RADIOPHARMACEUTICAL SCIENCE

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INTRODUCTION

Radiopharmaceutical science is defined as the science of incorporating a radionuclide with a biologically active molecule or pharmaceutical molecular entity. The radioactive compound present in a radiopharmaceutical emits radiation which is used for diagnosis and therapeutic treatment.

"Radiopharmaceuticals are radioactive compounds which have a bound radionuclide in their structure, whose purpose is directing the radionuclide to a location to be treated or to obtain images".[1]

Radiopharmaceutical products include inorganic compounds, organic compounds, peptides, proteins and monoclonal antibodies, which are labeled with radionuclides with half-lives varying from a few minutes to several days. It gives relevant information about the anatomy and physiology of the organ.

Substances such as iodine radiotracers have been used since last 80 years for the diagnosis and treatment of thyroid disorders. However, use of radionuclides in treatment of cancer have been used from last two decades.[1][3]

Funkhouser et al. introduced the term ‘theranostics’ as a single compound containing both diagnostic and therapeutic properties. Dual- functioning Radiopharmaceutical is also called as Theranostic. It could be a single isotope with multiple emitting capacities such iobenguane iodine-131 (Azedra®), or in combination of different isotopes with unique emitting capacities, such as lutetium-177 and galium-68 used together to diagnose and treat neuroendocrine tumors.[2]

•Benefits of theranostic system-

Targeted therapy

Minimal tissue toxicity

Better diagnosis and treatment

Improved biological activities such as enhanced bio-distribution and cellular uptake.[6]

Radiation therapy is a technique, which delivers radiation dose to the affected tissue or lesion with tiny sealed radioactive source.

Radiopharmaceuticals can be administered orally (in pill/ solid dosage form), intravenously (injected into a patient's vein) or interstitially (inserted into a cavity in the body).[4]

Once the drug is administered ,then oncologist track the radioactivity throughout the body. Then gamma cameras detect these radiation and gives static and dynamic images of the concerned tissue.[4]

Radioactive Isotopes-

These are defined as atoms with excess energy in their nucleus or unstable neutron-proton combinations. The natural decay of atoms produces a class of chemical elements known as radioactive isotopes or radioisotopes. They are used for diagnosis and treatment purposes.[5]

• Uranium is the naturally occurring radioisotope. The only other form of naturally occurring uranium, uranium-235, which has three fewer neutrons in its nucleus and is less stable or radioactive.[7]

•Technetium-99m , a gamma emitter with minimal therapeutic efficacy and is mostly utilized in diagnostic imaging. It can be used to image several structures, including the thyroid, lacrimal, vascular and pulmonary perfusion.[7]

• A radioisotope with a wide range of uses is iodine-131. It undergoes beta decay, which causes alterations in the cells. It is used in the treatment of thyroid cancer as only thyroid is the organ that consumes iodine, making radioactive Iodine to cause thyroid ablations.[7]

•Ceasium-137 undergo beta decay and Gamma emission. It is chemically unstable and extremely reactive. Used for low dose transient intracavity brachytherapy.[7]

•Fluorine-18 mostly emits positrons. Used as a radiotracer for PET scans.[7]

• A radioactive isotope of xenon called xenon-133 undergo beta decay. It is an inhaled radionuclide that is used to measure cerebral blood flow and pulmonary function.[7]

• Rubidium-82 experiences both positron and gamma emission. It is mostly given intravenously to evaluate cardiac imaging.[7]

Synthesis of radioisotopes-[8]

•Bombardment with neutrons

•Bombardment with charge particles

•Decay of radioisotopes

RADIOPHARMACEUTICALS IN DISEASES

Radio pharmaceuticals can be used for both to detect (diagnose)medical conditions and to treat certain ailments.

Radiopharmaceuticals in diagnosis/ as diagnostic tools-

They produce diagnostic images of tissues and organs a process called scintigraphy. Radiopharmaceuticals are basically, radio isotopes bound to biological molecules that target specified organ tissue and cell inside the human body. Once they enter the body, they get incorporated into biological pathways, metabolized and excreted and further used for investigation for the flow of blood in the brain heart liver etc.[9]

Radiopharmaceutical comprises -

Radioactive Element(Radionuclide) +Biologically activemolecule (carrier/ligand)

• Radioactive element (radionuclide) permits external scan.

• Biologically active molecule, drug or cell (RBC & WBC labelled with radionuclide)

conducts radionuclide to specific site. Also called as a carrier or ligand.

Targeted or specified radionuclide imaging gives convenience for disease detection. Radiopharmaceuticals labelled with PET and SPECT radionuclide are known to show high accuracy to detect tumors, neurological disorders, inflammation, bacterial infection. Most commonly used radionuclide is Technetium 99 m (detect bone metastasis).[11]

Some Radiopharmaceuticals used for diagnosis are:-**[10]**

•Abscess and infection—Gallium Citrate Ga 67, Indium In 111 Oxyquinoline,

•Biliary tract blockage—Technetium (^{99m}Tc) Disofenin, Technetium (^{99m}Tc) Lidofenin, Technetium (^{99m}Tc) Mebrofenin,

•Blood volume studies—Radioiodinated Albumin, Sodium Chromate Cr 51,

•Blood vessel diseases—Sodium Pertechnetate (^{99m}Tc),

•Bone diseases—Sodium Fluoride F 18, Technetium (^{99m}Tc) Medronate, Technetium (^{99m}Tc) Oxidronate, Technetium (^{99m}Tc) Pyrophosphate, Technetium (^{99m}Tc) (Pyro- and trimeta-) Phosphates,

•Bone marrow diseases—Sodium Chromate Cr 51, Technetium (^{99m}Tc) Albumin Colloid, Technetium (^{99m}Tc) Sulfur Colloid,

•Brain diseases and tumors—Fludeoxyglucose F 18, Indium In 111 Pentetreotide, Iofetamine I 123, Sodium Pertechnetate (^{99m}Tc), Technetium (^{99m}Tc) Exametazime, Technetium (^{99m}Tc) Gluceptate, Technetium (^{99m}Tc) Pentetate,

•Cancer, tumors—Fludeoxyglucose F 18, Gallium Citrate Ga 67, Indium In 111 Pentetreotide, Methionine C 11, RadioiodinatedIobenguane, Sodium Fluoride F 18, Technetium (^{99m}Tc) Arcitumomab, Technetium (^{99m}Tc) Nofetumomab Merpentan,

•Colorectal disease—Technetium (^{99m}Tc) Arcitumomab,

•Disorders of iron metabolism and absorption—Ferrous Citrate Fe 59,

•Heart disease—Ammonia N 13, Fludeoxyglucose F 18, Rubidium Rb 82, Sodium Pertechnetate Tc 99m, Technetium (^{99m}Tc) Albumin, Technetium (^{99m}Tc) Sestamibi, Technetium (^{99m}Tc) Teboroxime, Technetium (^{99m}Tc) Tetrofosmin, Thallous Chloride Tl 201,

•Lung diseases—Krypton Kr 81m, Technetium (^{99m}Tc) Albumin Aggregated, Technetium (^{99m}Tc) Pentetate, Xenon (Xe 127), Xenon (Xe 133),

•Parathyroid diseases; parathyroid cancer—Technetium (^{99m}Tc) Sestamibi, Thallous Chloride Tl 201,

•Pernicious anaemia; improper absorption of vitamin B12 from intestines—Cyanocobalamin Co 57,

•Red blood cell diseases—Sodium Chromate Cr 51,

•Salivary gland diseases—Sodium Pertechnetate (^{99m}Tc),

•Spleen diseases—Sodium Chromate Cr 51, Technetium (^{99m}Tc) Albumin Colloid, Technetium (^{99m}Tc) Sulfur Colloid,

•Stomach and intestinal bleeding—Sodium Chromate Cr 51, Sodium Pertechnetate (^{99m}Tc), Technetium (^{99m}Tc) (Pyro- and trimeta-) Phosphates, Technetium (^{99m}Tc) Sulfur Colloid,

•Stomach problems—Technetium (^{99m}Tc) Sulfur Colloid,

•Tear duct blockage—Sodium Pertechnetate (^{99m}Tc),

•Thyroid diseases; thyroid cancer—Fludeoxyglucose F 18, Indium In 111 Pentetreotide, RadioiodinatedIobenguane, Sodium Iodide I 123, Sodium Iodide I 131, Sodium Pertechnetate (^{99m}Tc), Technetium (^{99m}Tc) Sestamibi,

•Urinary bladder diseases—Sodium Pertechnetate (^{99m}Tc).

Radiopharmaceuticals in treatment of diseases -[3][12][13]

Radiopharmaceuticals in treating diseases or as therapeutic agents work by strongly binding with the tumor. They deliver targeted dosage of radiation directly to the tumors leaving normal healthy cells behind. The choice of molecule that carry the radiation depends upon it's affinity or

binding power to the tumor target structure such as antigen.

An ideal radiopharmaceutical for therapeutic purposes should:

•Act only on the cells of malignant tumors;

•Reach all the cells of malignant tumors wherever they are localized;

•Leave healthy tissues and organs unhurt while bringing maximum doses of radiation to the tumor; and

•Eliminate malignant tumor cells with great effectiveness.

Physical and biochemical characteristics of radiopharmaceuticals should be taken into consideration such as-

Physical Characteristics-

•Physical half life,

•Energy radiation,

•Type of emission daughter product,

•Production method,

•Radionuclide purity.

Biochemical characteristics-

•Tissue targeting,

•Radioactivity retention in the tumor,

• In-vivo stability,

• Toxicity,

• Effective half-life within the patient's body.

Advancements in nuclear medicine is been stimulated by introducing new radionuclides and

radiopharmaceuticals. The biological action of radiopharmaceutical is determined by the form of ionizing radiation emitted by the radionuclide. Alpha and beta(emit radiation) are used as radionuclides due to short penetrating power and also they release there energy within the target.

Beta particles-

Beta particles are produced by the beta decay process which facilitates the conversion of neutron to a proton creating an energetic electron(beta particle). They are negatively charged particles and have low linear energy transfer (LET) of approximately 0.2 KeV/μm. High energy beta particles, like 90Y and 188Re, can cause crossfire doses to neighbor cells. So, they are

preferable for higher volume solid tumors. For the small tumor, low-energy β-rays

such as lutetium-177 (^{177}Lu) is more efficient. The most commonly and frequently used beta particle is iodine-131 (^{131}I) for hyperthyroidism and thyroid cancers therapy.Samarium-153 (^{153}Sm) is a β-emitting radionuclide that is used in the treatment of breast and prostate cancer with bone metastases.

Auger electrons-

They are very short-range emissions, of the order of 1–1000 nm. Auger electron is intermediate (4–26 keV/μM) of LET. These emissions tend to be highly cytotoxic if the Radiopharmaceutical drug localizes within the cell nucleus. Bromine-77, indium-111, iodine-123, and iodine-125 are the most commonly used Auger electron emitters. Some in vitro experiments show highly effective and specific tumor cell killing when they are labeled with targeting vehicles that can localize these sub cellular-range radiations close to cellular DNA.

Alpha particles-

Alpha particles have same structure as 4 He nucleus without electrons (sometimes denoted as He2+). They are produced in alpha decay. Alpha particles- are more cytotoxic than beta particles. Ionization products of alpha particles are known to travel shorter distances as compared

to beta particles thereby, reducing damage to surrounding healthy cells. The effect is not dependent on dose and oxygen concentration during any cell cycle. Targeted alpha therapy (TAT) is a useful therapeutic option for multiple micro-metastases. Alpha particles can be attached to a biological molecule such as monoclonal antibodies with the help of bi-specific relating agent or a vector. Hence, RPT selectively delivers a high radiation dose directly to the target, with limited toxicity to the surrounding normal tissues.

Some α-particles are - bismuth-212 (^{212}Bi), bismuth-213 (^{213}Bi) and astatine-211 (^{211}At), actinium-225 (^{225}Ac), radium-223 (^{223}Ra) and thorium-227 (^{227}Th). $^{223}RaCl_2$ is the first alpha-emitting radiopharmaceutical for prostate and breast cancer patients' bone pain palliation. Bismuth-213 (^{213}Bi) and astatine-211 (^{211}At) labeled monoclonal antibodies treats leukemia and brain tumors.

Concept of therapy -

For effective treatment various alpha and beta radiation emitting isotopes are labelled with peptides or antibodies to target specific tumor used as vehicles to deliver ionizing radiations to the tumor tissue. For targeting molecular receptors different radioligands are being developed. For more therapeutic effect to target cells radionuclides are coupled with ligands to recognize and bind with the tumor associated molecules. Unlike radiotherapy, Radiopharmaceuticals are administrated intravenously to a target tumor. Radiopharmaceuticals helps in treating systemic malignancy in areas such as the bone or brain, which cannot be treated using external radiotherapy. The targeted tumor cell absorbs radiation dose which exponentially decreases with time.

Radiopharmaceuticals in treatment of cancer-[3][12][14]

Radiopharmaceutical therapy is used in the treatment of cancer. Radiopharmaceutical therapy can be targeted at tumors including metastasis sites. As compared to others, radiopharmaceutical therapy is more suitable as it does not require many cycles of therapy, like as in chemotherapy, side effects are also less severe in this. Alpha or beta particles and auger electrons are used for

therapy purposes. Radiopharmaceuticals are administered intravenously which attacks the target tumor. Some studies suggest that targeting radiation therapy at basic or cellular level has the potential to reduce the risk of both short and long term side effect of treatment while enabling any deposits of Cancer cells to be killed from the body. Once a radiopharmaceutical has been inserted with the cancer cell the radioactive compound naturally breaks down leading to the release of energy that damages the DNA of nearby cells. When the cell's DNA is damaged the cell dies , cancer cells are particularly sensitive to radiation induced DNA damage.

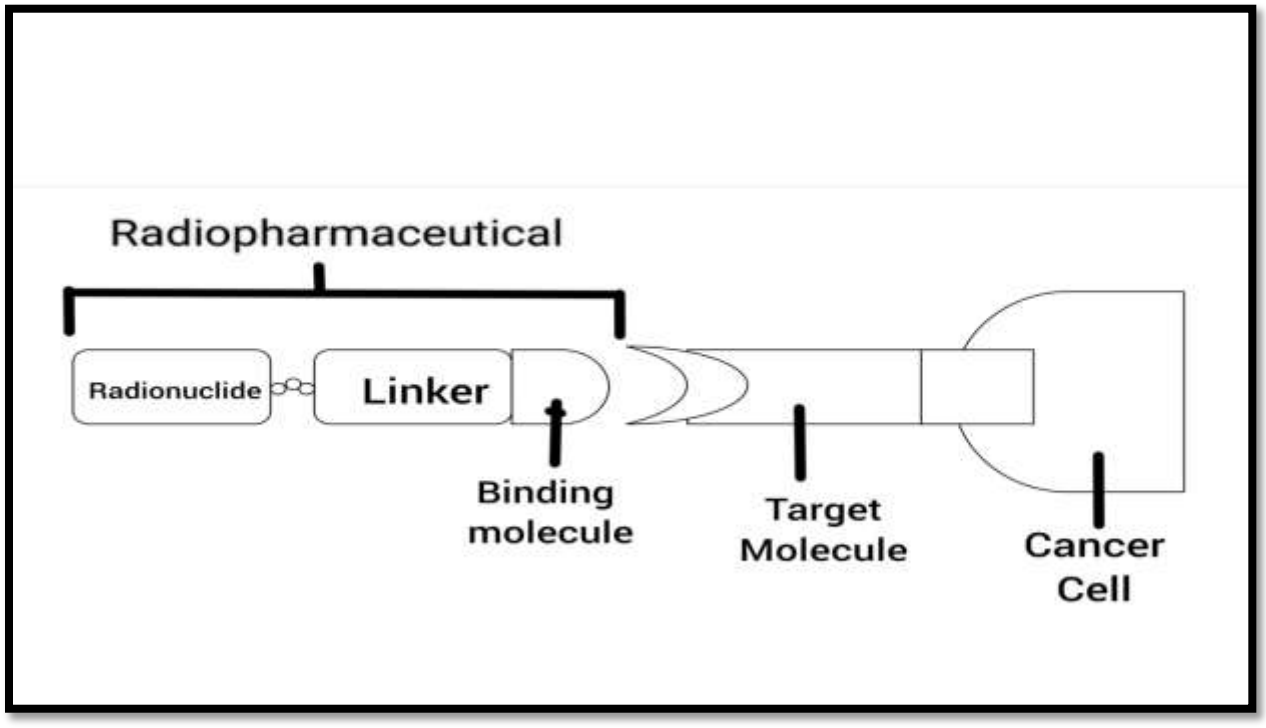

Fig. 1 Radioactive compound attacking cancer cell.

Radionuclides with alpha and beta emitting particles treat bulky solid tumors while radionuclides containing auger elements usually treats tiny cluster of Cancer cells.

These particles allow ionization radiation to be emitted by radionuclides linked to the carrier kill cancer cells by damaging their DNA, causing the tumors to shrink.

Among the radiopharmaceuticals approved by the U.S. Food and Drug Administration for treating cancers are:

•Radium-223 dichloride (Xofigo®) for metastatic prostate cancer in the bones,

•Sodium iodide I-131 (Hicon®) for thyroid cancer,

•Lobenguane iodine-131 (Azedra®) for adrenal gland tumors,

•Lutetium-177 (Lutathera®) for neuroendocrine tumors of the digestive tract,

•Yttrium-90 (Zevalin®) for non-Hodgkin lymphoma.

PRODUCTION OF RADIONUCLIDES

Radionuclides used in radiopharmaceuticals are artificially produced by the action of radioactive decay of other radioactive atoms. The preparation of radiopharmaceuticals involves three basic steps:

I. Production of the radionuclides,

II. Synthesis of the non-radioactive compound, and

III. Reaction of the radionuclide with the non-radioactive compound.

The chemical and isotopic composition of Target molecules is also taken into consideration while producing radionuclides.[16]

This production can be carried out by any of the following methods:-[15]

1. Radionuclide generator-

A radionuclide generator is a glass or plastic column (ion exchange column) which contains resin or alumina and the bottom of the column is filled with adsorbent material on which the parent nuclide is adsorbed. In radionuclide generators, sometimes known as “cows,” a

long-lived radionuclide, or “parent nuclide,” is present. This parent nuclide will eventually decay into a short-lived radionuclide of interest, or “daughter nuclide,”. It includes production of ^{68}Ga, ^{82}Rb, ^{99m}Tc and ^{113m}I radionuclide. It is a device that helps in the production of short lived radionuclide known as 'daughter' from the radioactive transformation of a non-medical long lived radionuclide called as 'parent'.

2. Nuclear fission-

This process causes the nucleus of an atom to split into two lighter nuclei. This

process is typically seen in nuclides with high atomic numbers, such as when Uranium-235 is fissioned in a nuclear reactor using neutrons. Either spontaneous nuclear fission or nuclear excitation can cause nuclear fission to occur.

During the fission process, a significant quantity of energy is released, resulting in the creation of radioactive materials and the emission of many neutrons. These neutrons have the potential to start a chain reaction by further inducing nuclear fission in neighbouring fissionable nuclei. The

tremendous amounts of energy that are then released as a result of this chain reaction have the potential to create an atomic bomb if left unchecked. Nuclear fission can produce radioisotopes in a laboratory setting that can be employed for diagnostic and/or therapeutic procedures. All individuals involved in such a regulated procedure must have had the necessary training, and it must be carried out inside of machinery intended to handle radioactive materials.

3. Charged particle bombardment-

In this method, target materials are bombarded with charged particles within particle accelerators like the cyclotron to create radionuclides.

4. Neutron bombardment-

In nuclear reactors, radionuclides are often created by blasting the target material with neutrons, which is similar to the procedure described above. In essence, the target material's purity, isotopic composition, and incoming particle energy all play a key part in causing the desired nuclear reaction.

TESTING OF RADIOPHARMACEUTICALS[17][18]

ACTIVITY CHECK

The extent of radioactivity that is to be administered have some limit to it. The limit is set by a committee or government bodies of different countries. The radioactive preparations or dosage forms are examined for their activity before administered to an individual.

In radio pharmacy radionuclide calibrators are used and more specifically the ionization chambers are employed. They work by taking the ionizing ability of the isotope and have scaling element for different radionuclides. The reading Is given in kBq or MBq or mCi but here is to note that these calibrators are not appropriate for all radionuclides.

In case of low energy releasing radiations , the radiations are weakened before reaching the gas chamber and may cause lack of precised readings. In the case of high energy beta radiations , the readings or measurement are based on Bremsstrahlung radiations produced. The calibrators have precision rate of approximately 2-5%. These calibrators must undergo strict QA supervision for accuracy against a long lived reference like Cobalt etc. A scintillation counter is used for determining the activity of X-ray and gamma rays emitting radionuclides. In this a scintillant crystal is present which produces a flash of light when a photon strikes it. Gamma rays can be best detected with Thallium activated sodium iodide crystals. Liquid scintillation is used to check the activity of beta rays emitters like hydrogen and carbon

RADIONUCLIDE IDENTIFYING

It can be identified by two methods:

- Measuring the half life of radionuclide :

A detector is used to measure half life. Multiple readings are taken at least for 3-4 times so that dead time losses are minimized. The readings are to be taken at similar geometrical conditions.

Graph is drawn with logarithm of instrument against time and with the help of it half life is calculated . The graphs of different readings should not differ by more than 5% from the half life mentioned in the pharmacopeia.

- By governing the energies of the radiations:

Different procedures are employed on the basis of the type of radiations that are emitted and their spectrum. For instance; Gamma spectroscopy is used in the determination of X-rays. The spectrum in which the radiations lie help in governing the type of nuclides present and in how much quantity.

RADIONUCLIDIC PURITY

In this the measured activity of the radiopharmaceutical is compared with the radioactivity of the nuclide. The amount of radionuclide impurities that are allowed is mentioned in pharmacopoeiae's monograph. It is measured in percentage. The impurities can lead to alteration in the biological responses produced by the radiopharmaceutical preparation. The impurities can be caused due to improper manufacturing process. For example; impurities can be produced by energy of reaction or due to the pre presence of contaminants in the cyclotron. Yttrium used in PET [Positron Emission Tomography] is result of reaction on a target of strontium protons with 16 Mev energy. If energy is increased to 30 MeV then it may target bones causing serious damage.

When a parent nuclide is present in stated nuclide which is obtained from a separation technique like generator elution , this can also give rise to impurities. For example; molybdenum in technetium solution. This could be lethal due to the beta emission of radionuclide and long half life [66 hours]. Gamma spectroscopy or half life determination is used in identification of radionuclide impurity.Theradionuclidic purity changes with time due to the contrast in the half lives of different radionuclides present in pharmaceutical preparations.

RADIOCHEMICAL PURITY [RCP]

RCP is the total radioactivity present in the radioactive pharmaceutical. RCP must be quick , accurate and economical. In recently introduced methods , thin layer and paper chromatography are on the move.

- Paper and thin layer chromatography:

In this strips of chromatography paper are introduced to microliter sample of radiopharmaceutical. It is then put into a container having small amount of solvent [e.g. 0.9% saline, methyl ethyl ketone etc.]. The solvent migrates up the strip. The constituents of radiopharmaceuticals gets separated based on their solubility in the solvent and extent of adsorption to the support media.

- Detection of radioactivity in the chromatographic strip:

The most easiest and quick method is by cutting the strip and counting the segments in the radionuclide calibrator or a scintillation counter.

For e.g. - strip is cut into two sections i.e. A and B

Then percentage if radioactivity is (A = A x 100/A+B)

But this method has higher chances of lack of accuracy and limited to low activity radiopharmaceuticals.

•A gamma camera can be used to image the strip. Count percentage in regions of strips can be determined. Relics of strips can be seen by imaging the chromatography. But this method is not economical for most users because of the camera used.

•Radiochromatograph scanner can be used in the analysis of the chromatography strips. It consist of sodium iodide detector to detect the radioactive rays. On a note it is unable in counting of certain isotopes like chromium due to low activity statistics.

•Phosphorous imaging is also employed in strip analysis. A latent image is accumulated in a phosphorous screen. The image shows the distribution of radioactivity in the strip. The screen is later scanned with a laser and the strength of radioactivity is detected. This can be further stored for future reference.

- Solid Phase Extraction:

Disposable cartridges with different bonded silica sorbents are accessible. The sorbent present in the cartridges has the ability to retain certain chemical compounds from the sample that is to be

analyzed. Elution of different solvents can be performed by employing different solvents based on their activity. Then the eluates having satisfactory activity can be counted in the radionuclide calibrator. It takes so less time that the RCP can also be determined just before dose administration to an individual or patient.

- High-Performance Liquid Chromatography [HPLC] :

HPLC separation works on the hydrophilic/lipophilic properties of the constituents. It has higher responsiveness and resolving power than simple TLC. Gamma radiation emitters can be detected using a well-scintillation counter that is further connected to a rate meter. For other detectors, they can be connected in series which helps in the identification of different compounds.

Licensed cold kits are important for performing HPLC in radiopharmaceuticals. It reduces the chances of any abnormal patient scan. HPLC do not find colloidal contaminants, instead TLC method is used.

- ELECTROPHORESIS

In electrophoresis, the components are separated on the basis of charge and size of radioactive molecules. The most persistent methodin radio-pharmacy is in the RCP determination of radio-labeled albumin in which a barbitone buffer is used into which the sample is run with the aid of a filter.

METHODS FOR ASSESSING PHARMACEUTICAL PARAMETERS

a. pH:

pH of the radiopharmaceuticals should be between a range of 5.5-8 . It is essential in determining the pH of PET radiopharmaceuticals because during the preparation of the formulation may reach extreme pH which may require neutralization.

pH can be determined by using pH paper and then comparing it to the calorimetric pH scale. In recent times micro pH papers are available which reads a drop of liquid [10 ul] that is further placed on the electrode.

b. VISUAL EXAMINATION:

Visual examination is an essential part of the testing of radiopharmaceutical preparations. This examination takes into consideration the radiation protection issues for the operator. The preparation is examined behind a suitable shielding.

These vials are examined for cracks, closures, etc, presence of glass particles in liquid, and particulate contamination are also analyzed. Syringes are also checked for particulate contamination.

c. APYROGENICITY:

This test is done to check the presence of pyrogens in the preparations. Pyrogens are bacterial endotoxins having polysaccharide cell membranes. Pyrogens are known for inducing fever and can cause leukopenia in immunosuppressed patients.Therefore it is important that the radiopharmaceuticals must be pyrogen-free.

The most known method is the Limulus amoebocyte lysate test. However, some studies suggest that radiopharmaceuticals may result in precipitation or interfere with the forming gel.

Advantages of Radiopharmaceuticals in Healthcare System- [15]

• It can be used for diagnosis and treatment of patients.

• It can provide fast onset of pain relief.

• It is common to cure cancer.

• Can treat multiple disease sites.

• Widely available mode of treatment.

• Directly treats tumors, especially useful for bone metastasis.

• Single dose is effective for some patients.

• Nuclear medicine tests can be performed on children.

• Nuclear medicine procedures have no side effects and are

completely safe.

Disadvantages of Radiopharmaceuticals in Healthcare System- [15]

• When multiple fractions are given, it may produce prolonged inconvenience and discomfort for patients.

• Higher doses of head and neck radiation can be associated with cardiovascular complications, thyroid dysfunction, and pituitary axis dysfunction.

• Nuclear medicine tests are non-recommended for pregnant women because unborn babies have a greater sensitivity to radiation than children or adults.

• Filling in the patient's teeth, dental braces, and permanent bridges may cause some distortion around the mouth area.

• Can produce some allergic reactions.

• It has a radiation risk.

• Myelosuppression may occur, especially with prior chemotherapy.

APPLICATIONS OF RADIOPHARMACEUTICALS[15]

1. Diagnostic application-

Radiation for diagnostic purposes must be strong enough to pass through tissues from inside the body to the detecting device. Some radioisotopes that are used for diagnosis are-

Iodine - 131

Phosphorus - 32 ($_{15}P^{32}$)

Chromium-51 ($_{24}Cr^{51}$)

Cobalt – 57 ($_{27}Co^{57}$) & Cobalt - 58 ($_{27}Co^{58}$)

Technetium-99m

For scanning and imaging purposes-

Optical imaging, brain imaging, gastrointestinal imaging, imaging of inflammatory lesions, cardiovascular imaging, bone imaging, lung imaging, spleen imaging, and renal imaging.

2. Radiotherapy-

It helps in the treatment of thyroidcarcinoma, cancer, bone tumors, neuroendocrine tumors, lymphomas,

•Radiopharmaceuticals for radiosynoviorthesis:

Radiosynoviorthesis or radiosynovectomy is a technique where a radiopharmaceutical is delivered into the affected synovial compartment (the interior of joints that is lubricated by fluid) of patients suffering from joint pain, as in the case of rheumatoid arthritis.

Phosphorus-32, yttrium-90, samarium-153, holmium-166, erbium-169, lutetium-177, rhenium-186, etc, are used in the treatment of joint pain.

•Therapeutic radiopharmaceuticals containing radionuclides such as strontium-89, samarium-153, and rhenium-186/188 are used for effective palliation of pain from skeletal metastases.

The development and clinical application of lutetium-177-based radiopharmaceuticals for bone pain palliation is also undergoing.

3. Sterilization techniques:

Radioisotopes are employed in radiation sterilization of heat-labile drugs like hormones, vitamins, antibiotics and surgical dressings, disposable syringes etc.,

Cobalt-60 ($_{27}Co^{60}$):This is used as a radiation source for sterilization by y-irradiation of disposable syringes, catheters and surgical dressings.

4. Research applications:

Radioisotopes are used in biochemical research for the determination of the mechanism of the reaction

lodine - 131: Sodium iodohippuric is used in determination of effective renal plasma flow.

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