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Radiation Risk in Nuclear Medicine – A Short Review

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ABSTRACT

The purpose of this review was to provide all information, risks and perspectives about nuclear medicine. This paper also concluded the investigational researches that both support and those that do not support the theory and the safety guidelines and practice about nuclear medicine. There are a lot of misconceptions about nuclear medicine eventhough nuclear medicine gave a lot of benefits in the medical world. However, it also have a lot of risks and dangers that will occur to the patient if they do not follow the procedures and safety guidelines. This is important because it will trigger our thoughts to know more about nuclear medicine. Also in this review paper, historical and current perspectives of nuclear medicine was also discussed. The review provides the reader with a better understanding of radiation hormesis. An understanding of the complexities and historical development of the theory will then give readers a better understanding of radiation safety and regulations.

1. Introduction

In nuclear medicine, radionuclides are used in a variety of therapeutic and diagnostic procedures. Radiation dose that was received by different organs in body need acknowledge because it was very essential when it was need to evaluate the risk and benefits of any procedure. In 2011, a huge nuclear disaster happened at the Fukushima Daiichi nuclear powerplant. From this incident, radiation safety has become an important issue in nuclear medicine. There are many structured safety guidelines or recommendations of various international campaigns and academic societies demonstrate about important issues of radiation safety in nuclear medicine procedures [1].

Ionizing radiation is widely used to treat cancer cells because it generates ions in the cells of the tissues it passes through. Ions are formed by removing electrons from atoms and molecules. As a result, it can either destroy the genes or stop their expansion. Ionizing radiation has an effect on the entire world, but the molecular processes driving tissue damage show that ionizing radiation also chemo-selectively modifies a number of biomolecules [2]. A recent study has found that radiation can modify the phenotypic, immunogenicity and microenvironment of tumour cells, ultimately changing the biological activity of cancer cells worldwide. The presence of high "omics" tools for sequencing

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DNA and protein changes have transformed research into the effect of ionizing radiation on biological systems. This review looks at the negative outcome of ionizing radiation on cancer cells in terms of alterations in ribosomal structure, mitochondrial behaviour, endoplasmic reticulum behaviour and last but not least, cell membrane biological characteristics [3].

Cancer occurs when cells multiply uncontrollably and spread into nearby tissues. Cancer is caused by changes in the DNA. The bulk of cancer-causing DNA changes occurs in the gene regions of DNA. These differences are also referred to as genetic variants. Cancer cells have gene alterations that transform them from normal to cancer cells. These genetic mutations can be passed down *via* our families, develop over time as our genes age or arise as a result of exposure to anything that weakens our DNA, such as alcohol, cigarette smoke or ultraviolet (UV) radiation from the sun [4].

The majority of associations discuss between radiation exposure and cancer. They are groups that have experienced extremely high levels of ionizing radiation, such as survivors of the Japanese atomic bomb and those who have had particular diagnostic or therapeutic medical treatments. High levels of exposure have been related to leukaemia, breast, liver, lung, ovarian, multiple myeloma and stomach cancer. According to the US Department of Health and Human Services, there may be a link between ionizing radiation exposure and prostate, nasal cavity orsinus, pharyngeal and laryngeal malignancies and pancreatic cancer.

2. Effects of Ionizing Radiation

2.1 Ionizing Radiation Caused Changes in Ribosomal Structure

A ribosome is an interstitial structure made up of both RNA and protein that acts as the cell's protein production centre in the body. The ribosome's primary purpose is to detect the messenger RNA (mRNA) sequence and convert it into a particular string of amino acids that grow into lengthy chains, also known as polypeptide chains that fold to generate proteins. Numerous tumour forms can exhibit altered Ras/MAPK activity and changes in ribosome synthesis, and one of the most often found abnormalities in human cancer is disturbedp53 function. The relationship between the key signaling pathways and ribosome synthesis has the potential to be extremely important for tumour biology [5].

2.2 Ionizing Radiation Affects the Behaviour of Mitochondria

The “powerhouses” of the cell are referred to as mitochondria. Mitochondria can contribute up to 30 % of overall cell volume in some cases, such as in lymphocytes. Interestingly, mitochondria are the only locations where extra-nuclear DNA are found. Strand breaks, base mismatches and large deletions, which are also found in nuclear DNA can occur in circular mitochondrial DNA as a result of ionizing radiation. Overall, it is anticipated that mitochondria will be the primary target of ionizing radiation in addition to the cell nucleus. Ionizing radiation disrupts mitochondrial function, raises oxidative stress and promotes apoptosis. Radiation produces changes in mitochondrial gene expression that are linked to cell survival and mitochondria have been discovered as the major target for apoptosis [6].

The radiation interacts with the target either directly or indirectly. The direct effect of radiation on mitochondria by direct contact with DNA leads to detrimental mutations, which in turn might drive cancer growth. Radian, on the other hand, might interact with mitochondrial macromolecules indirectly and create reactive oxygen species (ROS) e.g. superoxide anion, hydrogen peroxide and hydroxyl radicals, which have the potential to damage mitochondrial DNA or cause disastrous mutations. As a result, mitochondrial activity is impaired as are indications of apoptosis, ageing, endothelial damage and tissue toxicity, without producing an increase in ROS.

2.3 Ionizing Radiation Damages the Endoplasmic Reticulum

The function of the endoplasmic reticulum which can be smooth or rough, is typically to produce proteins that enables the body of the cell to function. Protein synthesis is carried out by ribosomes, which are small, spherical organelles located in the rough endoplasmic reticulum. Ionizing radiation-induced tumour cell death has been linked to endoplasmic reticulum disruptions, according to research. As a key radiation target organelle, it is highly sensitive to changes in the inner environment. Radiation-induced milieu interne alterations trigger an endoplasmic reticulum stress (ERS) response. ERS is a response that put tumour cells under stress.

3. Introduction to Nuclear Medicine

Nuclear medicine is a type of diagnostic and therapeutical procedure that uses radioactive material which enters the body and assist organs or tissue functioning, or to target and destroy damaged, diseased organs or tissue. Nuclear medicine is very different from common imaging procedures that uses X-ray. Nuclear medicine material uses a type of tracer that will be injected or ingested and also inhaled by the patient following the dose given by the physician while X-ray is a beam of radiation that passed through the body. For the imaging, nuclear medicine will only show the images of the body where and how the tracer was absorbed while X-ray will show all the structure in the body. Nuclear medicine will show the function while X-ray shows the structure. Nuclear medicine is used in diagnosis or treatment while X-ray is only applied in diagnoses.

In this century, we are all exposed to ionizing radiation everyday from the natural environment but the exposure from nuclear medicine procedures make slightly increase the risk of developing cancer. The common uses of nuclear medicine in for diagnosis include for lung, heart, kidneys, gallbladder and thyroid. Positron emission tomography (PET) is an example of analysis in nuclear medicine. It is used to show the natural activity of cells, providing more detailed information on how organs are working and if the cell have some type of damage. PET, CT and MRI all of this are often combined to provide 3D images of the organ. For the treatment, the tracer will target a harmful organ or tissue. There are 2 types of nuclear medicine treatments, inclusive of radioactive iodine therapy and brachytherapy.

4. Subjective Perception of Radiation Risk

The perception of radiation dose by patients strongly influences their acceptance of radioactive diagnostic tests or therapies. In this section, we examine laymen and medical experts' perceptions and concerns about radiation and radioactivity. According to several studies, physicians are frequently misinformed about radiation levels associated with nuclear medicine and radiologic examinations. Furthermore, patients' decisions to forego an imaging procedure are frequently based on incomplete, and sometimes incorrect information. As a result, physicians must take their patients' concerns seriously. We conclude from the literature and our own experience that it is critical to thoroughly and carefully educate all parties involved in patient care about radiation exposure levels and perceived, or actual health risks. Although the benefits of imaging examinations should always outweigh the risks, the benefits of imaging examinations should always outweigh the risk of secondary illness, and that patients' concerns must still be addressed [7].

Patients have the right, to adequate information before undergoing ionizing radiation diagnostic and therapeutic procedures, and they have the right to know the facts. The topic of ionizing radiation should be discussed between the physician and the patient prior to the radiologic procedure. Diagnostic procedures appear to be widely accepted in general. Patients do not appear to regard the risk as high, and they appear to be more concerned with receiving a diagnosis for their condition than with theoretical considerations. In contrast, some patients consider the risk of radiation to be so great that they refuse critical diagnostic procedures [8].

There are significant differences in the evaluation and perception of ionizing radiation between patients and specialists, both in general and in a medical context. Patients' perceptions, as strange as they may appear to the experts, form a strong foundation for the decisions that patients make. As a result, before an investigation or therapy can begin, the concepts that patients share with their physicians during informational conversations must be considered.

5. Radiation Dosimetry in Nuclear Medicine

Radionuclides are given to patients during nuclear medicine procedures for a variety of diagnostic and therapeutic purposes. A crucial consideration of the absorbed dose to different organs in the patient is a concern in such cases. This concern is naturally heightened in therapy applications, where a significant absorbed dose may be received by other organs, particularly radiosensitive organs.

Many useful reports and other aids to calculate absorbed dose estimates have been published by the Society of Nuclear Medicine's Medical Internal Radiation Dose (MIRD) Committee in the field of nuclear medicine. First, there is a series of technical reports known as MIRD Pamphlets that contain a wealth of useful information. Some pamphlets, such as those containing old compilations of decay data, were omitted. Many of them are still quite useful because they contain information that is not available anywhere else and is useful in many practical problems today (for example, the pamphlets that give photon absorbed fractions for small objects). A series of reports are also available that detail metabolic models and dose estimates for various radiopharmaceuticals. Many of the dose estimate reports are for radiopharmaceuticals that are no longer in use but many, particularly those for sodium iodide, are for current radiopharmaceuticals and sodium pertechnetate, which continue to be useful. The most recent reports are immediately relevant [9].

The authors provide several valuable examples for many different types of calculations, making the document useful to practitioners. This publication is a useful tool for designing kinetic studies however, each individual is unique. It is the investigator's responsibility to adequately describe the time activity curves in all source organs that have a significant uptake of the radiopharmaceutical, the organs involved in compound excretion and tissues in the rest of the body.

6. Radiation Exposure (Protection and Risk from Nuclear Medicine Procedures)

Since the Fukushima Daiichi Nuclear Power Plant disaster in 2011, radiation safety has become a major concern in nuclear medicine. There are numerous structured guidelines or recommendations from various academic societies or organizations. International campaigns highlight critical radiation safety issues in nuclear medicine procedures. There are ongoing efforts to incorporate basic radiation protection principles into daily nuclear medicine practice [10]. Nuclear medicine procedures have been used as prerequisites in the diagnosis and treatment of various human diseases since Saul Hertz's 1941 use of I-131 for the treatment of thyrotoxicosis. Since the advent of nuclear medicine in 1959, there has been a meteoric rise in nuclear medicine imaging and therapeutic procedures in Korea, particularly in F-18 fluorodeoxyglucose PET (FDG PET) and I-131 ablation therapy.

However, the Fukushima Daiichi nuclear power plant disaster in 2011, which included a radiation accident, earthquake and tsunami, raised serious concerns and even social phobia about ionizing radiation exposure. As a result, radiation safety has emerged as a priority issue in medical fields that use ionizing radiation and it is currently being addressed. Nuclear medicine's medical contribution in clinics is now extremely important. As the first important step in radiation exposure management, the Korean Society of Nuclear Medicine (KSNM) began standardizing nuclear medicine procedures. In 2013, the first standard procedure for F-18 FDG PET was completed. Furthermore, the Medical Radiation Agency reported the preliminary data on diagnostic reference levels (DRLs) for nuclear medicine procedures in Korea.

These recent products are encouraging, but most other aspects of radiation safety in Korea remain unexplored. As a result, it is difficult to refer to important radiation protection principles when deemed necessary. Despite ongoing efforts to improve radiation protection in nuclear imaging, the complexity and diversity of individual, physical / geometric and biological factors make it more challenging and difficult [11].

It is more difficult to provide nuclear medicine professionals with a single, identical dose prescription guide. As a result, no additional guidelines for tailoring individual radiation exposure in nuclear medicine have been provided. In nuclear medicine, radiation protection is still optimized using a dose prescription based on the patient's body weight or fixed dose tables. The ICRP Publication 94 contains comments on patient release following I-131 ablation therapy, which is the most commonly used radiopharmaceutical therapy in the world. It proposes a public dose limit of 1 mSv / year and a dose constraint [12].

Acceptable limits for relatives are 5 mSv / episode. In Korea, the legal restriction of patient isolation was applied at 33 mCi of I-131, and dose survey should be performed at 1m distance and fulfil a dose rate of 70 uSv / hr. Furthermore, it has recently become mandatory to provide appropriate instruction to patients who are being treated with radioiodine and are expected to expose the public to significant radiation.

This topic is covered in detail in ICRP Publications 84 and 88, which were approved in 1999 and 2001, respectively. Radiation exposure to pregnant women and foetuses can be considered in two scenarios: Those that do not cross the placenta and those that do. When a radionuclide that does not cross the placenta is given to the mother, the radioactivity in her tissues only serves as an external source of irradiation to the foetus. As a result, the risk to the mother of not performing the examination is usually greater than the risk to the foetus from radiation.

Every country has already established DRL for better radiation protection in nuclear medicine procedures. The first DRL values for nuclear medicine imaging studies performed in Korea were published in Korea. Nuclear imaging studies in Korea now have the potential guidance of radiopharmaceutical dose prescription, which was previously unavailable. The first DRL values were derived from a thorough review of dosing data from 155 domestic hospitals. Expert discussions were also included, as previously recommended in order to maintain reasonable dose levels while maintaining acceptable image quality.

7. Hormesis

This review concentrated on the interaction between ionizing radiation and cancer cells in order to better understand how ionizing radiation impacts the biological structure of cells. Ionizing radiation can cause DNA damage or cell membrane damage, as well as altering the immunogenicity and microenvironment of cancer cells, regulating apoptosis, differentiation, migration and biological activities. Ionizing radiation is a risk to everyone. This exposure consists of around 82 % background radiation from cosmic and terrestrial sources and 18 % artificial sources. Ionizing radiation exposure in public or environmental radioactivity pollution causes extreme apprehension. Prior to the radiation procedure, it is important to identify and deal with any emotional or psychological difficulties brought about by exposure.

Hormesis is the concept that biologic systems can respond positively or be stimulated by physical or biologic exposure to low doses of a toxic agent. Furthermore, hormesis is defined as "A physiological effect that occurs at low doses that cannot be predicted by extrapolation when affected from toxic effects observed at high doses". Radiation hormesis is thus the theory that biological systems can respond positively to low doses of ionizing radiation [13].

Low radiation doses may stimulate or positively affect biologic tissue, according to radiation hormesis [14]. Since the discovery of x-rays, scientists have been attempting to determine the effects of radiation at various levels and whether a safe level of radiation exists. The theory of radiation hormesis received scientific and public support early in its development. At the same time, many toxicology experiments revealed hormetic effects from various toxicants. Radiation scientists at the time failed to see parallels between radiation research and toxicology research, and as a public opinion, scientific criticism and other external factors changed, the theory of radiation hormesis lost steam.

On the other hand, studies have shown that low-dose radiation has no effect on, or even inhibits the repair of DNA double-strand breaks. Conflicting the findings from both sides of the radiation hormesis debate show that the precise effects at low radiation doses are still unknown. As radiation science advances, the validity of the linear no-threshold model at lower doses must be questioned, and more research into radiation hormesis must be conducted. Nuclear medicine is an important part of medicine that will only grow in the future [15]. Nuclear medical imaging has advanced alongside it. Important radiation protection principles should also be firmly established in daily practices. The use of DRL is likely to aid in the optimization of radiation protection in nuclear medicine. Eventually, the best and safest practices will be implemented in all clinical settings.

8. Conclusion

There are a lot of subjective perception about radiation risk. All medical staff in general become sensitized about the exposure of diagnostic or therapeutic procedures. The increased patient number that undergone imaging procedures who applied ionizing radiation, had make all the medical staff who attended the procedure, sickened due to risk of radiation. The risks come from that radiation dosimetry in nuclear medicine.

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