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### ASSIGNMENT QUESTION:

### What are Radioactive Tracers?

### Discuss one application of tracers in medicine?

1. Radioactive tracers
 A **radioactive tracer** is a chemical compound in which one or more atoms have been replaced by a radioactive atom or radionuclide so by virtue of its radioactive decay it can be used to explore the mechanism of chemical reactions by tracing the path that the radioisotope follows from reactants to products.

 Radioactive tracers are made up of carrier molecules that are bonded tightly to a radioactive atom. These carrier molecules vary greatly depending on the purpose of the scan. Some tracers employ molecules that interact with a specific protein or sugar in the body and can even employ the patient’s own cells.

For most diagnostic studies in nuclear medicine, the radioactive tracer is administered to a patient by intravenous injection. However a radioactive tracer may also be administered by inhalation, by oral ingestion, or by direct injection into an organ. The mode of tracer administration will depend on the disease process that is to be studied.



*Researchers demonstrate that combined PET/CT (right) of a mouse provides a more complete view of the spine than CT (left) or PET (middle) alone.*

Approved tracers are called radiopharmaceuticals since they must meet FDA’s exacting standards for safety and appropriate performance for the approved clinical use. The nuclear medicine physician will select the tracer that will provide the most specific and reliable information for a patient’s particular problem. The tracer that is used determines whether the patient receives a SPECT or PET scan.

 SPECT (Single Photon Emission Computed Tomography)

 SPECT imaging instruments provide three-dimensional (tomographic) images of the distribution of radioactive tracer molecules that have been introduced into the patient’s body. The 3D images are computer generated from a large number of projection images of the body recorded at different angles. SPECT imagers have gamma camera detectors that can detect the gamma rays emissions from the tracers that have been injected into the patient. Gamma rays are a form of light that moves at a different wavelength than visible light. The cameras are mounted on a rotating gantry that allows the detectors to be moved in a tight circle around a patient who is lying motionless on a pallet. SPECT scans are primarily used to diagnose and track the progression of heart disease, such as blocked coronary arteries. There are also radiotracers to detect disorders in bone, gall bladder disease and intestinal bleeding.

 PET (Positron Emission Tomography)

PET scans also use radiopharmaceuticals to create three-dimensional images. A positron is a particle with roughly the same mass as an electron but oppositely charged. These react with electrons in the body and when these two particles combine they annihilate each other. This annihilation produces a small amount of energy in the form of two photons that shoot off in opposite directions. The detectors in the PET scanner measure these photons and use this information to create images of internal organs. The major purpose of PET scans is to detect cancer and monitor its progression, response to treatment, and to detect metastases. A combination instrument that produces both PET and CT (Computed Tomography) scans of the same body regions in one examination (PET/CT scanner) has become the primary imaging tool for the staging of most cancers worldwide.

 The main difference between SPECT and PET scans is the type of radiotracers used. While SPECT scans measure gamma rays, the decay of the radiotracers used with PET scans produce small particles called positrons.

Over 10,000 hospitals worldwide use radioisotopes in medicine, and about 90% of the procedures are for diagnosis. The most common radioisotope used in diagnosis is technetium-99 (Tc-99), with some 40 million procedures per year, accounting for about 80% of all nuclear medicine procedures and 85% of diagnostic scans in nuclear medicine worldwide.

In developed countries (26% of world population) the frequency of diagnostic nuclear medicine is 1.9% per year, and the frequency of therapy with radioisotopes is about one-tenth of this. In the USA there are over 20 million nuclear medicine procedures per year, and in Europe about 10 million. In Australia there are about 560,000 per year, 470,000 of these using reactor isotopes. The use of radiopharmaceuticals in diagnosis is growing at over 10% per year.

 Risk of using Radioactive Tracers

Radioactive tracers utilize the positive qualities of radioactivity, the ability to emit a signal, while minimizing the negative effects. The total radiation dose conferred to patients by the majority of radiopharmaceuticals used in diagnostic nuclear medicines studies is no more than what is conferred during routine chest x-rays or CT exams. There are legitimate concerns about possible cancer induction even by low levels of radiation exposure from cumulative medical imaging examinations, but this risk is accepted to be quite small in contrast to the expected benefit derived from a medically needed diagnostic imaging study.

Like radiologists, nuclear medicine physicians are strongly committed to keeping radiation exposure to patients as low as possible, giving the least amount of radiotracer needed to provide a diagnostically useful examination.

 Isotopes use elements with a short half-life to reduce the dangers of radioactive exposure to the patient. A half-life represents the amount of time it takes for one-half of a substance's radioactivity to decay. For example, a material with a half-life of six hours will lose half of its radioactivity in six hours and then another one-half at the 12-hour mark, leaving one-fourth of its strength. The shorter the half-life the less radioactive exposure.

Examples of Tracers Isotope

1. Hydrogen: Tritium is produced by neutron irradiation of 6Li

6Li + n → 4He+ 3H

Tritium has a half-life of 4,500±8 days (approximately 12.32 years) and it decays by beta decay

1. Nitrogen: 13N decays by positron emission with a half-life of 9.97 min. It is produced by the nuclear reaction. It is used in PET scan.

1H+ 15O → 13N + 4He

1. Fluorine**:** 18F decays by emission with a half-life of 109 min. It is made by proton bombardment of 18O in a cyclotron or LINAC (Linear Accelerator). It is an important isotope in the radiopharmaceutical industry
2. Calcium: 11C decays by positron emission with a half-life of ca. 20 min. 11C is one of the isotopes often used in PET scan. 14C decays by beta-decay, with a half-life of 5730 years.
3. Technetium: 99mTC is a very versatile radioisotope, and is the most commonly used radioisotope tracer in medicine. It is easy to produce in a technetium-99m generator, by decay of 99MO.

99MO → 99mTC+ e- + v

1. Oxygen**:** 15O decays by positron emission with a half-life of 122 sec. It is used in positron emission tomography.

Properties of Tracers Isotope

Using the Technetium-99m (99mTC) which is a commonly-used radioactive tracer isotope. The isotope undergoes gamma decay with a half-life of less than a day, making it feasible for deep-tissue applications like imaging the circulatory system. In such experiments, the tracer is injected into the patient’s tissue and allowed to circulate while a radiation detector is held outside the body. Careful imaging allows the shape and flow characteristics of various parts of the circulatory system to be imaged. For example, in cases where doctors need to know the exact source of intestinal bleeding, they may radiolabel (add radioactive atoms) to a sample of red blood cells taken from the patient. They then re inject the blood and use a SPECT scan to follow the path of the blood in the patient. Any accumulation of radioactivity in the intestines informs doctors of where the problem lies.

### APPLICATIONS OF TRACERS IN MEDICINE

There are so many applications of tracers in medicine. Some of them are:

1. Nuclear medicine diagnosis
2. Diagnostic radiopharmaceuticals
3. Nuclear medicine therapy
4. Sterilization
5. Therapeutic radiopharmaceuticals

NUCLEAR MEDICINE THERAPY

Radioactivity is used for treatment of cancer. The

radiations when absorbed by the tissues, produce

ionization in the path. The nucleic acid in the cell is

damaged, so that the next cell division is not

possible. The radiotherapy is mainly affecting the

cells in the division phase. Since cancer tissue

contains more dividing cells than the normal tissue,

cancer cells are preferentially affected by radiation.

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The radiotherapy may be classified as:

The uses of radioisotopes in therapy are comparatively few, but nevertheless important. Approximately 10% of medical procedures use radiation to treat a variety of diseases, including many types of cancers, heart disease, gastrointestinal, endocrine, neurological disorders and other abnormalities within the body. Radioactivity is used for the treatment of cancer. The cancerous growths are sensitive to damage by radiation because when the tissues absorb radiation, they produce ionization in their path. The nucleic acid in the cell is damaged so that the next cell division is not possible. The radiotherapy is mainly affecting the cells in the division phase. Since cancerous tissues contain more dividing cells than the normal tissues, cancerous growths can be controlled or eliminated by irradiating the area containing the growth.

The radiation can be in the form of:

* External irradiation: sometimes called Tele therapy, can be carried out using a gamma beam from a radioactive cobalt-60 source, though in developed countries the much more versatile linear accelerators are now being used as high-energy X-ray sources (gamma and X-rays are much the same). An external radiation procedure is known as gamma knife radiosurgery, and involves focusing gamma radiation from 201 sources of Co-60 on a precise area of the brain with a cancerous tumor. Worldwide, over 30,000 patients are treated annually, generally as outpatients. Tele therapy is effective in the ablation of tumors rather than their removal; it is not finely tuned.
* Internal irradiation: also called internal radionuclide therapy is administered by planting a small radiation source, usually a gamma or beta emitter, in the target area. Short-range radiotherapy is known as brachytherapy, and this is becoming the main means of treatment. Iodine-131 is commonly used to treat thyroid cancer, probably the most successful kind of cancer treatment. It is also used to treat non-malignant thyroid disorders. Iridium-192 implants are used especially in the head and breast. They are produced in wire form and are introduced through a catheter to the target area. After administering the correct dose, the implant wire is removed to shielded storage. Permanent implant seeds (40 to 100) of iodine-125 or palladium-103 are used in brachytherapy for early stage prostate cancer. Alternatively, needles with more-radioactive Ir-192 may be inserted for up to 15 minutes, two or three times. Brachytherapy procedures give less overall radiation to the body, are more localized to the target tumor, and are cost-effective.
* Treating leukemia may involve a bone marrow transplant, in which case the defective bone marrow will first be killed off with a massive (and otherwise lethal) dose of radiation before being replaced with healthy bone marrow from a donor.
* Many therapeutic procedures are palliative, usually to relieve pain. For instance, strontium-89 and (increasingly) samarium-153 are used for the relief of cancer-induced bone pain. Rhenium-186 is a newer product for this.
* Lutetium-177 dotatate or octreotate is used to treat tumors such as neuroendocrine ones, and is effective where other treatments fail. A series of four treatments delivers 32 GBq. After about four to six hours, the exposure rate of the patient has fallen to less than 25 micro Sieverts per hour at one meter and the patients can be discharged from hospital. Lu-177 is essentially a low-energy beta-emitter (with some gamma) and the carrier attaches to the surface of the tumor.
* A new field is targeted alpha therapy (TAT) or alpha radio immunotherapy, especially for the control of dispersed (metastatic) cancers. The short range of very energetic alpha emissions in tissue means that a large fraction of that radioactive energy goes into the targeted cancer cells, once a carrier such as a monoclonal antibody has taken the alpha-emitting radionuclide such as bismuth-213 to the areas of concern. Clinical trials for leukemia, cystic glioma, and melanoma are underway. TAT using lead-212 is increasingly important for treating pancreatic, ovarian, and melanoma cancers.
* Radionuclide therapy has progressively become more successful in treating persistent disease and doing so with low toxic side-effects. With any therapeutic procedure the aim is to confine the radiation to well-defined target volumes of the patient. The doses per therapeutic procedure are typically 20-60 Gy.