

Impact of Radiopharmaceuticals in Healthcare System

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ABSTRACT

The radioactive agents used in the nuclear medical field are called radiopharmaceuticals. A radiopharmaceutical is a drug, that contains a radionuclide in the form of a simple salt or a complex. It may exist as a solid, liquid, gas or a pseudo gas. It is used in nuclear medicine for the diagnosis and therapy of many diseases. The chemical and physical identity and a form of a radiopharmaceutical are very important because in each case, once administered the radiopharmaceutical is intended to target certain tissues, binding sites, biochemical pathways. As the use of image has been increased, so has the use of prescription medications. These trends increase the risk of interactions between medications and radiopharmaceuticals. Many of the radiopharmaceuticals used for the diagnostic purpose, like C14 for pancreatic study and breath test, Cr51 used for red cell volume and GFR measurement, Co57 used for gastrointestinal absorption. In radiopharmaceuticals, technetium has a versatile activity due to its large usage. This review article describes the production of the radiopharmaceutical, types of radiation source used in healthcare, diagnostic imaging technique, the therapeutic application as well as advantage and disadvantage of radiopharmaceuticals or radiation therapy. The main aim of this review article is to describe how radiation source or radiopharmaceuticals affect the healthcare system.

Keywords: Radionuclides, Imaging technique, Technetium

INTRODUCTION

Radiopharmaceuticals As the name suggests, “radiopharmaceuticals” are preparations containing radioisotopes used in medicine either for diagnosis or treatment. However, radiopharmaceuticals differ from the regular pharmaceuticals in many aspects and this branch has grown into a specialty. Radiopharmaceuticals are most often prepared by radiolabelling a molecule with a radionuclide of choice, though in few cases, the inorganic ions themselves act as the radiopharmaceuticals such as radio-iodine and ^{99m}Tc-pertechnetate. Diagnostic radiopharmaceuticals are used for getting information for diagnostic purposes. This could be by the way of static imaging where the radiopharmaceutical is injected into the body (*in-vivo*), allowed to localize in the part of interest and then imaged to obtain data on the size, shape, location of tissues of interest. Some examples are imaging of organs such as liver, thyroid to find the occurrence and extent of damage, tumors to find out their exact location and size. Therapeutic radiopharmaceuticals are employed in a similar way, but with an aim to achieve a therapeutic effect. Hyperthyroidism, thyroid cancer, polycythemia vera

are a few disorders treated with radiopharmaceuticals. Depending on the usage, the radionuclide needs to be selected to give diagnostic information or therapeutic effect.

METHODOLOGY FOR PRODUCTION OF RADIONUCLIDES:-^(2,3,4,5,6,11,12,18)

Radionuclides used in radiopharmaceuticals are produced artificially by the radioactive decay of other radioactive atoms. This production can be carried out by any of the following methods.

1. RADIONUCLIDE GENERATOR:-

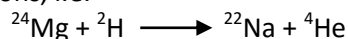
The radioisotope generator is an ion exchange column containing resin or alumina upon which a long-lived parent nuclide has been absorbed. Typical radionuclide generator is a glass or plastic column and the bottom of this is filled with adsorbent material on which parent nuclide is adsorbed. After the secular equilibrium that is after 4-5 half lives, the daughter nuclide growth is eluted in carrier free state with an appropriate solvent. It includes the production of ⁶⁸Ga, ⁸²Rb, ^{99m}Tc and ^{113m}I radionuclides, out of which ^{99m}Tc is of particular importance. Due to its ideal imaging energy and

physical half-life as well as the ability to bind to so many compounds, approximately 85% of all imaging procedures are performed following administrations of ^{99m}Tc . The versatile chemistry of technetium emerging from the 8 possible oxidation states, along with a proper understanding of structure-biologic activity relationship, has been exploited to yield a plethora of products meant for morphologic and functional imaging of different organs. Recent efforts have been directed toward the design of ^{99m}Tc . Labeled compounds for estimating receptor or transporter functions. A number of bi-functional chelating agents that provide ^{99m}Tc labeled proteins and peptides of high *in vivo* stability with high radiochemical yields have also been developed.

2. CYCLOTRON PRODUCED RADIONUCLIDES:-

The cyclotron and similar particle accelerators can be used only with charged particles such as electrons, protons and deuterons. This is because the operation of such machines depends upon the interaction of magnetic and/or electrostatic fields with the change of particles undergoing acceleration. A beam of charged particles is produced by accelerating ions around a widening circle using the magnetic field for control and electric current for acceleration. Various separation techniques are available to separate product from the target. It is required that chemical forms of target and product must be different to effect separation. It includes the production of positron emitting isotopes such as ^{11}C , ^{13}N , ^{15}O and ^{18}F . Cyclotron yields are dependent upon a number of target atoms, the energy of particles, the decay of product after it is formed, the length of irradiation and isotope enrichment of target.

An example of this method is production of ^{22}Na , where a target of ^{24}Mg is bombarded with deuterons, i.e.



A deuteron is the second most common isotope of hydrogen, i.e. ^2H . When it collides with a ^{24}Mg nucleus, a ^{22}Na nucleus plus an alpha particle is produced. The target is exposed to the deuterons for a period of time and is subsequently processed chemically in order to separate out the ^{22}Na nuclei.

3. PILE PRODUCED ISOTOPE:-

Most of the radioactive materials produced today for use in industry, academic research and medicine are produced in a nuclear pile (nuclear reactor). Uranium fission reaction produces a large supply of neutrons. One neutron for each uranium atom, undergoing fission is used to sustain the reaction. The remaining neutrons are used either to produce plutonium or used to produce radioactive products by causing the neutrons to interact with specific substances, which have been inserted into the pile, the latter process being known as neutron activation. Production of ^{133}Xe , ^{99}Mo and ^{131}I is carried out by this method.

4. THERMAL NEUTRON REACTOR-PRODUCED RADIOISOTOPE:-

For thermal neutron reactor-produced radioisotopes, the reactor is a source of thermal neutrons. An (n, gamma) reaction occurs. It causes an increase in atomic weight by one and no change in atomic number. The same element is therefore present.

E.g. ^{98}Mo after reaction produces ^{99}Mo .

COMMONLY USED RADIATION SOURCES:- (2,4,11,12,18)

There are many radiation sources used in the healthcare system. The three main divisions of radiation therapy are external beam radiation therapy (EBRT or XRT) or teletherapy, brachytherapy or sealed source radiation therapy, and systemic radioisotope therapy or unsealed source radiotherapy. The differences relate to the position of the radiation source; external is outside the body, brachytherapy uses sealed radioactive sources placed precisely in the area under treatment, and systemic radioisotopes are given by infusion or oral ingestion.

EXTERNAL BEAM RADIATION:-

The radiation is beamed into the tumor from outside the body for approximately two to three minutes for each treatment. External beam radiotherapy (EBRT) or teletherapy is the most common form of radiotherapy. The patient sits or lies on a couch and an external source of ionizing radiation is pointed at a particular part of the body. In contrast to internal radiotherapy (brachytherapy), in which the radiation source is inside the body,

external beam radiotherapy directs the radiation at the tumor from outside the body.

IMAGE-GUIDED, INTENSITY-MODULATED RADIATION THERAPY:-

Intensity-modulated radiation therapy (IMRT) is used to treat patients with prostate cancer, cancers of the head and neck, and cancer at the base of the skull or parts of the brain. IMRT allows the tumor to be targeted with higher doses of radiation, particularly in the vicinity of critical structures, with greater potential for a cure and greater likelihood of limiting late complications from treatment. The incorporation of image-guided technology with IMRT allows doctors to track tumor position and location while the patient is actually on the treatment table. Image-guided IMRT affords more precise coverage, allowing doctors to respond immediately to any tumor movement and, if necessary, to recalculate the radiation fields during the treatment session.

STEREOSTATIC RADIOSURGERY:-

A precise, single dose of radiation is delivered in cases where tumors of the brain are adjacent to critical areas, such as the brainstem, eyes or optic nerves. Stereotactic radiosurgery further minimizes the side effects associated with conventional radiation. A neurosurgeon is present during treatment to attach a halo-like frame to the scalp to assist with proper positioning. CyberKnife is a robotic system for stereotactic radiosurgery.

STEREOSTATIC RADIOTHERAPY:-

Similar to stereotactic radiosurgery, lower doses of focused radiation are delivered with pinpoint accuracy during a series of treatment sessions that usually last between eight to 10 days. This method of multiple treatments is called "fractionation." During treatment, a halo-like frame held in place by a mouthpiece helps position the head for treatment.

VIRTUAL SIMULATION, AND 3-DIMENSIONAL RADIATION THERAPY :-

The planning of radiation therapy treatment has been revolutionized by the ability to delineate tumors and adjacent normal structures in three dimensions using specialized CT and/or MRI scanners and planning software.

Virtual simulation, the most basic form of planning, allows more accurate placement of radiation beams than is possible using conventional X-rays, where soft-tissue structures are often difficult to assess and normal tissues difficult to protect.

An enhancement of virtual simulation is 3-dimensional conformal radiation therapy (3DCRT), in which the profile of each radiation beam is shaped to fit the profile of the target from a beam's eye view (BEV) using a multileaf collimator (MLC) and a variable number of beams. When the treatment volume conforms to the shape of the tumor, the relative toxicity of radiation to the surrounding normal tissues is reduced, allowing a higher dose of radiation to be delivered to the tumor than conventional techniques would allow.

VOLUMETRIC MODULATED ARC THERAPY (VMAT):-

Volumetric modulated arc therapy (VMAT) is a new radiation technique, which can achieve highly conformal dose distributions on target volume coverage and spare of normal tissues. The specificity of this technique is to modify the three parameters during the treatment. VMAT delivers radiation by rotating gantry (usually 360° rotating fields with one or more arcs), changing speed and shape of the beam with a multi-leaf collimator (MLC) ("sliding window" system of moving) and fluence output rate (dose rate) of the medical linear accelerator. VMAT also has the potential to give additional advantages in patient treatment, such as reduced delivery time of radiation, compared with conventional static field intensity modulated radiotherapy (IMRT).

PARTICLE THERAPY:-

In particle therapy (proton therapy being one example), energetic ionizing particles (protons or carbon ions) are directed at the target tumor. The dose increases while the particle penetrates the tissue, up to a maximum (the Bragg peak) that occurs near the end of the particle's range, and it then drops to (almost) zero. The advantage of this energy deposition profile is that less energy is deposited into the healthy tissue surrounding the target tissue.

AUGER THERAPY:-

Auger therapy (AT) makes use of a very high dose of ionizing radiation in situ that provides molecular modifications at an atomic scale. AT differs from

conventional radiation therapy in several aspects; it neither relies upon radioactive nuclei to cause cellular radiation damage at a cellular dimension nor engages multiple external pencil-beams from different directions to zero-in to deliver a dose to the targeted area with reduced dose outside the targeted tissue/organ locations. Instead, the in situ delivery of a very high dose at the molecular level using AT aims for in situ molecular modifications involving molecular breakages and molecular rearrangements such as a change of stacking structures as well as cellular metabolic functions related to the said molecule structures.

TOTAL BODY IRRADIATION (TBI):-

Patients who are awaiting a bone-marrow or stem-cell transplant can receive this important preparatory treatment. When combined with chemotherapy, TBI is used to suppress the immune system and eliminate any pre-existing tumor cells. TBI treatments can last anywhere from 20 to 60 minutes. Additional time may be needed for treatment planning and simulation. The specific amount of radiation the doctor prescribes is divided into a number of doses and may be given one or more times a day for one to four days, depending on the individual case. A specially designed stand may be used for support during treatment. The stand includes a bicycle seat and hand grips for support. Alternatively, a patient may be treated lying on a stretcher.

PROSTATE SEED IMPLANTS (BRACHYTHERAPY):-

An advanced form of radiation therapy, also called brachytherapy, uses radioactive seed implants to treat early prostate cancer. In this minimally invasive procedure, doctors use ultrasound-guided needles to insert tiny radioactive seeds (Iodine 125 or Palladium 103) into the prostate gland. The seeds emit low-energy gamma rays that specifically target cancer cells in the prostate. The seeds lose 90 percent of their radioactivity within a few months following the implant, and within a year they are considered inert or not active.

DEEP INSPIRATION BREATH-HOLD:-

Deep inspiration breath-hold (DIBH) is a method of delivering radiotherapy while limiting radiation exposure to the heart and lungs. It is used primarily

for treating left-sided breast cancer. The technique involves a patient holding their breath during treatment. There are two basic methods of performing DIBH: free-breathing breath-hold and spirometry-monitored deep inspiration breath hold.

DIAGNOSTIC IMAGING TECHNIQUES:- ^(4,8,11,15)

CT (Computer tomography):-

The principal of CT is the measuring of the spatial distribution of physical material to be examined from different directions and to compute superposition free images from this data. It is basically a technique of X-ray photography by which a single plane of a patient is scanned from various angles in order to provide a cross-sectional image of the internal structure of that plane. A CT scan has many diagnostic clinical applications. It improves the diagnosis accuracy by delineating details of the organs including soft tissues and bones. CT scan can provide information about the spread of an infection or tumors to different body parts and can assist surgical interventions, biopsies, and radiotherapies.

MRI (Magnetic resonance imaging):-

An MRI is similar to a computerized topography (CT) scanner in that it produces cross-sectional images of the body. Looking at images of the body in cross section can be compared to looking at the inside of a loaf of bread by slicing it. Unlike a CT scan, MRI does not use X-rays. Instead, it uses a strong magnetic field and radio waves to produce very clear and detailed computerized images of the inside of the body. MRI is commonly used to examine the brain, spine, joints, abdomen, and pelvis. A special kind of MRI exam, called Magnetic Resonance Angiography (MRA), examines the blood vessels.

ECHOGRAPHY/ULTRASOUND:-

Ultrasound uses high-frequency sound waves to look at organs and structures inside the body. Health care professionals use them to view the heart, blood vessels, kidneys, liver and other organs. During pregnancy, doctors use ultrasound tests to examine the fetus. Unlike x-rays, ultrasound does not involve exposure to radiation. During an ultrasound test, a special technician or doctor moves a device called a transducer over part of your body. The transducer sends out sound waves, which bounce off the tissues inside your body. The transducer also captures the

waves that bounce back. Images are created from these sound waves.

NUCLEAR MEDICINE:-

Nuclear medicine is a mainly medical diagnostic discipline for imaging metabolism and other functional processes in the human body. Prior to the imaging process, a radioactively labeled tracer is administered to the patient. The strength of the technique lies in the fact that substances move to organ systems in very selective ways. Labeling these substances to radioactive tracers (particular technetium) enables imaging of the distribution of such substances in the human body with the aid of gamma cameras or PET scanners. Three different modalities are available for this process: planar scintigraphy, SPECT (single photon emission computed tomography) and PET (positron emission tomography).

PLANAR SCINTIGRAPHY:-

It is the simplest available technique, yielding a two-dimensional projection image of tracer activity distribution in the human body. The technique is based on gamma radiation that is created in the decay process of a radionuclide.

SPECT (single-photon emission computed tomography):-

It was developed on the basis of planar imaging, which involves gamma cameras taking series of planar shots during rotations around the patient. It generates three-dimensional images of nuclear activity distribution, enabling the physician to view activity distributions in cross-sections of the human body.

PET (positron emission tomography):-

It has entered clinical practice in the last few decades. PET is an imaging technique whereby a radioactive isotope (a PET radionuclide) is administered into the patient's body. During decay, the isotope produces positrons (particles with the mass of electrons but with a positive charge). Electron and positron interaction causes the annihilation of both particles, releasing energy in the form of two gamma photons. The resulting gamma rays are detected by a ring of hundreds of detectors.

INTRACAVITARY THERAPY:-

The direct intra-cavitary administration is a means of delivering in radiopharmaceuticals in high concentration to tumors that are spread out over the serosal linings of cavities and tumors cell presence in the malignant effusions. In order to minimize leakage of the radionuclide from the cavity, it is usually given in the form of radio colloid. Intracavitary therapy is applied to the peritoneal, pleural and pericardial cavities as well as to cystic brain tumors and to the spinal canal. Colloidal ^{198}Au was formerly the most widely used agent, but the radionuclide emits unwanted gamma radiation, leading to unnecessary exposure of non-target tissue within the patient. The agents of choice are now ^{32}P and ^{90}Y radio colloids, with perhaps radio, labeled antibodies having a wider role to apply in the future.

IMAGING STATUS:- ^(4,8,11)

In recent years, scanning techniques have developed rapidly and are now among the most useful tools in diagnostic medicines. By means of scanning, tissues and organs can be visualized and such visualization facilitates the detection of abnormalities in their function. Radioactive materials are administered to the individual and distribution of the radioactive material in the body is measured by using imaging techniques.

CARDIOVASCULAR IMAGING:-

Radiopharmaceuticals are useful in cardiac imaging as agents that provide information of regional myocardial blood perfusion. There administered to provide information at peak cardiac output. The study involves stressing the patient with exercise in a treadmill or giving i.v. injection of dipyridamole. An injection of thallium chloride or technetium-99m ($^{99\text{m}}\text{Tc}$) labeled methoxy isobutyl isonitrile is then given an imaging is carried out.

BONE IMAGING:-

This method widely used in the diagnosis of benign and malignant, primary and metastatic bone tumors. Bone imaging radiopharmaceuticals consist of diagnostic (primarily single photon emitters) and therapeutic agents. The therapeutic radiopharmaceuticals are utilized on the basis of their particulate emissions (primarily Beta) and those are treated differently than the single photon bone

imaging agents. For the *in vivo* studies, ^{99m}Tc labeled polyclonal human immunoglobulin (^{99m}Tc -HIG) was used as the radiopharmaceutical to demonstrate arthritic lesions by gamma scintigraphy. After the induction of arthritis in knee joints of rabbits, the radio-labeled microspheres loaded with DS were injected directly into the articular cavity and gamma scintigrams were obtained at periodic intervals to find the residence time of microspheres in the knee joints in order to determine the most suitable formulation.

LUNG IMAGING:-

The main purpose of the lung imaging is the diagnosis of pulmonary emboli and to evaluate pulmonary perfusion and pulmonary ventilation, and to assess pulmonary function prior to pneumonectomy. The agent used is ^{99m}Tc macro aggregated albumin. Iseri et al. prepared albumin and gelatin micro sphere incorporating a tuberculostatic agent, rifampicin and its *in vivo* distribution were studied by causing its accumulation in the target organ, i.e., lung bio-distribution was determined by intravenous administration of particles of 25-27 microns ^{99m}Tc – labeled microspheres to Swiss mice. The radioactivity of lungs was compared with that of the liver, spleen, kidney, stomach, and heart. The percentage accumulation was higher in the lungs than in the other organs for both albumin and gelatin microspheres.

RENAL IMAGING:-

This is used to determine renal function, renal vascular flow, and renal morphology. These are also used for evaluation of renal transplant patients for complication such as obstruction, infarction, leakage, tubular, necrosis and rejection. ^{99m}Tc – diethylenetriaminepentaacetic acid and ^{131}I -iodohippurate are commonly used radiopharmaceuticals.

SPLEEN IMAGING:-

Radiopharmaceuticals are used for spleen imaging for various purposes. Spleen imaging is performed by using ^{99m}Tc -denatured erythrocytes. After a blood sample is withdrawn from the patient, the erythrocytes are labeled with ^{99m}Tc *in vitro*; the labeled cells are denatured by heating at 49.5° for

15 min following reinjection into the patient, the cells are then taken off by the spleen. Imaging with ^{99m}Tc -denatured erythrocytes is used to detect spleen nucleus.

IMAGING OF INFLAMMATORY LESIONS:-

Scintigraphic imaging of inflectional inflammation is a powerful diagnostic tool in the management of patients with infectious or inflammatory diseases. Many radiopharmaceuticals have been introduced for the scintigraphic demonstration of infectious and inflammatory lesions. They can be classified into two major categories according to their specificity. Specific radiopharmaceuticals include *in vitro* labeled leukocytes, radio-labeled monoclonal antibodies, and receptor specific small proteins and peptides. Nonspecific radiopharmaceuticals include radio-labeled nano-colloids, liposomes, macromolecules such as human immunoglobulin, dextran and human serum albumin.

GASTROINTESTINAL IMAGING:-

Latex particles coated with either amino or carboxyl group can be efficiently labeled with ^{99m}Tc and used in the studies of gastrointestinal function. ^{99m}Tc -labeled mono-disperse latex particles coated with amino or carboxyl groups for studies of GI function.

BRAIN IMAGING:-

Brain imaging is performed using radiopharmaceuticals by single photon emission computed tomography (SPECT) and positron emission tomography (PET). SPECT and PET radiopharmaceuticals are classified according to blood-brain-barrier (BBB) permeability, cerebral perfusion and metabolism receptor-binding, and antigen antibody binding. The blood brain barrier SPECT agents, such as ^{99m}Tc -DTPA, ^{201}Ti and ^{67}Ga -citrate are excluded by normal brain cells but enter into tumor cell because of altered BBB. The radiopharmaceuticals uptake into tumor cells was rapid and temperature and pH-dependent. The radioactivity concentration in tumor cells varied from 10 to 33% of the total activity following 30min incubation at 37° (pH 7.4). In comparison, accumulation of the radiopharmaceuticals into the normal brain and pancreatic tissue remained relatively low.

Imaging of brain tumors require a disrupted BBB, however, it is intact in the early stages of brain tumor growth, when the diagnosis is most critical. Relative to normal brain, brain tumor cells frequently over express peptide receptors, such as the receptor for epidermal growth factor (EGF). Peptide radiopharmaceuticals such as radio labeled EGF could be used to image early brain tumors.

OPTICAL IMAGING:-

Optical imaging is a technique based on interference and the bending of light that is fired onto a body or tissue from a laser or infrared light source. The body is injected with proteins marked by, for example, a fluorescent marker. Optical imaging may be subdivided into diffusion and ballistic imaging systems. Since the penetrability of the body in relation to light is relatively small, optical imaging is unsuitable in certain contexts, for example, organ examinations.

⁽¹⁴⁾There are also another several imaging statuses which are shortly described below.

Tumor Imaging - Evaluation location and spread of tumor and evaluation of metabolic tumor.

eg- Ga-67, F-18FDG

Receptor Imaging- Peptide based imaging designed to bind to a receptor within the body.

Infection Imaging- Localize internal sources of infection.

Eg- Tc-99m, Ga-67

THERAPEUTIC APPLICATIONS OF RADIOPHARMACEUTICALS ^(1,3,4,7,9,11,13)

Today, nuclear medicine offers nearly one hundred procedures that are immensely helpful to a broad span of medical specialties ranging from oncology and cardiology to psychiatry due to which several millions of patients benefit annually, all over the world. Health care applications of radioisotopes are several and can be widely classified Diagnostic and Therapeutic. Some therapeutic applications are described below.

TREATMENT OF HYPERTHYROIDISM:-

¹³¹I-iodine is used extensively for the treatment of hyperthyroidism. Upon oral administration of the radionuclide, approximately 60% of the radioactivity

is taken up by the overactive gland. The principal disadvantage of the radioiodine therapy is the high incidence of early and late hypothyroidism, making it necessary to monitor patients adequately during treatment. As a consequence, treatment is no longer restricted to older patients and now adolescents and even children, being treated with radio iodine.

TREATMENT OF THYROID CARCINOMA:-

Radioiodine has been used for several decades in the treatment of differentiated thyroid carcinoma, a tumor which metastases to bone, lungs and other soft tissues. However, it is slow growing and the prognosis is relatively good, allowing long term follow up treated patients. Repeating radionuclide imaging with radioiodine can assess response to therapy and, if necessary, further therapeutic dosages of ¹³¹I may be required in advanced or resistant cases.

TREATMENT OF NEUROENDOCRINE TUMORS:-

Metaiodobenzyleguanidine is similar in structure to the adrenergic neuron blocker guanethidine and the neurotransmitter noradrenaline. Due to the structural similarity, it is taken off by the adrenal medulla and other tissues with rich sympathetic innervations but unlike nor-adrenaline it is not metabolized and is largely excreted unchanged in the urine. ¹³¹I-metaiodobenzyleguanidine (¹³¹I-MIBG) has been used with success in the treatment of neuroendocrine tumors such as neuroblastoma, carcinoid tumors, and medullary carcinoma of the thyroid. Several other agents are being investigated as alternatives to ¹³¹I-MIBG and include ¹⁶¹Terbium-diethylenetriaminepentaacetic acid-octreotide and ¹¹¹Indium-diehylnetriaminepentaacetic acid (¹¹¹In-DTPA) for tumors containing somatostatin receptors.

TREATMENT OF BONE TUMORS:-

Bone metastases are a common finding in patients suffering from cancers of the prostate, breast and lungs, and in these patients control of bone pain is a significant clinical problem. External beam radiotherapy, in combination with analgesic drugs, remains the mainstay of treatment but the proportion of the body that can be treated is limited. Several beta emitting radionuclides, in a variety of chemical forms, can be used for the treatment of

bone metastases. ^{32}P , ^{89}Sr , 186-Rhenium and 153-Samarium have been carried out.

TREATMENT OF MYELOPROLIFERATIVE DISEASE:-

^{32}P has been used for more than 50 years in the treatment of a variety of hematological disorders. Following intravenous injection, ^{32}P as the orthophosphate is concentrated selectively by rapidly proliferating tissue and there is also bone uptake. In this way, a significant radiation dose is delivered to the bone marrow and results in growth retardation of the hematopoietic cell lines. The primary application of ^{32}P is in the treatment of polycythemia rubra vera. In this condition, there is an abnormal increase in the number of red cells in the circulation. However, treatment with phlebotomy, radioactive phosphorus or chemotherapy all results in significant increase in life expectancy.

ADVANTAGES OF RADIOPHARMACEUTICAL IN HEALTHCARE SYSTEM ^(16,17,19)

It can be used as diagnosis and treatment of the patient.

- 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 the tumor, especially useful for bone metastasis.
- A 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 RADIOPHARMACEUTICAL IN HEALTHCARE SYSTEM ^(16,17,19)

- When multiple fractions are given, it may produce prolonged inconvenience and discomfort for patients.
- Higher doses of the head and neck radiation can be associated with cardiovascular complication, thyroid dysfunction and pituitary axis dysfunction.
- Nuclear medicine tests are not recommended for pregnant women because unborn babies have a greater sensitivity to radiation than children or adults.
- Filling in 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.

RESULT

In the present era, there is an important role of radiopharmaceutical due to its correct and effective diagnosis of disease, advances in all imaging modalities changing the pattern of diagnostic imaging. Nowadays, the modern healthcare system will not be perfect without radiation source because of its effectiveness. Due to its large use in the healthcare system, there is also a risk of interaction of medication and radiopharmaceuticals.

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