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IONIZING RADIATIONS AND CANCERS

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ABSTRACT

Ionizing radiations are types of energies that have sufficient force to remove electrons from atoms, creating ions in the process. They include all electromagnetic waves from ultraviolet light to x-rays and gamma rays as well as alpha to beta particles. Ionizing radiations results in harmful effects on living organisms such as damage of cell structures and DNA due to their ability to ionize atoms and molecules. This paper seeks to review the effects of these radiations and how to be protected in real time. Exposure to high levels of ionizing radiations cause immediate symptoms, such as burns, nausea, and vomiting, also it can lead to serious health problems, including cancer, genetic mutations and death. Long-term exposure to lower levels of ionizing radiation can increase the risks of cancer and other diseases. Cancers have become a scourge in today's world, with breast cancer, leukemia, cervical and prostate cancers being the most notable types. The development of cancer is a complex multistage process that usually takes many years. The contributions of ionizing radiations to its development cannot be overemphasized. However, ionizing radiation is also used for beneficial purposes, such as medical imaging, radiation therapy, and for energy production. The key is to use it safely and responsibly so as to reduce its debilitating effects.

Keywords: *Cancers, Debilitating Effects, DNA, Ionizing Radiation*

INTRODUCTION

Ionizing radiation is a type of energy which has enough force and momentum to remove (ionize) electrons from atoms and molecules of materials such as water, and tissues, creating ions in the process. They include all electromagnetic waves from ultraviolet light, x-rays and gamma rays, as well as alpha, beta particles; reason being that the localized interaction of light with matter is by photons which energy is equal to its frequency. Photons in the part of the electromagnetic spectrum with frequencies lower than ultraviolet lack the necessary energy to break the bonds in typical organic molecules.

Subatomic particles with high kinetic energy can ionize atoms within organic tissue, potentially leading to harmful effects. On the positive side, mild radiation results in genetic mutation, necessary for evolution, and strong radiation can be used in therapy to purposely kill aberrant cells (Parke, 2020). These radiations are formed by disintegration of unstable nuclei which could be naturally occurring or man-made and have been used for different beneficial effects (Gupta, 2020). They can come from a variety of sources, including the sun, radioactive materials, and medical imaging devices (Zamanian and Hardiman 2005). It can cause damages to living cells and tissues, leading to a range of health effects from skin burns to cancer (Donya *et al*., 2014; Irunkwor *et al*., 2022).

Ionizing radiation delivers enough electromagnetic energy to ionize atoms and molecules within tissues, meaning it removes electrons and alters the course of chemical reactions in the body (completely or partially converting molecules into charged ions). X-rays and gamma rays, both types of ionizing radiation, can damage living tissue. To protect ourselves, lead vests are worn during X-ray procedures, and similar shielding is used extensively around nuclear power plants. Background radiation, consisting of low-level ionizing radiation, continuously surrounds us from natural sources. This type of radiation is referred to as natural background radiation, and its main sources are: visible light, ultraviolet light and infrared light (sunlight), radioactive materials on the earth's surface (contained in coal and granite), radioactive gases leaking from the earth (radon), cosmic rays from outer space entering the earth's atmosphere through the ionosphere (Posudin, 2014).

Effects of Ionizing Radiations on Man and the Environment

Genetic Mutations:

Biological effects of radiations can result in damage of deoxyribonucleic acid DNA which can result in cancers, birth defects and even death.

Cell Destruction:

Radiation results in the alteration of cells in living organisms, which lead cell to irreversible damage of various organs in the body and even death.

Acute Radiation Syndrome (ARS) and Cutaneous Radiation Injuries:

They occur when radiation exposure can result in nausea, vomiting, headache, diarrhoea, burns, skin lesions, sores and skin cancer (Zamanian and Hardiman 2005).

Soil Infertility:

Soil exposed to radiation can be severely damaged by alteration of its physical and chemical properties thereby destroying its nutrients and ability to support plants (Zangina and Ali, 2021). Soil poisoned with toxins causes crops to absorb radiation, rendering them unsafe for consumption.

Effect on Animals:

Herbivorous animals within the affected area can consume radiation-laden crops and result in accumulated radiation. Predatory animals like lions eat these herbivores, leading to increased levels of radiations (bioaccumulation).

Effects on Plants:

Exposure to ionizing radiation can disrupt plant cell structure and inhibit plant growth. This leads to mutations such as altered shapes, sizes and health of the affected plants. When humans eat these plants, ingestion of radiation occurs.

Effect on Aquatic Organisms:

The release of radioisotopes such as cesium, radon, krypton and zinc from power plants into waterways accumulates within fishes and other aquatic organisms. Although these wastes are released in permissible amounts, this does not indicate safety. For these reasons, minimizing the release of ionizing radiation into the environment and closely monitoring its effects on ecosystems and living things is crucial.

Contributors to the Risk of Cancers

Natural Background Radiation

Notable among this category is radon gas. The gas which often results from natural sources accounts for most of the average person's exposure to ionizing radiation globally. Radon gas is frequently the main culprit behind an individual's background radiation exposure, and its levels vary significantly depending on location. Confined spaces in buildings, particularly attics and basements, tend to accumulate higher concentrations of radon. It can also be found in some spring waters and hot springs (NCRP, 2009). Exposure to high concentrations of radon gas, as shown by epidemiological studies, is a significant risk factor for lung cancer. Radon is considered a significant indoor air contaminant in areas where it is present in high concentration (Jones, 1999).

Medical Imaging

In industrialized countries, medical imaging contributes almost as much radiation dose to the public as natural background radiation especially with the growing use of 3D scans that impart much more dose per procedure than traditional radiographs (NCRP, 2009). It has been estimated that computerized tomography (CT) scans performed in the US in 2007 alone would result in 29,000 new cancer cases in the future years (Berrington *et al*., 2009; Roxanne, 2009).

Sources of risks of ionizing radiations in medical imaging include:

X rays

Imaging techniques using radiation, including CT scans, Positron Emission Tomography (PET) scans, fluoroscopy, and other nuclear medicine procedures

Occupational Exposures

Majority of workers are exposed to risk of ionizing radiations in their work places. Most nuclear plant workers, in accordance with the International Commission on Radiological Protection (ICRP) are permitted to receive up to 20 times more radiation dose than is permitted for the general public (ICRP, 2007). Accidental overexposures beyond the regulatory limits happen globally several times a year (Turai *et al.,* 2001). While nuclear accidents can devastate their immediate environment, their overall contribution to global cancer rates pales in comparison to natural background radiation and medical exposures. The Chernobyl disaster, arguably the most serious nuclear accident in history, serves as a stark reminder of this. In addition to conventional fatalities and acute radiation syndrome fatalities, nine children died of thyroid cancer, and it is estimated that there may be up to 4,000 cancer deaths among the approximately 600,000 most highly exposed people (WHO, 2006; IAEA, 2008).

Astronauts face an elevated risk of cancer during extended missions due to cosmic radiation exposure beyond Earth's protective atmosphere. Similarly, airline crews are exposed to higher levels of this radiation while flying at high altitudes. Meanwhile, miners, particularly those in uranium mines, encounter occupational hazards from radon gas. Workers in a granite building, such as the US Capitol, are likely to receive a dose from natural uranium in the granite (Ahmad *et al.,* 2021).

Ionizing Radiations and Cancers

Ionizing radiation (IR) refers specifically to types with enough energy to directly remove electrons from atoms or molecules in materials, creating a phenomenon called ionization. Ionizing radiation can take two shapes: high-energy electromagnetic waves (like X-rays or gamma rays) or speedy subatomic particles (like neutrons or alpha particle. In the world of electromagnetic radiation (light waves), shorter wavelengths have higher energy. This high energy allows ionizing radiation, unlike its non-ionizing counterpart, to directly remove electrons from atoms and molecules. Thus, IR is more likely to produce a biological effect. Ultraviolet (UV) light sits on a bit of a fence. It has a middle-ground wavelength and energy compared to other types of radiation. Normally, it doesn't knock electrons off atoms like ionizing radiation does. But, UV light can still be harmful because it can damage DNA, potentially causing mutations and even cancer Although, perhaps, recognized later than its chemical counterparts, ionizing radiation is now regarded as a carcinogen and can act independently or synergistically with other carcinogens to produce neoplasia in living systems due to its unique mechanisms of mutation and biological effects (Valente *et al.,* 2022). Being exposed to ionizing radiation is a known risk factor for developing cancer later in life, especially leukemia. Scientists understand how this happens, but creating precise models to predict the exact level of risk is still a debated topic. The most widely accepted model posits that the incidence of cancers due to ionizing radiations increases linearly with effective radiation dose at the rate of 5.5% per Sievert (ICRP, 2007).

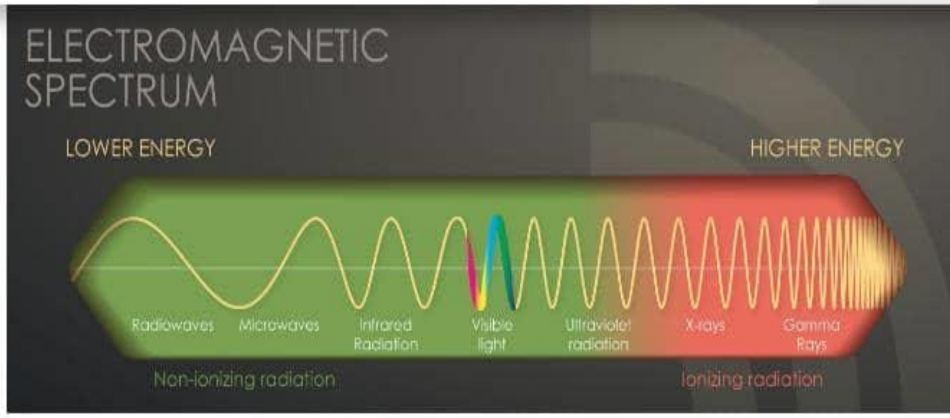

Figure 1: The Electromagnetic Radiation (EMR) Source: Valente *et al*., 2022

Surprisingly, the biggest threat of radiation exposure for most people comes from natural sources in the environment, not from medical procedures. Medical imaging comes in a close second. It's also important to note that the vast majority of non-invasive skin cancers, like basal cell carcinoma, are caused by ultraviolet (UV) radiation, which exists on the borderline between ionizing and non- ionizing radiation. Non-ionizing radio frequency radiation from mobile phones, electric power transmission, and other similar sources have been investigated as possible carcinogens by the WHO's International Agency for Research on Cancer, but to date, no evidence of this has been observed (IARC, 2008). Scientists generally believe that any level of radiation exposure can potentially increase cancer risk. The main culprits include the natural radiation, medical imaging procedures, workplace hazards, and accidents involving nuclear materials.

Ionizing radiations can pass through the human body and its energy gets absorbed by human tissue. This has the potential to cause harmful effects to people, especially at high levels of exposure (CDC, 2021). When ionizing radiation hits our cells, it can directly damage important molecules or indirectly strike water molecules. These 'hit' water molecules turn into unstable, reactive chemicals called radicals. In a flash, these radicals lash out at nearby molecules, breaking their bonds or basically rusting them. This breakage can occur either on a single strand or on the double strand of the DNA. Breakages on single strands are easy to repair owing to the complementary nature of the DNA molecule. This is not so with damages on the double strand, repair is often more taxing and errors can occur during rejoining of broken strands. These errors can induce mutations, cell aberrations, or cell death.

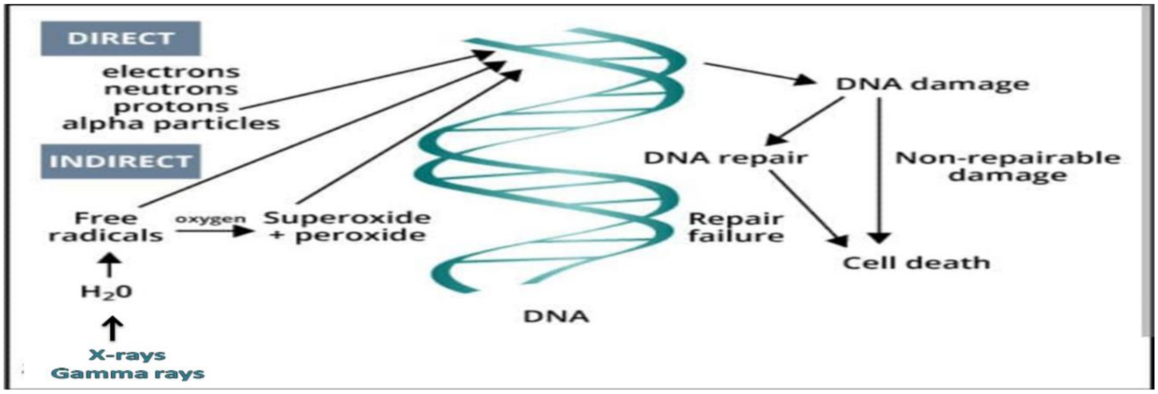

Figure 2: Mechanism of Cancer Development via Ionizing Radiations Source: Valente *et al*., 2022

Mechanism of Cancer Development due to Ionizing Radiations

Cancer is a stochastic effect of radiation, meaning it is an unpredictable event. The probability of occurrence increases with effective radiation dose, but the severity of the cancer is independent of dose. The rate at which cancer advances, the prognosis, the degree of pain, and every other feature of the disease are not functions of the radiation dose to which the person is exposed. This contrasts with the deterministic effects of acute radiation syndrome which increase in severity with dose above a threshold. Cancer starts when a single cell operation is disrupted. Normal cell operation is controlled by the chemical structure of DNA molecules, also called chromosomes (Vyjayanti and Kalluri, 2006).

When radiation deposits enough energy in organic tissue to cause ionization, this tends to break molecular bonds, and thus alter the molecular structure of the irradiated molecules. Less energetic radiation, such as visible light, only causes excitation, not ionization, which is usually dissipated as heat with relatively little chemical damage. Ultraviolet light is usually categorized as non-ionizing, but it is actually in an intermediate range that produces some ionization and chemical damage. Hence the carcinogenic mechanism of ultraviolet radiation is similar to that of ionizing radiation (Valente *et al*., 2022).

Unlike chemical or physical triggers for cancer, penetrating radiation hits molecules within cells randomly. Molecules broken by radiation can become highly reactive free radicals that cause further chemical damage. Some of this direct and indirect damage will eventually impact chromosomes and epigenetic factors that control the expression of genes. Cellular mechanisms will repair some of this damage, but some repairs will be incorrect and some chromosome abnormalities will turn out to be irreversible.

Deoxyribonucleic acid double-strand breaks (DSBs) are generally accepted to be the most biologically significant lesion by which ionizing radiation causes cancer (Little, 2000). In vitro experiments show that ionizing radiation cause double-strand breaks (DSBs) at a rate of 35 DSBs per cell per Gray and removes a portion of the epigenetic markers of the DNA, (Valente *et al*., 2022) which regulate the gene expression. Most of the induced DSBs are repaired within 24h after exposure, however, 25% of the repaired strands are repaired incorrectly and about 20% of fibroblast cells that were exposed to 200mGy died within 4 days after exposure

(Katre, 2016; Mavragani, 2019). A portion of the population possess a flawed DNA repair mechanism, and thus suffer a greater insult due to exposure to radiation (Vyjayanti and Kalluri, 2006).

Severe damage from radiation usually kills the cell or prevents it from reproducing. This is what causes acute radiation sickness. However, these heavily damaged cells are unlikely to become cancerous. Lighter damage may leave a stable, partly functional cell that may be capable of proliferating and eventually developing into cancer, especially if tumor suppressor genes are damaged (Little, 2000; Cleaver and Mitchell, 2000; Gawkrodger, 2004; William and Timothy 2006). New research suggests that radiation's harm isn't always immediate. Even if cells survive the initial hit, their DNA seems to become less stable, making them more likely to develop mutations in future divisions. These mutations can take years to build up, eventually transforming healthy cells into tumors through neoplastic transformation. The neoplastic transformation can be divided into three major independent stages: morphological changes to the cell, acquisition of cellular immortality (losing normal, life-limiting cell regulatory processes), and adaptations that favor formation of a tumor (Little, 2000)

In some cases, a small radiation dose reduces the impact of a subsequent, larger radiation dose. This has been termed an 'adaptive response' and is related to hypothetical mechanisms of hormesis (Freedberg *et al.*, 2003).

It can take many years, even decades, for cancers caused by radiation exposure to show up. These cancers look exactly like cancers that happen naturally or from other causes, making it difficult to pinpoint the exact reason. It can take many years, even decades, for cancers caused by radiation exposure to show up. These cancers look exactly like cancers that happen naturally or from other causes, making it difficult to pinpoint the exact reason. Furthermore, studies by the National Cancer Institute show that exposure to chemicals, physical hazards, and lifestyle choices like smoking, drinking alcohol, and unhealthy eating also play a big role in causing many of these cancers. Evidence from uranium miners suggests that smoking may have a multiplicative, rather than additive, interaction with radiation (Little, 2000). Evaluations of radiation's contribution to cancer incidence can only be done through scientists conducting large-scale studies that track people's health over time and consider all the other things that might influence cancer risk, like smoking or diet.

Ways to Protect Ourselves from Ionizing Radiations

- Minimize exposure time: Limit your duration near sources of ionizing radiation (Donya *et al.*, 2014);
- Distance: Whenever possible, move further away from the source of radiation;
- Employ shielding: Utilize materials like concrete or lead to create a barrier that blocks or absorbs radiation;
- Personal Protective Equipment: Wear appropriate protective clothing such as gloves and a respirator, to minimize exposure to radioactive particles (Manahan, 2010);
- Monitoring: Using radiation detection devices, such as dosimeter, or Geiger counters, to monitor radiation levels and avoid high-risk areas (Rinkesh, 2022);
- It is important to note that the best way to be protected from ionizing radiation exposure is through proper safety and radiation protection practices, and adhering to all the safety guidelines and regulations.
- Opt for non-radiation imaging techniques: Choose options like Magnetic Resonance Imaging (MRI) and ultrasound imaging which utilize alternative methods to visualize the body, avoiding the use of radiation.

CONCLUSION

Ionizing radiation is a known carcinogen and can cause cancer in humans. Cancer is a probabilistic effect of radiation, meaning the risk of developing it increases with exposure, but the occurrence itself remains uncertain. Ionizing radiation can damage DNA, leading to mutations and chromosomal abnormalities. These mutations and chromosomal abnormalities can lead to cancer if they are not repaired correctly. The risk of developing cancer from radiation exposure increases with the dose and the severity of the cancer is independent of dose. The latent period between radiation exposure and the development of cancer can be decades. The type of cancer that develops from radiation exposure depends on the type of radiation and the tissue that is exposed. Some people are more susceptible to radiation-induced cancer than others. This is due to factors such as age, genetics, and lifestyle. There is no safe level of radiation exposure. However, the risk of developing cancer from low-dose radiation exposure is very small. Radiation therapy is used to treat cancer, but it can also cause cancer. The risk of developing cancer from radiation therapy depends on the dose and the type of radiation used. There are a number of ways for protection from the harmful effects of ionizing radiation, such as avoiding exposure to unnecessary radiation, wearing protective clothing, and using lead shielding. On exposure to high levels of ionizing radiation, it is important to seek medical attention immediately.

COMPETING INTERESTS

The authors declare that they have no competing interests

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