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Review Article

Common sources of radiations in a medical environment

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ABSTRACT

Use of radiation is now a days so common in most of the tertiary care hospitals for diagnostic and therapeutic purpose. The ionizing radiation provides many benefits in both diagnostic as well as therapeutic interventions, but they are also potential harmful. Radiation risks, exposure and mitigation strategies should always be in mind while using to an individual (public, radiation worker, and patient) and the environment should not exceed the prescribed safe limits. Regular monitoring of hospital area and radiation workers is mandatory to assess the quality of radiation safety. This review article emphasis on radiation risks, exposure and prevention and treatment strategies.

Keywords: Radiations, Ionizing, Non-ionizing, Decontamination, Medical

INTRODUCTION

Radiation is energy that comes from a source and travels through space at the speed of light. This energy has an electric field and a magnetic field associated with it, and has wave-like properties. They are also known as "electromagnetic waves".[1] There is a wide range of electromagnetic radiation in nature (Figure 1). Visible light is one example.

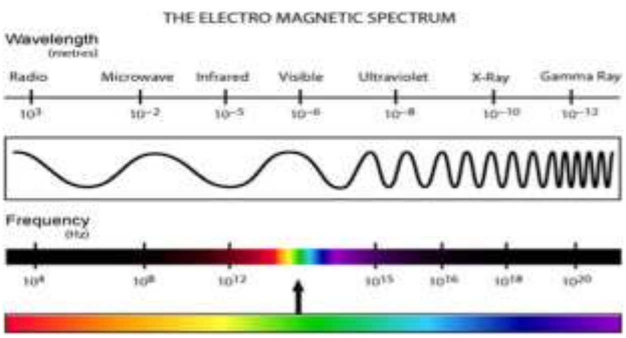

Figure 1: The electromagnetic spectrum.[5]

Radiation with the highest energy includes forms like ultraviolet radiation, x-rays, and gamma rays. X-rays and gamma rays have so much energy that when they interact with atoms, they can remove electrons and cause the atom to become ionized.[2]

Radioactive atoms have unstable blends of protons and neutrons. Radioactivity is the spontaneous release of energy from an unstable atom to get to a more stable state. Ionizing radiation is the energy that comes out of a radioactive atom. Radioactive isotopes are radioactive atoms of the same element that have different numbers of neutrons.[3] There are two types of radiation; non-ionizing radiation and ionizing radiation.

Non-ionizing radiation

People use and are exposed to non-ionizing radiation sources every day. This form of radiation does not carry enough energy to ionize atoms or molecules. Microwave ovens, global positioning systems, cellular telephones, television stations, FM and AM radio, baby monitors, cordless phones, garage-door openers and ham radios all use non-ionizing radiation.[4] Other forms include the earth's magnetic field and magnetic field exposure from proximity to transmission lines, household wiring and electrical appliances. These are defined as extremely low frequency (ELF) waves.

Ionizing radiation

Some types of radiation have enough energy that they can knock electrons out of their orbits around atoms, upsetting the electron/proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. The radiation that can produce ions is called ionizing radiation. Radioactive atoms can give off four types of ionizing radiation: alpha particles, beta particles, gamma rays, and neutrons (Figure 2). Each type of radiation has different properties that affect how we can detect it and how it can affect us. Radioactive decay happens when an unstable atom gives off radiation and changes into a more stable atom of a different element. The length of time it takes for half of the radioactive atoms in a group of radioactive isotopes to decay is called a half-life.[5,6]

Alpha radiation

Alpha radiation consists of two protons and two neutrons; since they have no electrons, they carry a positive charge. Due to their size and charge, alpha particles are barely able to penetrate skin and can be stopped completely by a sheet of paper.

Beta radiation

Beta radiation consists of fast-moving electrons ejected from the nucleus of atom. Beta radiation has a negative charge and is about 1/7000th size of an alpha particle, so it is more penetrating. However, it can still be stopped by a small amount of shielding, such as a sheet of plastic.

Gamma radiation

Gamma radiation is a very penetrating type of radiation. It is usually emitted immediately after the ejection of an alpha or beta particle from the nucleus of an atom. Because it has no mass or charge, it can pass through the human body, but it is absorbed by denser materials, such as concrete or lead.

X-rays

X-rays are a form of radiation similar to gamma radiation, but they are produced mainly by artificial means rather than from radioactive substances.

Neutron radiation

Neutron radiation occurs when neutrons are ejected from the nucleus by nuclear fission and other processes. The nuclear chain reaction is an example of nuclear fission, where a neutron being ejected from one fissioned atom causes another atom to fission, ejecting more neutrons. Unlike other radiations, neutron radiation is absorbed by materials with lots of hydrogen atoms, like paraffin wax and plastics.

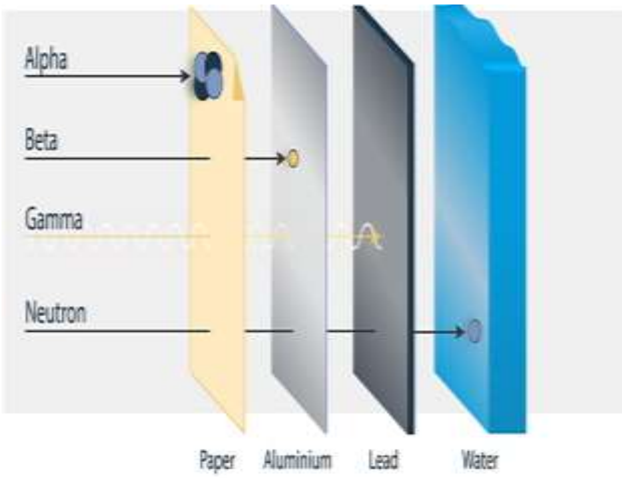

Figure 2: Types of decay.[4]

COMMON SOURCES OF RADIATION

Background radiation is present on Earth at all times. The majority of background radiation occurs naturally from minerals and a small fraction comes from man-made elements. Naturally occurring radioactive minerals in the ground, soil, and water produce background radiation. The human body even contains some of these naturally-occurring radioactive minerals. Cosmic radiation from space also contributes to the background radiation around us. There can be large variances in natural background radiation levels from place to place, as well as changes in the same location over time.

Cosmic radiations[7]

Cosmic radiation comes from extremely energetic particles from the sun and stars that enter Earth's atmosphere.[7] Some particles make it to the ground, while others interact with the atmosphere to create different types of radiation. Radiation levels increase as you get closer to the source, so the amount of cosmic radiation generally increases with elevation. The higher the altitude; higher will be the dose. That is why those living in Denver, Colorado (altitude of 5,280 feet) receives a higher annual radiation dose from cosmic radiation than someone living at sea level (altitude of 0 feet).[8]

Radioactive materials in the earth and in our bodies

Uranium and thorium naturally found in the earth are called primordial radionuclides and are the source of terrestrial radiation. Trace amounts of uranium, thorium and their decay products can be found everywhere. Terrestrial radiation levels vary by location, but areas with higher concentrations of uranium and thorium in surface soils generally have higher dose levels. Traces of radioactive materials can be found in the body, mainly naturally occurring potassium-40.[9] Potassium-40 is found in the food, soil, and water we ingest. Our bodies contain small amounts of radiation because the body metabolizes the non-radioactive and radioactive forms of potassium and other elements in the same way.

Man-made sources

A small fraction of background radiation comes from human activities. Trace amounts of radioactive elements have dispersed in the environment from nuclear weapons tests and accidents like the one at the Chernobyl nuclear power plant in Ukraine. Nuclear reactors emit small amounts of radioactive elements. Radioactive materials used in industry and even in some consumer products are also a source of small amounts of background radiation.

Medical sources

Radiation has many uses in medicine. The most well-known use is in X-ray machines, which use radiation to find broken bones and diagnose disease. X-ray machines are regulated by Health Canada and provincial authorities. Another example is nuclear medicine, which uses radioactive isotopes to diagnose and treat diseases such as cancer. These applications of nuclear medicine, as well as the related equipment, are regulated by the CNSC. The CNSC also licenses those reactors and particle accelerators that produce isotopes destined for medical and industrial applications. Radiation therapy used in the treatment of patients lead to radiation exposure in very large amount.[10,11] Many commonly used machines lead to radiation exposure are fluroscopy, chest x-ray, dental x-ray, CT-scan, teletherapy, brachytherapy and LINAC (Figure 3).

Fluoroscopy: dynamic (real time) imaging

This is a type of medical imaging that shows a continuous x-ray image on x-ray monitor much like x-ray movie. During fluoroscopy x-ray beam is passes through body. It is used in many types of procedures like barium x-rays, cardiac catheterization, arthrography, lumbar puncture, placement of intravenous catheters.

X-rays

X-rays are types of electromagnetic radiation probably most well-known for their ability to see through a person's skin and reveal images of the bones beneath it. Advances in technology have led to more powerful and focused X-ray beams as well as ever greater applications of these light waves, from imaging teensy biological cells and structural components of materials like cement to killing cancer cells.

Figure 3: Medical sources of radiation including an x-ray, CT scan, nuclear medicine, and a particle accelerator that produce isotopes.[4]

Teletherapy

Teletherapy (Figure 4) is administered by telecobalt unit or linear accelerator. Here the source of radiation is placed away from the patient. Liner accelerators give superior dose distribution to cobalt units. Also, modern methods of radiotherapy via 3D CRT and IMRT are deliverable by these machines only.

Figure 4: Teletherapy (Image source: Google).

Brachytherapy

In brachytherapy, the source of radiation is placed within or close to the patient's body. Brachytherapy (Figure 5) uses radioactive isotopes such as Cesium 137 (Low dose rate brachytherapy) or Iridium 192 (High dose rate brachytherapy). HDR brachytherapy is preferable as it allows precise computerized planning of the treatment and also is of much shorter duration. Brachytherapy is most commonly used to treat prostate cancer. It also can be used for gynecologic cancers such as cervical cancer and uterine (endometrial) cancer, as well as breast cancer, lung cancer, rectal cancer, eye cancer, and skin cancer. Side effects of brachytherapy can include swelling, bruising, bleeding, or pain and discomfort at the spot where the radiation was delivered.

Figure 5: Brachytherapy (Image source: Google).

LINAC (Linear accelerator)

The linear accelerator (Figure 6) uses microwave technology (similar to that used for radar) to accelerate electrons in a part of the accelerator called the "wave guide," then allows these electrons to collide with a heavy metal target to produce high-energy x-rays. These high energy x-rays are shaped as they exit the machine to conform to the shape of the patient's tumor and the customized beam is directed to the patient's tumor. The beam is usually shaped by a multi-leaf collimator that is incorporated into the head of the machine. The patient lies on a moveable treatment couch and lasers are used to make sure the patient is in the proper position. The treatment couch can move in many directions including up, down, right, left, in and out. The beam comes out of a part of the accelerator called a gantry, which can be rotated around the patient. Radiation can be delivered to the tumor from many angles by rotating the gantry and moving the treatment couch.

Figure 6: LINAC (Linear accelerator) (Image source: Google).

MAXIMUM ALLOWABLE RADIATION[12]

Maximum allowable radiation for radiation worker is whole body: 5,000 mrem, lens of the eye: 15,000 mrem, skin: 50,000 mrem, extremity: 50,000 mrem, pregnant radiation worker 500 mrem (0.5 rem)/gestation period, and general public: 100 mrem (0.1 rem)/year.[12]

HAZARDS OF RADIATION[13]

Hemopoietic syndrome (>200,000 mrads,) depression or ablation of bone marrow, malaise and fatigue, epilation potential death due to infection if no medical treatment given, gastrointestinal syndrome (>1,000,000 mrads), destruction of intestinal epithelium, severe nausea, vomiting, diarrhoea, central nervous system syndrome (>2,000,000 mrads), damage to central nervous system and other body organs and unconsciousness within few minutes are common.[13]

MEASURING RADIATION[13]

Three common measurements of radiation are the amount of radioactivity, ambient radiation levels, and radiation dose.[13] But, to get accurate and reliable measurements, both the right instrument and a trained operator are needed. It is important to maintain radiation detection equipment to ensure it is working properly. Amount of energy the material is emitting is the most important things while working in a radiation environment. The size, weight, and volume of material do not necessarily matter. A small amount of material may give off a lot of radiation. On the other hand, large amount of radioactive material may give off small amount of radiation.

Measuring the amount of radioactivity

Amount of radioactivity is measured by finding out how many radioactive atoms decay every second. These atoms may be giving off alpha particles, beta particles, and/or gamma rays. The amount of radioactivity is reported in Becquerel (Bq), which is the international unit, or the Curie (Ci), which is the unit used in the United States. Geiger counters (Figure 7) are commonly used to measure the amount of radioactivity, but there are other types of detectors that may be used.

Figure 7: Geiger counters (Image source: Google).

Measuring ambient radiation levels

Ambient radiation levels measure how much radiation is in the environment around us. Ambient radiation levels are reported in Gray per hour (Gy/h) or Sievert per hour (Sv/h), which are the international units. In the United States, we use Roentgen per hour (R/h) or rem per hour (rem/h). Instruments called pressurized ionization chambers are best suited for measuring ambient radiation levels.

Measuring radiation dose

Radiation dose is the amount of radiation absorbed by the body. Radiation doses are reported in Gray (Gy) or Sievert (Sv), which are international units. In the U. S., we use rad or rem. Alarming dosimeters (Figure 8) can be used by first responders and safety officers to monitor dose in real time. There are also specialized instruments used by hospitals and laboratories that can measure dose.

Figure 8: Alarming dosimeters (Image source: Google).

PREVENTION OF RADIATION EXPOSURE[15]

Anybody who works with radiation should work with their safety officers and radiation safety professionals to determine what personal protective equipment, or PPE, and instrumentation they need to stay safe on the job. Personal protective equipment use can minimize exposure, respirators help in protecting from inhalation hazards; protective clothing helps keep radioactive material off of skin and hair.[15] Alarming dosimeters help manage stay time and track your accumulated doses in an area with elevated radiation levels.

The guiding principle of radiation safety is "ALARA". ALARA stands for "as low as reasonably achievable". This principle means that even if it is a small dose, if receiving that dose has no direct benefit, you should try to avoid it.[16] Three basic protective measures should be used for radiation safety: time, distance, and shielding.

Time

Time simply refers to the amount of time you spend near a radioactive source. Minimize your time near a radioactive source to only what it takes to get the job done. If you are in an area where radiation levels are elevated, complete your work as quickly as possible, and then leave the area. There is no reason to spend more time around it than necessary.

Distance

Distance refers to how close you are to a radioactive source. Maximize your distance from a radioactive source as much as you can. This is an easy way to protect your-self because distance and dose are inversely related. If you increase your distance, you decrease your dose.

Shielding

To shield yourself from a radiation source, you need to put something between you and the radiation source. The most effective shielding will depend on what kind of radiation the source is emitting. Some radionuclides emit more than one kind of radiation.

DECONTAMINATION

Radiation safety: removal of radioactive material (Decontamination)

We are exposed to normal, low levels of background radiation on a daily basis. These levels of radiation are not likely to cause human health effects. If, however, a radiation emergency was to occur, there is a possibility that you may become contaminated with radioactive material. This could be harmful to your health. Contamination is a word used to describe unwanted radioactive materials on or inside the human body. Removing radioactive material from a person, object, or place is called decontamination.[1] It is important to remove radioactive material from your body as soon as possible to lower your risk of harm and reduce the chance of spreading contamination to others. Radiation exposure differs from radiation contamination. For a person to be contaminated, radioactive material must be on or inside of his or her body. A person exposed to radiation is not necessarily contaminated with radioactive material. X-rays are an example of radiation exposure.

External decontamination: Removing radioactive materials on your skin, hair, or clothing is known as external decontamination.[1] You can remove radioactive materials that are on the body of others or you can remove radioactive materials if they are on your body (self-decontamination). You can wash your hands, face, and parts of your body that were uncovered at a sink or faucet. Use soap and plenty of water. You can take a warm shower and gently wash yourself with lots of soap to decontaminate you (Figure 9).

Figure 9: External decontamination.[1]

Internal decontamination: Removing radioactive materials you swallow or inhale is known as internal decontamination.[1] Internal contamination occurs when people swallow or breathe in radioactive materials, or when radioactive materials enter the body through an open wound or are absorbed through the skin. In certain situations, radioactive materials can be removed from inside your body through the use of special medical treatments under the supervision of medical providers.

CONCLUSION

In present scenario, radiation exposure is very much common due to enhancement of technologies in medical field for diagnostic and therapeutic purpose. So, we should be aware bout the basic knowledge as well as various preventive measures to avoid radiation exposure. Three principles like minimize time, maximize distance and use of shield should be practiced properly in medical environment to avoid exposure.

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REFERENCES

1. Radiation and your health. Available at: https://www.cdc.gov/nceh/radiation/default.htm. Accessed on 14 July 2021.
2. Radiation: Ionizing radiation. Available at: https://www.who.int/news-room/q-a-detail/radiation-ionizing-radiation. Accessed on 14 July 2021.
3. Radiation Basics. Available at: https://www.nrc.gov/about-nrc/radiation/health-effects/radiation-basics.html. Accessed on 17 July 2021.
4. Types and sources of radiation. Available at: http://nuclearsafety.gc.ca/eng/ resources/radiation/introduction-to-radiation/types-and-sources-of-radiation.cfm. Accessed on 17 July 2021.
5. Donya M, Radford M, ElGuindy A, Firmin D, Yacoub MH. Radiation in medicine: Origins, risks and aspirations. Global Cardiol Sci Practice. 2014;57:438-48.
6. Christensen DM, Iddins CJ, Sugarman SL. Ionizing radiation injuries and illnesses. Emerg Med Clin North Am. 2014;32(1):245-65.
7. Bagshaw M, Illig P. The Aircraft Cabin Environment. Travel Med. 2019;4.
8. Natural and man-made radiation sources. Available at: https://www.nrc.gov/reading-rm/basic-ref/students/for-educators/06.pdf. Assessed on 20 August 2021.
9. Shahbazi-Gahrouei D, Gholami M, Setayandeh S. A review on natural background radiation. Adv Biomed Res. 2013;2:65.
10. Introduction to radiation. Available at: https://archives.bape.gouv.qc.ca/sections/mandats/uranium-enjeux/documents/GEN2%20-%20AN.pdf. Accessed on 26 August 2021.
11. Hricak H, Brenner DJ, Adelstein SJ, Frush DP, Hall EJ. Managing radiation use in medical imaging: A multifaceted challenge. Radiology. 2011;258(3):889-905.
12. Radiation dose limit. Available at: https://www.wku.edu/ehs/radiation/module-3_radiation_limits.pdf. Accessed on 28 August 2021.
13. Radiation sickness. Available at: https://rarediseases.org/rare-diseases/radiation-sickness/. Accessed on 29 August 2021.
14. Measuring radiation. Available at: https://www.nrc.gov/about-nrc/radiation/health-effects/measuring-radiation.html. Accessed on 17 July 2021.
15. Gray JE, Archer BR, Butler PF. Reference values for diagnostic radiology: Application and impact. Radiology. 2005;235:354-8.
16. Asefa G, Getnet W, Tewelde T. Knowledge about radiation related health hazards and protective measures among patients waiting for radiologic imaging in Jimma University Hospital, Southwest Ethiopia. Ethiop J Health Sci. 2016;26(3):227-36.

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