterization. It has also been reported that inflammatory cytokine mRNA expressions are increased in both healthcare workers and patients, possibly through NF-kB activation (Jin et al., 2022).

5. Cancer

Among radiation health care workers, those working in interventional radiology departments have the highest lifetime risk for all cancers up to retirement age. Thyroid cancer has the highest lifetime risk of all cancers in terms of organ region in those exposed to occupational radiation (Lee et al., 2021). Research on survivors of the Japanese atomic bomb reveals that the radiation-induced lung cancer risk is about three times higher in female than in male. In light of this information, a study of one million people found little evidence that fragmented or chronic radiation exposure increases the lung cancer risk. There was also no difference in lung cancer risk between women and men (Boice et al., 2022). Healthcare workers make up the largest group of workpeople who are vocational exposed to low-dose ionizing radiation worldwide. Occupations that are more exposed, such as nuclear medicine workers and interventional radiology workers, should be carefully monitored for cancer risk (Chartier et al., 2020).

In a study of 36,394 diagnostic radiation workpeople, the risks of brain cancer and thyroid cancer were significant in female workers. The risk of colon and rectal cancer in men workpeople showed a significant upward trend compared to the average annual radiation dose increase. The relative risk of leukaemia in men workpeople and the risk of brain cancer in women workpeople was importantly higher in the group exposed to more than 5 mSv per year compared to those exposed to less than 5 mSv per year (Choi et al., 2013). Occupational radiation exposure has been found to be related with a importantly increased risk of cancer compared to the control group, particularly in esophageal cancer and breast cancer (Wang et al., 2015).

Epidemiological studies of healthcare ionizing radiation workpeople reported extreme cases of skin cancer, leukemia and women breast cancers before 1950. On the other hand, there is little consistent evidence of an increased risk of cancer later on. Recent research shows that vocational doses at which healthcare workpeople are exposed to ionizing radiation decrease over time. There is an urgent need to expand the limited knowledge of the mean annual, time trend, and organ doses of vocational radiation exposure and to assess the lifetime cancer risks of ionizing radiation for healthcare professionals. More information on occupational doses should be gathered for technologists and physicians performing interventional procedures and long term follow up studies of cancer and other serious disease risks should be initiated. Such studies will help optimize standardized protocols for radiological procedures, determine whether current radiation protection measures are adequate for healthcare radiation workpeople, provide guidance on cancer screening needs, and provide valuable information about the cancer risks related with chronic radiation exposure (Linet et al., 2010).

6. Conclusion

Radiation used in both diagnosis and treatment in the field of health is an indispensable element. Health workers working in these radiation areas are exposed to low doses of radiation. Exposure to radiation can cause various health problems in healthcare workers who experience this exposure. In order to avoid these health problems or to experience fewer health problems, health workers working in these units should apply all kinds of protection methods. These prevention methods should be evaluated both individually and in terms of the patient. In addition, other health professionals should make use of the radiation environment, which is an indispensable element in health, as little as possible. Exposure to radiation during diagnosis or treatment may cause delays in the healing process.

CONFLICT OF INTEREST

There is no conflict of interest between the authors. In addition, no support or funding was received in this study.

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