The Effects of Radiation on the Development and Survival of a Cell

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Abstract: ***Radiation is a naturally occurring phenomenon. Energy is emitted by air, water, sun and soil. This energy moves in the forms of an electromagnetic wave and can affect human cells and tissues. But since this radiation is non-ionizing, it does not produce haphazard to the cells. On the other hand, the decay of radioactive atoms releases powerful energy, a form of ionizing radiation, which is very harmful to the cells. Other sources of ionizing radiation are man-made, for example, X-rays, gamma radiation, nuclear reactors and radiopharmaceuticals. Radiation can damage the DNA sequence and result in the collapse of the cell structure. Radiation, in general, is harmful to those cells only that are reproducing and differentiating. It does not affect the dormant cells. Ionizing radiation is very harmful to the developing embryo as the embryonic cells are constantly developing, regenerating and differentiating. Excessive exposure to radiation may lead to carcinogens in the body. Radiation can cause so much damage to the DNA that this malfunctioning is carried in the future genes, leading to genetic disorders. Radiation has such a penetrative power that it can damage the single strand bond and the double strand bonds in the DNA of the cell structure. Although radiation is harmful to us, it has a positive side also. Through the use of MRI, CT scans, IMRT and X-rays the radiologists can visualize the damage to the DNA, and by using a beam of x-rays, gamma, or beta radiation, kill the damaged cell. Radio imaging has given us chances to heal without resorting to conventional surgeries or chemotherapies. Today ionizing radiation is used extensively in the treatment of various cancers and brain tumors. Radiopharmaceuticals, such as Technetium-99m, Iodine-131, Cesium-137, Fluorine-18 etc. belong to types of radioactive agents generally used for either diagnostic or therapeutic interventions. They can be administered both internally and externally to the human cells. There are a number of drawbacks in radiotherapy as it is expensive, time consuming and not fool proof. Moreover, there are a number of side effects seen on the patients that can also be recurring in nature. This therapy can cause infertility in men and women as the beams cannot always focus on a particular cell; the adjacent cells are also killed by the beam. FDA has set a number of regulations before radio-oncologist practices this therapy on a patient. if the radiation exceeds the threshold of 2000 rad, it leads to death inevitably. Although there are a number of drawbacks in the use of radiation therapy, there is no doubt in saying that the future of radiotherapy promises foolproof results as these techniques are getting better with recent innovations in the field of biochemistry.***

Keywords: Radiation, Ionizing radiation, DNA damage, Radiotherapy, Radiopharmaceuticals

1. Introduction

Kinds of Radiation

The foremost knowledge of radiation was given by "James Clerk Maxwell" in the year 1873, who first suggested the wave nature of electromagnetic radiation, thereby explaining the effects behind natural phenomena such as interference and diffraction etc. This knowledge was further elaborated in the year 1900 by Planck's quantum theory, which proved that "the energy of the radiation absorbed or emitted is directly proportional to the frequency of the radiation." Thus the waves are created by different sources such as radio, infrared or microwaves, and consequently absorbed by human bodies. The most dangerous kind of radiation to human cell is the ionizing radiation that has enough energy to knock electrons out of atoms. This radiation affects the atoms in the cells also, which leads to a damage in the DNA of the genes in a cell. Once the electron is removed out of the orbit by radiation, it gets the potential to disrupt the nucleotide also. As a chain reaction takes place, the disrupted DNA nucleotide creates subversive effects on the RNA sequence along with the amino acids and the proteins. Radiation induces reactive oxygen species which in turn oxidises the lipids and the protein, eventually breaking the strands. Depending on the power of radiation, there can be either deletions or insertions of the DNA profile. As a consequence, the rate of cell division is thwarted, which in turn can lead to carcinogenesis.

Most ionizing radiation that affects human cells comes from X-rays, cosmic particles, radioactive elements, radiopharmaceuticals and nuclear reactors. Ionizing radiation emits alpha particles, beta particles and gamma rays, which are as dangerous as the X-rays. The saga of the cell destruction starts when radiation is exposed to the atoms of a cell. The chain reaction is caused as radiation attacks the atoms thereby affecting the molecules, the tissues, the organs and the entire human body. The radioactive materials are highly unstable, and in order to balance them, they undergo a constant process of decay. This process releases energy, contributing to radiation. If a person gets exposed to this radiation, radioactive contamination gets deposited on his body. Nuclear reactors and nuclear fission are two most potential sources of harmful radiation.

The best example of direct radiation comes from the plethora of the use of medical equipment, for instance, the use of X-rays and radioisotopes in diagnostic imaging. Ionizing radiation is so powerful that it can penetrate the atom easily thereby creating adverse effects in the cell structure. Depending upon the energy of the ions, a cell may die, its chromosomes can start malfunctioning and there can be a formidable alteration in the information carried by the DNA molecule. Since most of the cell volume is made of water, radiation can break the molecular bonds thereby disintegrating the water molecule into hydrogen and hydroxyls, which can in turn further interact with the ions to create a toxic compound: hydrogen peroxide, eventually leading to the collapse of the cell.

Cell Sensitivity

Although the destruction to a cell depends on the ionizing energy yet it must be noted that radiation may not have equal effects on all the cells. In other words, many cells that are in the dormant state remain unaffected by exposure. These cells are insensitive to radiation. But on the other hand, the cells that are reproducing, differentiating, or developing may be highly affected by radiation. The cells that are reproducing require exact DNA information so as to transmit it to the offspring, and if at this moment the cell is exposed to radiation, it can cause death or some kind of a mutation in the cell structure. There are billions of cells in the human body, and they have different sensitivity levels. For example, the cells such as WBCs that are constantly producing blood are constantly regenerating, thereby increasing the level of exposure to themselves. They are the most sensitive cells. On the other hand, cells such as the gastrointestinal cells are not regenerating regularly and hence, they are not sensitive, and can avert exposure to a great extent. The least sensitive cells are the cells found in the nerves and muscles as they regenerate very slowly. Thus, it can be said that exposure depends on the speed of the regeneration of the cells.

Millions of cells can escape radiation exposure as they have an inherent tendency to repair themselves.This ability gives the body and opportunity to heal itself without resorting to operations and surgeries. There are instances when a cell is damaged, but it is still able to reproduce but in case a daughter cell is exposed to radiation, it may essentially die as it lacks the life sustaining component. Other cells end up being mutated once exposed, and once this kind of a mutated cell starts reproducing, it gives birth to other mutated cells thereby creating a malignant tumor. Another important feature that accentuates harmful exposure is the presence of oxygen, which makes the cells more sensitive. Anoxic cells are not as sensitive as other cells since they don't receive as much oxygen as the WBCs.

Exposure to Embryonic Cells

With the advancements in the medical sciences and epidemiology, it has become indispensable for a pregnant mother to undergo diagnostic radiology, thereby putting the foetus to radiation exposure. Radiation here becomes a necessary evil as its advantages outnumber the disadvantages. It is believed that a mother not going for radiology puts the foetus at a larger speculated potential risk. The fetus which is regularly developing is very sensitive to the ionizing radiation, and may undergo harmful consequences. With a view to controlling and measuring the effects of radiation, the embryonic development is generally divided into 3 parts. The first being the pre-implantation period, which spans over the time from fertilization to the time taken by the embryo to attach to the uterus wall. The second is the organogenesis period, the time taken for the parts of the embryo to show formidable development. And the third is the foetal stage, the time taken by the fetus for the development of newly formed organs. The experiments conducted on animal embryos, and also observation of human foetus brings this information to us that the first stage, that is the pre-implantation stage is the most sensitive to radiation exposure. Irradiation here can lead to the demise of the embryo. But the second stage that is the organogenesis is not that sensitive to radiation. Irradiation here more often than not leads to a number of congenital anomalies in the sell structure. How much destruction is caused in the embryo depends on the number of cells damaged, and if the radiation is low, the fetus can survive with certain malfunctions. Too much exposure at this stage can lead to irregularities in cell migration and also in the proliferation besides the Milotic delay. The third part, the fetal stage is most critical and sensitive to radiation and it is at this stage that growth and mental retardation are observed in it. Many a time, a decrease in the diameter of the foetus head is also observed. Another observation shows that radiation affects the central nervous system seen as microcephaly as well as ocular abnormalities, all of which are detrimental to intellectual development of the child. "Microcephaly is the most frequently seen manifestation of radiation injury in utero." But all this once again depends on the amount of exposure sustained by the fetus. It here becomes important to understand how we measure the exposure and what are the limits of radiation for diagnostic radiology. Generally the foetal radiation dose is kept under the threshold to avert potential damage to the cells. It is less than 0.01Gy (unit "rad" or the SI unit "gray" Gy) for the conventional radiographic tests. If the embryo is taken for fluoroscopic tests, the radiation dose can increase from 0.01 Gy as emitted by barium enema but it can be controlled by following the regulatory protocols. When the foetus is taken for a CT or computed tomographic scan, the range of the dose varies between 0.01 to 0.04Gy. All these regulations ensure that the foetus is minimally exposed to irradiation. But if the doses are increased inadvertently, there is a massive repercussion to the foetal development. For instance there is a potential risk of developing carcinogenic effects or childhood cancer in later stages of the foetal development. If the new born is exposed to radiation more than the set prescribed dose, incidence of developing leukaemia is observed. This fact has also been collaborated with the research conducted in Hiroshima and Nagasaki on the children born right after the atomisation of the two cities.

The effects of high doses radiation are similar to catastrophic events such as the atomic bombing but there have been incidents of indirect exposure to radiation as well. Many incidents have been reported all over the world where people died from some discarded medical therapy sources. Take for instance four people died in 1987 in Golania, Brazil of Caesium-137, which was left cut open near a river side, and it not only killed a number of people there but also spread contamination to more than 250 people. Since we live in a world where radiology is essential, we are susceptible to radiation and a large number of diseases are reported worldwide. Radiation has severe effects on the skin cells and people often suffer from diseases such as erythema and desquamation after being exposed to high radiation. In particular x-ray, gamma and beta radiation is known to have caused a lot of skin lesions on people. Radiation exposure can also lead to hair loss, infertility and cataracts.

Effect on the Genes

Cells are the tiniest units of a human body, and are also called microscopic building blocks given the fact that they are dynamic in that they have the ability to reform themselves by millions every second. These cells are not specialized which means that they have not grown into a particular kind of cells earmarked for a specific functioning. Since the cells can develop into other kinds of cells, this process is called differentiation. And if once a cell is mutated by radiation, further mutation takes place and as a result there are malfunctions and anomalies in the DNA structure, which passes from one generation to the other. Radiation can also lead to mutation in the sperm or egg cells, a trait or deformity which is passed on to the next generation of the exposed person. When there is a constant exposure of radiation, the germ cells start mutating and are transmitted to the progeny. Such diseases are known as genetic diseases. There can be several mutations, depending upon the frequency and power of radiation, for instance, when there is one gene mutation, this disease is called Mendelian disease, which is further divided into "autosomal dominant, autosomal recessive, and X-linked, depending on the chromosomal location and transmission patterns of the mutant genes. In an autosomal dominant disease, a single mutant gene is sufficient to cause disease. Examples include achondroplasia, neurofibromatosis, Marfan syndrome, and myotonic dystrophy." The mutation of two genes is called autosomal recessive mutation, and examples of such diseases are Bloom's syndrome, cystic fibrosis, and phenylketonuria etc. "The X-linked recessive diseases are due to mutations in genes located on the X chromosome and include Duchenne's muscular dystrophy, Fabry's disease, steroid sulfatase deficiency, and ocular albinism."

Multifactorial Diseases

Apart from the Mendelian disease, there are other abnormalities of various genes, that have multiple genetic and environmental determinants. This kind of disease is known as multifactorial diseases. These diseases have a complex etiology, and they include diseases such as neural tube defects, congenital heart diseases, cleft lip, and palate. These diseases are present at birth and sometimes they show their symptoms at adulthood also, for instance coronary heart diseases, Diabetes and Hypertension. "The relationships between mutations and disease are complex in the case of multifactorial diseases. For most of them, knowledge of the genes involved the types of mutational alterations, and the nature of environmental factors remains limited." A study conducted by Motulsky and Brunzell 1992, shows that "first-degree relatives of patients affected with coronary heart disease have a two- to sixfold higher risk of the disease than those of matched controls, and the concordance rates of disease for monozygotic twins are higher (but never 100%) than those for dizygotic twins."Besides, Mendelian, and Multifactorial genetic diseases, neurologists mention another set of disease called Chromosomal disease which appears as a result of a malfunctioning in the chromosomes. Example of this disease is Down's syndrome. Radiation is also responsible for producing carcinogens as is established by a number of research on the human and animal cells. Cancer is caused as a result of "mutations, including alterations in the structure of single genes or chromosomes; changes in gene expression, without mutations; and oncogenic viruses, which, in turn, may cause neoplasia." "Double-strand DNA breaks (DSB), although rare, are perhaps the most lethal mechanism and are often produced by ionizing radiation. Several mutations in these genes increase the probability of developing breast and other neoplasias." It is important to understand that the study of cancer cells claims that it is literally very difficult to distinguish between cancer induced by radiation and that developed naturally through other physical and chemical hazards, such as smoking, alcohol, drugs, and lifestyles. A number of research conducted on the malignant cancer cells shows that there is a synergistic interaction between irradiation and specific promoting agents in many cell systems and organs. In the recent years, "it has been observed that research on the mechanisms of carcinogenesis has focused on such genes, of which two broad classes are now known to exist: protooncogenes and tumour-suppressor genes, or antioncogenes (Kn85)." It must be noted here that the effect of radiation is so powerful that it may often lead to mutations that become hereditary in nature. Experiments on animals also highlight the fact that genetic defects from radiation are inherited from one generation to the other. Report by the ICRP claims "the parental radiation exposure to a single (acute) gonadal dose of 1 gray (Gy) leads to one additional severe disease caused by radiation-induced mutations in 500 births. This genetic risk may last for up to two generations. Chronic radiation exposure may persist over several generations. In this case it is assumed that, with a gonadal dose of 1 Gy one additional mutation, which causes a severe disease, occurs in 100 births."

Positive Effects of Ionizing Radiation

Ionizing radiation was used extensively on patients after the scientists and radiologists were able to diagnose the amount of exposure on a patient. In the 1970s, they started using an index to measure the exposure. It is called ESK "entrance skin exposure" and it is measured in units of milliroentgen. The unit takes the name of Roentgen, the scientist who gave the first evidence of the exposure of the X rays to human body. Presently, all radiologists and scientists have accepted the international units miilgray or mGy. Internationally it is assumed that 100 milliroentgen exposure=0.869mGy. To calculate the dose of radiation for a particular patient, the radiologist has to measure both the attenuation and the scattering of the x-ray within the patient for a particular organ of ESK. There exists a specific radiographic procedure for the patient in consonance with the guidelines established by the FDA. These guidelines are in the forms of tableaus and computer codes available with the radiologist. Although X-rays remain one of the most used radiological applications, there are other two applications, ultrasound, and MRI. Medical imaging today uses radiographic imaging, fluoroscopic imaging, and computed tomography (CT) to treat radiation exposure. The dose to be administered on an individual also depends on a number of other factors such as patient's weight, radiation sensitivity of the image receptor, rate of exposure of radiation, and energy of the x-ray beam. "The vast majority of x-ray procedures are performed by radiographic imaging. These radiographic imaging procedures are in turn typically divided into what are considered "conventional" examinations, on the one hand, and "contrast studies," on the other."

Radiotherapy

Before the discovery of X-rays in 1895 by Roentgen, the physicians did not have diverse methods to treat human conditions, whether malignant or benign in nature. It was the joint efforts of Curie and her husband that we got to know about the radioactive properties of radium. By the 1950s, radium induced interstitial irradiation and high voltage x-ray tubes had been used by the physicians to deliver significant energy to the tunes of 150-200 KV. The X-rays were scientifically developed with a view to creating an electron beam that would target the specific organs for the treatment of tumors. The therapy was in practice, but the results were not promising as at that time computer applications were not included during the treatment. In order to understand how radiation can expose a danger as well as a cure, many radiologists in the early 20th century exposed their hands to radiation emitted by Roentgen or X-rays. They used beams to target a particular area until they got pinkish touch to their skin, somewhat resembling a sunburn. It was actually the incidence of a disease called erythema. Many of the radiologists who exposed themselves regularly to radiation developed symptoms of leukemia.

The technique which is used these days to eliminate or dissipate the residual tumour cells with the help of ionizing radiation is called radiotherapy. The techniques mostly use X-rays and gamma rays, "prophylactically or palliatively to reduce the risk of tumor recurrence or to relieve symptoms caused by tumor growth and associated metastases, respectively." This therapy is globally applied to kill or treat the cancer cells. High doses of ionizing radiation are directly linked to the formation of carcinogens, and radio imaging is used to treat various types of cancers such as liver, lungs, leukaemia, breast, ovarian, oesophagus and stomach cancers. The dose is administered in three different schemes, such as, accelerated fractionation, hyper fractionation and hypofractionation, depending on the severity as well as the age of the cancerous tumours. The dose is given more than once a day or sometimes once in a few days depending upon which cancer the patient has. Another form of radiotherapy used these days involves advanced form of 3D known as IMRT. This technique involves the use of computerised equipment that delivers beams on the patient moving around him constantly while delivering the doses. This projection helps the radio oncologist get a better view to understand the malignant DNA. These techniques have shown positive results on the treatment, and are less expensive than the traditional radiation therapies, such as chemotherapy. The radiation therapy can be both external and internal. In the external treatment the cancerous cells are exposed to the beam while in the internal radiation therapy, also called brachytherapy, cells are treated with "gamma-radiation sources such as radioactive isotopes like ^{60}Co and ^{137}Cs, which are placed within the patient's body."Another way to administer the medicine is the concept of nuclear medicine which wields the nuclear properties of radioactive elements such as uranium, radium and plutonium etc. The radiologist uses the stable nuclides of the elements and applies them for nuclear imagining in the thyroid, kidney, heart, liver and intestines. Radiopharmaceuticals are injected intravenously, or the patient has to inhale the nuclear medicine. The radiopharmaceutical is passed through the body nonuniformly, and once the medicine reaches the inside of the body, gamma rays are released, whose image is captured through position-sensitive scintillation detector, commonly called a gamma camera. This camera gives a fair picture of the damage to the DNA of the target specific object.

Cancer Treatment

There is enough evidence to show that there exists a linear relationship between exposure to ionizing radiation and the development of cancers in living beings. One of the most morbid diseases of the times is the breast cancer. It is the fifth biggest cause of the death of women in both the developed and developing nations. The severity of this disease can be understood from the fact that in the year 2012 there were 1.67 million cases of newly reported breast cancer, and the rate is rising even today. Radiation therapy has been very successful for the treatment of malignant breast cancer, although there are cases where the patients showed adverse reactions to this therapy. There are a number of tests available to treat the damage to SSBs and DSBs (single strand and double strand bonds) in a patient suffering from breast cancer. The most famous test is the comet assay test which very significantly measures the extent of damage in the SSB and DSB. This test uses an alkaline solution in an electrolyte plate which helps release the DNA from the proteins that are kept in an incubator. When viewed under a fluorescence microscope, DNA fragments can be seen forming a comet like image. The head of the comet and its tail help the radiologist to understand the extent of DNA break, and accordingly the dose is administered to repair the strands. Another test which is very conducive to the treatment of breast cancer is the H2AX test, which is a variant of histone H2A found in the nucleosomes. This test uses a protein, phosphoinositide 3 kinase which on the release of gamma rays makes a unique image of the protein. Through this process the extent of the DNA damage is gauged, and the chromatin at the DSB can be decondensed. Rather than create excision to remove the tumour in the breasts, the oncologists treat the cancerous cells with a dose of 45 to 50 Gy. The organ is further boosted with more dosage with the help of electrons or interstitial radioactive seed implants. In case the breast cancer is in the mature stages, the oncologist performs mastectomy and uses radiation therapy to irradiate the chest wall so as to reduce the rate of any such recurrence. Another test to measure the radiation is called the PBSR (proton beam source and dosimetry). The ion accelerator is used to induce proton beams in an electrostatic container kept at a voltage of 6MV. Dosimetry is calculated by using two silicon detectors. A quartz crystal fixed on a movable object in a highly vacuum environment helps scatter the proton beams across a 3m long tube with a titanium window. An SSB detector placed at an angle from the gold foil helps in taking the geometric image of the DNA. Although these tests have shown revolutionary results in the treatment of breast cancer, there are a number of disadvantages also. Comet assay tests don't give the same results as every laboratory is different. Even a slight difference of temperature during alkaline electrophoresis can result into varying values of the exposure. Moreover, the duration of the alkali treatment and electrophoresis conditions can also produce varying results. H2AX method is effective in calculating and treating the DNA damage but fails to discriminate between the damage caused between the SSB and the DSB, nor their sensitivity or resistance to ionizing radiation. PBSR also gives varying results, if the readings are repeated, and cannot assess the damage to the DSB.

Besides breast cancer, ionizing radiation is widely used in the treatment of thyroid cancer. The commonly used therapeutic radiopharmaceutical is Iodine 1-31. With the administration of this therapy, oncologists have been able to achieve positive results. A number of 50,000 administrations per year have proven to eliminate thyroid ablation while around 1,00,000 administrations are sufficient to deal with thyroid cancer. Radioiodine, administered intravenously has shown promising results for the treatment of B cell lymphoma. Besides I- 131, Phosphorus-32, Strontium-89 and Au-198 are also administered intravenously to treat these cancers.

In the treatment of prostate cancer again, we can see the immense contribution of ionizing radiation. The oncologists undertake prostrate specific antigen testing with the help of screen programming. They have been very successful in treating this disease, provided the cancer is in the initial stages, with the help of a surgery termed as prostatectomy or modern nerve sparing prostatectomy. This procedure involves using more than 4 radiation beams that intersect at the specific prostrate organ. Once the beams kill the cancer cells, radioactive seed implants are used. The dose is generally between 60 to 70 Gy which can be increased to treat the prostrate if it is in developed stages. The therapy is also used in the treatment of widespread metastasis of the skeletal cancer, and in palliative concerns. The therapy is again fructifying in the treatment of the cancer to the liver. For this treatment, the oncologist has to use 3D-CRT, IMRT and SBRT, which make it successful to target the specific liver cancerous cells without damaging the surrounding cells. Radiotherapy is extensively used to treat brain tumours also. The Comprehensive Brain Tumour Centre uses two kinds of radiation therapy for the treatment of metastatic brain tumours. The first therapy is known as whole brain radiation therapy that targets the entire brain to treat the microscopic tumours which cannot be seen through radio imaging or an MRI scan. Another therapy used at this centre is stereotactic radio surgery which uses a high dose of ionizing radiation to target a particular tumour. This kind of radiotherapy is time consuming but is more effective than the whole brain radiation therapy. The centre also uses proton therapy wherein the radio oncologist uses protons instead of the x-rays to terminate the tumour cells. This therapy is needed when there is a need of low dose of radiation, for example, in the treatment of the tumour at the base of the skull or at the optic nerve.

Preventative Measures

Owing to its side effects, the radiation therapy has to undergo a number of regulations set aside by the NRC state agreement in the US. The federal government keeps stringent regulations on external beam therapy wherein there is use of Co-60 cobalt teletherapy keeping in view that this radiopharmaceutical is reactor produced. Moreover, it becomes mandatory on the part of the radiologist and the oncologist to follow the protocols such as proper shielding to avoid the danger induced by radiation. The state requires that teletherapy physicist must be trained in the treatment and he must satisfy all conditions, besides having a license, before working in this profession. It is also important that the radio oncologist follows the bio markers before starting radiation therapy. The FDA regulates "equipment design and construction. Because linear accelerators and radiation therapy treatment planning systems are Class III medical devices, their safety and manufacture is controlled by the FDA." The FDA also requires the need of radioprotectors and radiosensitizers in the clinic in order that the radiologist and oncologists can "sensitize the tumour itself and eliminate the free radicals from cell damage in environment." Since the radiation therapy can sometimes kill the healthy cells also, there need to be taken utmost precautions before starting ionizing radiation on a patient.

2. Limitations and Side Effects

There are a number of limitations in this therapeutic use, considering the harmful nature of ionizing radiation particularly when the dose exceeds the threshold. Moreover, if the tumour cells cannot be seen on the imaging scans or if the cells of diseases such as metastatic disease don't leave an imprint on the 3D models, this therapy cannot work. The therapy does not give promising result if the tumour is large as the beam cannot kill all the cancerous cells. Sometimes it fails to provide mass effect which in turn forces the patient to undergo surgeries, after wasting so much time and money on this therapy. The therapy again fails if the cells don't have a proper supply of oxygen or there is a poor blood supply in the organ. In case a patient has to undergo surgery after radiotherapy, his immunity is compromised and it becomes difficult for the wound to heal due to the exposure to radiation. Another drawback is the time taken for this therapy. The treatment is long, often spanning a period of one to two months with the administration of doses 5 times a week. This therapy poses a serious threat to the stem cells. Stem cells are very important as with their presence, the body's repair and growth mechanisms are activated. They enable the body to heal itself without resorting to operations and surgeries. Stem cells act as future reservoir for the body and their vulnerability to exposure puts the body at a larger risk. Many a time, there is an occurrence of radiation induced secondary malignancies that are generally witnessed after 3 years of radiotherapy. If these secondary malignancies are not detected early, the survival of the patient becomes difficult. Sometimes radiation and tumour microenvironment affect healthy cells also by inducing harmful and inflammatory factors such as cytokines and free radicals. These factors in turn result in an oxidative DNA damage. Radiotherapy is expensive, and it is seen that around 20% of the cancer patients undergo complications after the therapy. Since radiotherapy can also cause mutations in the cells, it is highly probable that such DNA gets transmitted and expressed in the progeny of the surviving cell, thereby making the offspring a victim of genetic mutations. Women undergoing radiotherapy in the abdomen and the pelvic region become prone to infertility as high doses can kill the eggs in the ovaries and result into menopause. Similarly, there is witnessed a rising rate of infertility among men who undertake this therapy for testicular disorders. It is also observed that if the dose exceeds the threshold of 150 rad, there can occur damage to major tissues and organs. This condition is called Acute

Radiation Syndrome. It is diagnosed by early symptoms such as anorexia, nausea, fatigue and fever etc. High radiation dose can bring damage to skin cells resulting in erythema, dry desquamation, moist desquamation and epilation. Another side effect witnessed after radiotherapy is the development of cataracts which occurs as a result of neutrons that are affected by exposure. Since the eyes have enough water content, the alpha rays, beta and gamma radiations can cause malfunctions in the cell walls easily. If the dose exceeds 1000 rad, the gastrointestinal system ceases to work. By the time the dose exceeds 2000 rad, death is inevitable as the nervous system collapses, failing which the body cannot function.

3. Conclusion

Radiation therapy is one of the most successful therapies in the detection and elimination of cancerous cells. With the advancement of scientific studies, new radiation modalities and techniques continue to improve, thereby making this therapy highly successful in treating cell malfunctioning and anomalies. This therapy is an indispensable tool in the detection and deletion of the cancerous cells. Not only this, the therapy plays an influential role in organ preserving by eliminating the need and chances of surgeries. The therapy has an edge over chemotherapy as it can target a particular area, and unlike the drugs given to the patients in chemotherapy, there is no danger of spreading doses all over the body. In the near future, an interplay of radiotherapy and ayurvedic drugs might play an instrumental role in the elimination of cancerous cells. In order to minimize the risks of radiation after radiotherapy, another therapy is being practised these days. It is known as radiogenic therapy which will use cytotoxic agentsto be released in cancerous cells with a view to killing all the diseased DNAs. The latest research in computer technology is the AI, and with AI based auto contouring, the efficacy of radiotherapy is likely to increase tremendously. The ASTRO meeting held in 2019 was organized to analyse the clinical trials undertaken by Radionuclide therapy in the US, and consequently the National Institutes of Health predicts that within the next 15 years, all radio therapeutic procedures will be delivered with the aid of radiopharmaceuticals. It is hoped that in the near future this therapy will bring fool proof results thereby giving hundred per cent cure and satisfaction to the patients.

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