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A Review: Radioisotopes used in Cancer Therapy

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Abstract: The critical role that radioisotopes play in modern healthcare is examined in this review. In contemporary medicine, radioisotope atoms with unstable nuclei that release ionizing radiation have become indispensable instruments. Their special qualities make it possible to identify and treat a variety of illnesses, transforming medical care and enhancing patient outcomes. The most widely used radioisotopes, their properties, and their various uses in the diagnosis and treatment of various medical conditions are examined in this review. Special attention is paid to diagnostic methods like positron emission tomography (PET) and single-photon emission computed tomography (SPECT), which have since transformed imaging by making it possible to see an anatomical structures and metabolic processes in great detail. This study highlights the significance of medical radioisotopes in nuclear medicine in relation to cancer diagnosis and treatment. Additionally, potential medical radioisotope production techniques are asses sed, and by contrasting with experimental data from the literature, a method for producing two medical radioisotopes via neutron and deuteron-induced reaction processes is examined.
Keywords: Radioactive isotopes, Nuclear medicine, Oncology treatment, Atomic isotopes, Nucleonox, Radionuclides.

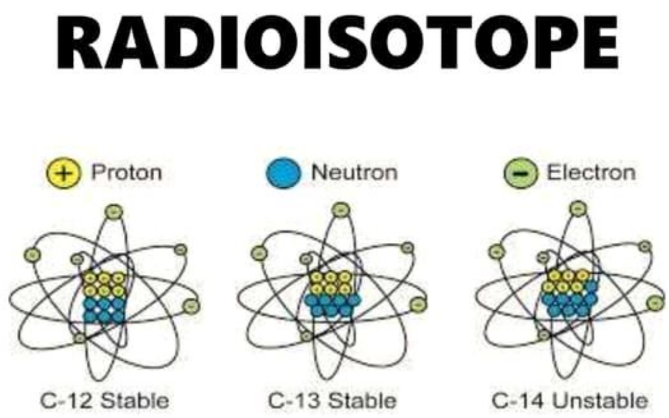
I. INTRODUCTION

Radiopharmaceuticals are radioactive substances used either to detect disease or to treat certain types of cancer. These substances contain unstable nuclei that release excess radiation or energy as they break down, eventually reaching a stable state.So far, scientists have identified radioactive compounds that can specifically target different forms of cancer, such as thyroid cancer, lymphoma, ovarian cancer, brain tumors, and cancers that have spread to the bones.The exact cause of thyroid cancer remains unclear, but it is believed to be influenced by both genetic predisposition and environmental factors. Radioisotopes are unstable atoms with nuclei that release radiation, and they have transformed the field of medicine. Although once mainly associated with their harmful effects, these radioactive substances have become essential tools in medical diagnosis, treatment, and scientific research. Their use has led to better patient care and a greater understanding of human biology.

The first use of a radioisotope in medicine occurred in 1938, when iodine-131 was employed to assess thyroid function. This groundbreaking application opened the door to advanced imaging methods like positron emission tomography (PET) and single-photon emission computed tomography (SPECT), which use radioisotopes to observe the metabolic processes and structural details of organs and tissues. Compared to traditional imaging techniques, radioisotopes provide several key benefits. Radioisotopes provide several benefits compared to traditional imaging methods. Because they can be integrated into specific molecules, they are able to target certain organs and tissues, offering detailed insights into how these areas function and identifying any abnormalities. This makes them incredibly useful for diagnosing a range of diseases such as cancer, heart conditions, neurological disorders, and infections (Fassbender, 2020). In addition to diagnosis, radioisotopes are also important in treating diseases. Through targeted radionuclide therapy, they deliver radiation precisely to affected cells, helping to avoid harming nearby healthy tissues. This technique has shown success in treating cancers like thyroid, lymphoma, and prostate cancer. Moreover, radioisotopes are vital in advancing medical research. The discovery of natural radioactivity was made by chance when French physicist Henri Becquerel observed that potassium uranyl sulfate crystals emitted radiation capable of fogging photographic plates. This accidental finding led to the identification of other naturally radioactive elements such as thorium, radium, and radon.

Today, radioactive isotopes have become indispensable tools in biological research, to the point that modern experiments often rely heavily on their application. These isotopes possess unstable atomic nuclei, which release energy or radiation in the process of transforming into more stable forms. So far, scientists have developed various radioactive substances that can help detect and monitor a range of diseases, including certain types of cancer such as those affecting the thyroid and ovaries. In the case of thyroid cancer, the precise cause remains unclear, though it is thought to involve a mix of genetic predisposition and environmental influences. Radioisotope therapy involves administering a liquid form of radiation, such as Lutathera, together with amino acids that help protect the kidneys, through an infusion. This liquid radiation specifically targets cancer cells while minimizing harm to healthy surrounding tissue. Radiopharmaceuticals are radioactive isotopes used either for diagnosing diseases or for cancer treatment.

To treat thyroid cancer, patients often undergo medication, surgery, and radiation therapy to eliminate any remaining cancer cells after surgery. Radioactive substances can be administered in several ways, including orally (in pill form), intravenously (IV), or interstitially (inserted directly into a body cavity. Their specific effects can be achieved through the in vivo use of radiopharmaceuticals." Isotopes are variants of the same element that contain an identical number of protons but differ in the number of neutrons. As a result, they share the same atomic number but have different atomic masses. Some of these isotopes are unstable and release energy to attain stability. This energy is emitted in the form of alpha particles, beta particles (electrons or positrons), or gamma radiation. Isotopes that emit such radiation are referred to as radioisotopes, or more technically, radionuclides.



A. Radiation Protection

Background radiation is always present in some quantity, approximately 150 m Rem/year. Twenty percent comes from the internal environment, thirty percent from the terrestrial environment, and roughly fifty percent comes from cosmic rays.

1) 40K decay. Brick and granite walls will enhance the outside scenery. There are more cosmic rays at higher elevations. At a height of 2000 meters, (e.g. A. irradiation is 20 percent higher in Gangtok , Sikkim state. Exposure may be detected if radiation is reaching the film because it becomes blackened. The radiation risks will be decreased by taking the following safety measures: a. Distance the source from you.
2) Protect the radioactive sources by covering them with bricks made of lead.
3) Handling is carried out by distant devices. Put on lead-rubber aprons and gloves. Handling radioactive materials requires quick thinking. The dose obtained decreases with decreasing time spent close to the source.

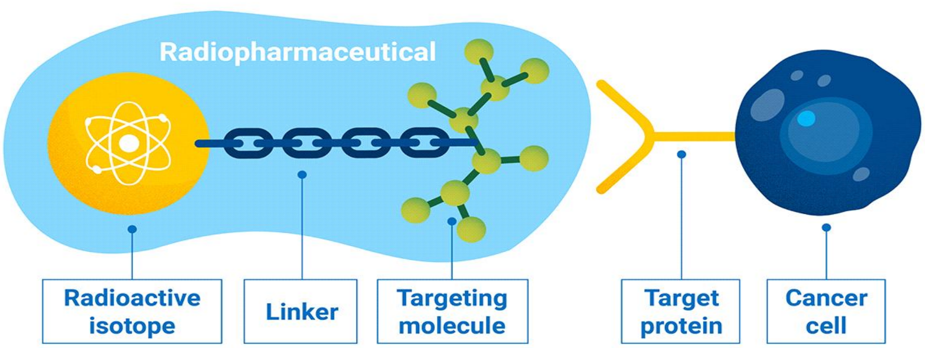
Table :- Radioisotopes from reactors employed in diagnostic procedures

Isotope	Half-life	Applications
Molybdenum-99	66 hours	Act as the “parent” source in generates to produce technetium-99m.It is most widely employed radionuclide in nuclear medicine.
Technetium-99m	6 hours	Commonly used to scan bones and heart; also used for imaging many body organs and systems
Chromium-51	27.7 days	Tags red blood cells; helps measure protein loss from the digestive system.
Copper-64	13 hours	Helps research genetic copper disorders like Wilson’s and Menke’s diseases.
Holmium-166	26 hours	Under development to diagnose and treat liver cancer
Iodine-125	60 days	Checks kidney filtering, leg vein clots; used in small-scale hormone detection

		tests.
Iodine-131	8 days	Detects problems in liver and kidney function, and urinary blockages.
Iron-59	46 days	Used to study how iron is processed in the spleen.
Potassium-42	12 hours	Measures how potassium moves in blood, especially in the heart
Rhenium-188	17 hours	Used to treat arteries after balloon angioplasty through beta radiation.
Selenium-75	17 hours	Helps study how digestive enzymes are made, using selenomethionine.

B. How does Radioisotope therapy work?

Chemotherapy and radiation therapy are two of the many techniques used in cancer treatment. The most popular method is conventional external radiation, but radioisotope therapy enables radiation to reach and treat cancer cells all over the body. It makes use of a medication that circulates in the bloodstream, just like chemotherapy. This substance, in contrast to chemotherapy, binds to particular cancer cells in a selective manner, protecting healthy tissues and reducing undesirable side.



II. ADVANTAGES OF RADIOISOTOPE IN CANCER

1) Precision Therapy: Internal radiation treatments, such as brachytherapy or radiopharmaceuticals, deliver radiation directly to the tumor site, helping to spare healthy tissues from unnecessary exposure.
2) High Cancer Cell Destruction: Radioactive isotopes release ionizing radiation (like alpha, beta, or gamma rays) that damages the DNA of cancer cells, preventing them from multiplying or surviving.
3) Less Invasive Treatment Methods: Some radioisotope therapies can be taken orally or injected, offering alternatives to traditional surgery with minimal discomfort and recovery time.
4) Suitable for Treating Spread Cancer: Certain radioactive treatments (such as radioactive iodine for thyroid cancer or radium-223 for bone metastases) circulate in the bloodstream, making them effective against cancers that have spread beyond the original site.
5) Organ Preservation Advantage: Internal radiation can target tumors without needing to remove or significantly harm the affected organ, which is especially helpful in treating cancers of the prostate, cervix, or thyroid.
6) Works Well with Other Therapies: Radioisotope therapy can be used alongside chemotherapy, surgery, or external radiation for a more comprehensive and effective approach to cancer treatment.
7) Reduced Treatment Duration: Some internal radiation therapies require fewer treatment sessions than traditional external beam radiotherapy, offering quicker relief for patients.
8) Dual Role in Diagnosis and Therapy (Theranostics): Certain radioactive isotopes (like Iodine-131 or Lutetium-177) can both identify and treat cancer, enabling personalized treatment based on the tumor’s characteristics and behavior.

III. DISADVANTAGES OF RADIOISOTOPE IMAGING

1) Radiation Exposure: Ionizing radiation is a problem for patients. Impact: Minimal but cumulative chance of later getting cancer Risk rises with more scans.
2) Expensive Procedures and Equipment: Needs radioactive tracers and specialized machinery. Impact: Expensive for patients and hospitals, possibly unavailable in low-resource areas
3) Short Tracer Half-Life Problem: Radioisotopes decompose rapidly (e.g. G. The half-life of fluorine-18 is approximately 110 minutes. Impact: Logistics can be complicated and expensive
4) Allergic Reactions: Although they are uncommon, some patients experience adverse reactions to radiopharmaceutics or carrier substances.
5) Problem: Nuclear imaging, such as PET or SPECT, provides functional information but lacks high-resolution structural detail.
6) Impact: Frequently required in conjunction with CT or MRI for accurate diagnosis; unable to clearly display minor anatomical change.

A. What is Radioactive Decay?

Radioactive decay is the spontaneous release of radiation when an unstable atomic nucleus changes into a more stable nucleus. Either particles or energy may be present in this radiation.

B. Why do Atoms Decay?

Unstable atomic nuclei are those that contain an excess of protons or neutrons. They release particles or energy through radioactive decay in order to achieve a stable configuration.

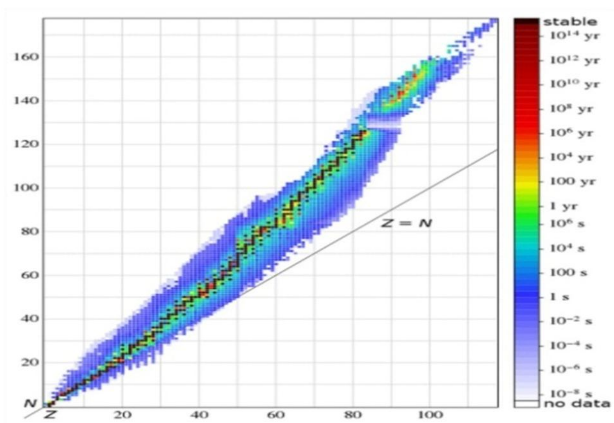


Fig: Radioactive Decay

C. Evaluation of Radioisotopes

The term "radioactive" was first used in 1898 when Pierre and Marie Curie discovered polonium. With the help of chemist G., the Curie team discovered radium six months after discovering polonium. Be calm. The role of radium was significantly greater than that of polonium. Its industrial, medical, and laboratory applications were made possible by its considerable separation. Henri Becquerel made the subsequent discovery of "uranic rays" in 1900. Although there are 1800 isotopes in total, only 200 radioisotopes are currently regularly used, and the majority are created artificially. There are various techniques for producing radioisotopes. In a nuclear reactor, neutron activation is the most typical method. Some radioisotopes are produced in a cyclotron, which was invented by Lawrence and Livingston in. This process involves an atom's nucleus capturing a neutron, producing an excess of neutrons (neutron rich), which results in the creation of the desired radioisotope dot.

IV. CONCLUSION

In conclusion, this article explains how radiopharmaceuticals can also be used to diagnose specific cancers because, once the drugs are administered, oncologists can monitor radioactivity throughout the body to detect the presence of cancer. Special imaging systems used for diagnostic purposes include gamma cameras and similar devices.

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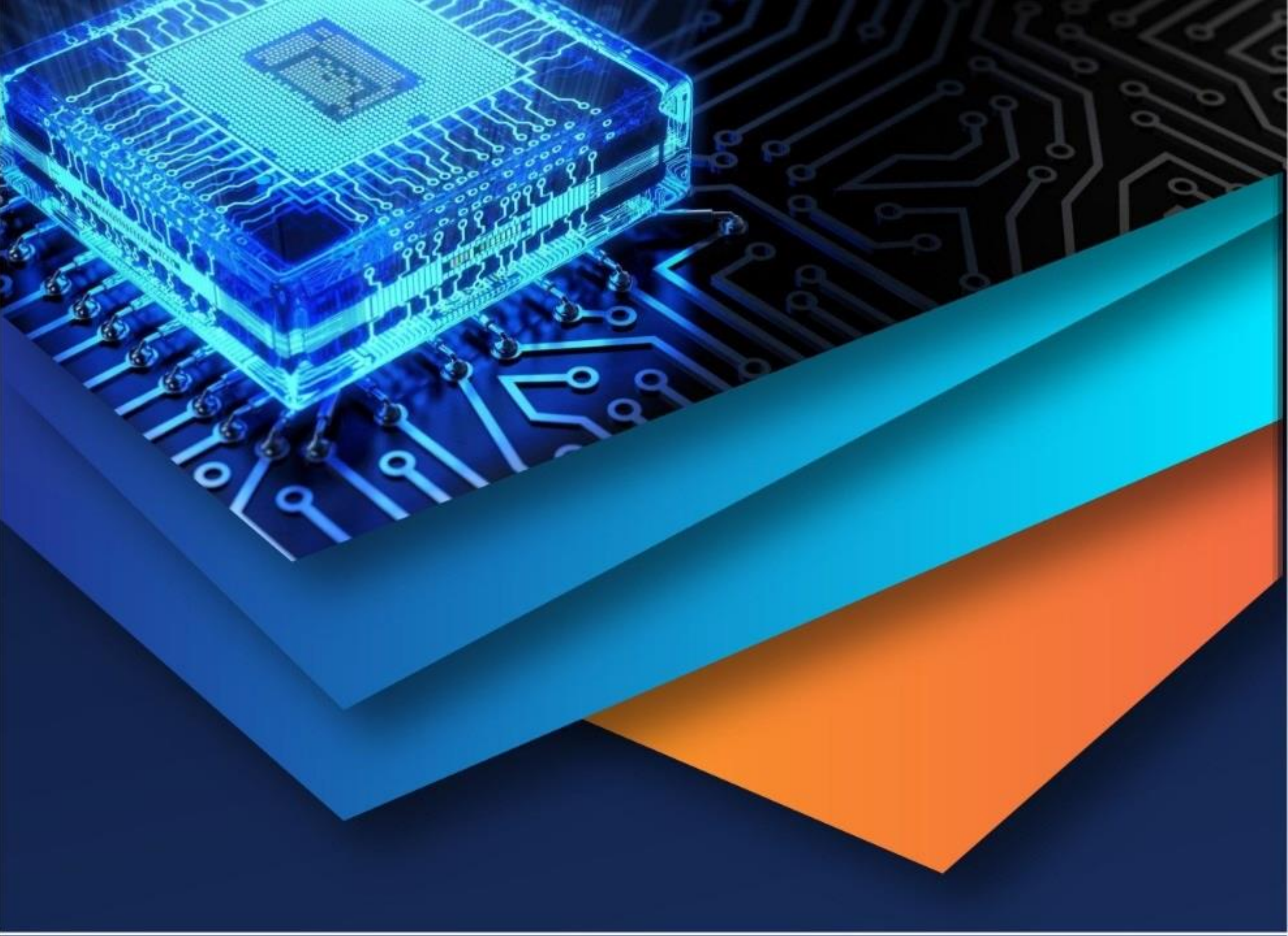

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