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Bio-Medical Applications of different radionuclides

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ABSTRACT

Radionuclides has been an integral part of medical sciences. From past 70 years demand of radioisotopes has increased many fold. It is increasing used for medical imaging, nuclear medicine and for radiotherapy techniques. In this paper we have discussed about the bio medical applications of different radioisotopes for different organs, infections and tumors.

Keywords: Radionuclides, radiopharmaceuticals, isotopes, decay scheme, medical uses.

Introduction

We often talk about use of radioisotopes or radionuclides in the medical sciences. Biomedical applications of radioisotopes or radionuclides means use of an unstable element which emits radiation in order to attain stability for the study of biology and medical sciences [1]. In this we will discuss use of various radionuclides for bio-medical applications.

Radionuclides

The use of radionuclides being first recognized in 1946 by Sam Seidlin in the Journal of the American Medical Association. Seidlin reported on the success of radioactive iodine (I-131) in treating a patient with advanced thyroid cancer. After this this work was being expanded and now researchers have established the therapeutic, safe use of radioisotopes in bio sciences. Radionuclides have been extensively used for the scanning purposes. Use of X-rays for imaging was always the first choice but X-rays are absorbed by the soft tissues so they can be used to study the anatomy of the body, so we use little amount of radioactive substance called radionuclides. They are being absorbed by the body tissues and after absorption its start emitting radiation can can be detected by special cameras like gamma cameras.

Radioactive Iodine

Radioactive Iodine is successfully used for the treatment of various thyroid disorders. We will discuss applications of different isotopes of Iron. Out of the 37 known isotopes of iodine, only four are ^{123}I, ^{124}I, ^{125}I, and ^{131}I suitable for SPECT or PET imaging [2]. Radioactive ^{131}I [3] with a half-life of 8.02 days is used as a nuclear medicine for the treatment of hyperthyroidism and thyroid cancer. It can be administrated in the form of capsule or liquid. Its mode of decay is β-decay and it is commonly used for β-therapy [3].^{123}I second radioactive isotope of Iodine which decay by electron capture [4] with half-life of 13.2 days it is ideal for 24 hour iodine uptake test. ^{123}I is produced in a cyclotron by the bombardment of protons with ^{123}Xe or ^{123}Te [5]. It is administer as Sodium Iodide capsule for the diagnostic study of Thyroid disease. ^{123}I offers an excellent image quality.^{124}I decays simultaneously by positron emission (25.6 %) and by electron capture (74.4 %) with a half-life of 4.2 days. This dualistic decay allows in principle to use ^{124}I in

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both diagnostic and therapeutic approaches.Although ^{124}I is not a widely used radioisotope but sodium [(124)I]-iodide is possiblybeneficial for diagnosis and dosimetry in thyroid disease [6] and [(124)I]-M-iodobenzylguanidine ([(124)I]-MIBG) has vast potential for use in cardiovascular imaging,diagnosis, and dosimetry of malignant diseases such as neuroblastoma, paraganglioma, , and carcinoids [6].^{125}I is a widely used radionuclide with half life of 59.5 days and its decays by low-energy Auger electrons [7]. It has both diagnostic and therapeutic application and used to treat variety of diseases like prostate cancer, brain tumors, breast cancer, hyperthyroidism.^{125}I seed implantation is an effective and safe method to regulate tumor growth [8].

Technetium-99m

Technetium-99m is the extensively used radioisotope all over the world which covers around 35 million procedures yearly. It is used to perform imaging for various organs, infections, tumors, heart disease, kidney problems, thyroid anomalies and also to guide some cancer procedures. It is broadly used as a radioactive tracer. Technetium-99m is artificially produced by the neutron activation of molybdenum-99 and can be prepared from a generator system (Mo-99/Tc-99m) with half-life of 6 hours and decay by beta emission with 140-keV gamma-ray emission [9]. When administered intravenously, Technetium Tc 99m Sulfur Colloid enters the lymphatic capillaries and is transported with lymph to lymph nodes where it can be used to detect drainage of primary tumours. When directed by intravenous injection, Tc 99m Sulfur Colloid is taken by the RES (reticuloendothelial system), which permit RES rich structures to be imaged. Uptake of the radioactive colloid by organs of the RES is dependent upon both their relative blood flow rates and the functional capacity of the phagocytic cells. When Tc 99m sulfur is taken orally its colloid can be used in gastroesophageal reflux scintigraphy and esophageal transit readings.

Yttrium-90

Y^{90} is a β emitter, which is formed by neutron bombardment of yttrium-89 in a reactor. Y^{90} has a physical half-life of 64.2 hours (2.67 days) and decays to stable zirconium 90 [10].Because of long half-life of Y^{90}it is an perfect source for the long-term continuous availability of no-carrier-added and it is appropriate for the preparation of radiopharmaceuticals for radionuclide therapy[11]. Y^{90} is used to shrink the tumors by injecting minute beads directly into the arteries that supply blood to tumor. These minute beads emits radiations for about 9-10 days and will keep working for several months or years not effecting the healthy tissues.

^{153}Samarium

Samarium-153 is a beta-emitting radiopharmaceutical with a half-life of 46.3 hours. It emits both beta and gamma rays.Samarium 153 EDTMP (Ethylene Diamine Tetra Methylene Phosphonate) is a radionuclide medicine [12] used to treat pain caused by cancer that has spread to the bone. The drug drives to the source of cancer bone pain and irradiates the osteoblastic tumor sites causing in pain relief.

Lutetium-177

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Lutetium-177 is a beta-emitting radionuclide with half-life of 6.7 days is one of the late admission in nuclear medicine but yet one of the emerging radionuclide being used today [13]. Lutetium-177 PSMA Therapy, also named Prostate-Specific Membrane Antigen Therapy, is becoming a primary preference for men experiencing advanced prostate cancer with metastatic or treatment-resistant prostate tumors. Lutetium-177 is a radiation-based treatment that employs a molecule to attach to the PSMA receptors which are positioned on the cancer cells. As it is a beta emitter so it effectively damages the cancer cells and terminates them.

Rubidium-82

Rubidium Rb 82 with a half-life of 76 secondsdecays by positron emission along with gamma emission. Rb 82is used as injection in adults to help diagnose heart disease by PET scan.The radiation exposure in Rb 82 is reasonably less than other radionuclides because of its short half-life. Rb 82 is used to quantify myocardial perfusion imaging [14]. The main advantage of using ^{82}Rb/PET over other radiopharmaceutical like Tc 99m is its capacity to precisely measure the myocardial perfusion imaging and flow reserve.

Rhenium-186

Re-186 with half-life of 3.8 days, decays by Beta emission (2.1 MeV) and gamma rays is a novel radionuclide which is boon for metastases bone pain. Re-186 labeled HEDP (1-hydroxy-ethylidene-1,1diphosphonic acid) complex, is widely used for palliative treatment [15] of bone metastases initiating from breast or prostate cancer.

Chromium 51 (Cr-51)

Chromium 51 with a half-life of 27.7 days decays with electron capture with gamma emission. Cr-51 is used for red blood cell survival studies. The long half-life of Cr-51 make is appropriate for this study. This long half-life positions some complications when multiple studies need to be performed in short duration, since the overlapping survival curves make separation of the individual studies bit challenging [16]. Direct exposure of Cr-51 is extremely toxic but it’s beneficial for diagnostic uses.

Gallium Ga 67

Gallium-67 (^{67}Ga) with a half-life of 78 hours decays with gamma emission. Gallium-67 is a cyclotron-produced radionuclide which is used for the imaging SPECT or PET scan to detect several malignancies like Hodgkin’s disease, lymphomas, and Hodgkin's disease. Gallium-67 exist in the form of various salts like citrate and nitrate. As Ga-67 is used to study lymphomas which demonstrates how much disease has spread inside the body.

Table 1: It shows different radionuclides with half-life, how they are being administrated, their decay and how they can be medically used.

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Radionuclide	Half Life	Administration	Decay	Medical Purpose
^{131}I	8.02 days	capsule or liquid	β-decay	Treatment of hyperthyroidism and thyroid cancer
^{123}I	13.2 days	Sodium Iodide capsule	electron capture followed by gamma decay	Used for imaging purpose for Thyroid disease
^{124}I	4.2 days	Taken orally	Positron emission (25.6 %) and electron capture (74.4 %)	PET imaging, tumor study, thyroid cancer
^{125}I	59.5 days	Implantation technique	Gamma emission, low energy Auger electrons	prostate cancer, brain tumors, breast cancer, hyperthyroidism
Tc-99m	6 hours	intravenous injection	Gamma Decay	Imaging purpose, infections, tumors, heart disease, kidney problems, thyroid anomalies, cancer procedures
Y^{90}	64.2 hours	intravenous injection	β-decay	Treat tumors, liver cancer
^{153}Sm	46.3 hours	intravenous injection	β-decay	Treat pain by bone cancer
Lu-177	6.7 days	intravenous injection	β-decay or Auger electron	Treat prostate cancer,cancers of the digestive tract, stomach, pancreas, and intestines.
Rb 82	76 seconds	intravenous infusion	positron emission, gamma decay	Assessment of myocardial perfusion
Re-186	3.8 days	intravenous infusion	β-decay	bone metastases,Prostate cancer
Cr-51	27.7 days	intravenously administered	Electron capture with gamma-ray emission	Used to find red blood cell volume
Ga 67	78 hours	intravenous infusion	gamma decay	Treat Hodgkin's disease, lymphoma, or lung cancer.

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Conclusion

In this we have summarized about the use of different radionuclides for the treatment of various malignancies like prostate cancer, bone metastases, lung cancer and many more. Use of different radionuclides depend on the specific activity and half-life of different radionuclides. Few radioisotopes have half-life as short as 76 seconds like Rb 82 which is used for the study of myocardial perfusion and few radioisotopes have half-life of 59 days like ^{125}I which is used to treat variety of diseases like prostate cancer, brain tumors, breast cancer, hyperthyroidism. Another example is Cr-51 whose half-life is 27.7 days which is used for blood volume studies.

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