Molecular imaging of radioactive material, safety guidelines

Course Code –BOTY 4204

Course Title- Techniques in plant sciences , biostatistics and bioinformatics

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Unit 3- Radiolabeling techniques

Detection and measurement of different types of radioisotopes used in biology, incorporation of radioisotopes in biological tissues and cells, molecular imaging of radioactive material, safety guidelines.

Molecular Imaging

- ✓ It is a techniques depend upon molecular mechanisms operative in vivo.

- ✓ This technique encompasses the visualization, characterization and measurement of biological processes at the molecular and cellular level in living system.

- ✓ The techniques used include positron emission tomography-computed tomography(PET-CT), Nuclear medicine , magnetic resonance imaging (MRI), magnetic resonance spectroscopy(MRS), optical imaging and ultrasound.

Molecular imaging modalities

Types of Molecular imaging modalities

Single modality

(Ultrasound, MRI, PET,SPECT, Optical Imaging)

Multimodalities (PET-CT, SPECT-CT, PET-MRI)

Nuclear Imaging

- Nuclear imaging or also called as radionuclide scanning
- It provide an effective diagnostic tools for the radiologist as it shows not only the structure of an organ but also the function of the organ.
- It uses small amounts of radioactive materials or tracer for diagnostic purpose.
- Radioactive tracer used in nuclear imaging is normally a specifically targeted probe.
- Probe may be antibodies , ligands or substrates to specifically interact with protein targets in particular cells or sub cellular compartments.

- These interactions are based on either receptor-radioligand binding or enzyme mediated trapping of a radio labelled substrate.

- Radioactive tracer are in most cases administrated into a vein and some are given orally.

- After administration of radio tracers, patient required to rest for a certain period to allow distribution of radioactive trracer in the body.

- For imaging purpose , a specialized gamma camera is used to detect the radiation throughout the body.

Most commonly used techniques in nuclear imaging are PET (positron emission tomography)and SPECT (Single photon emission computed tomography).

The most commonly used radioactive tracer is the glucose derivative , 2-(18F) Fluoro-2-deoxy-D-glucose or commonly known as (18F) FDG.

18F-FET (Fluroethyltyrosine) for amino acid metaboism and 18F-FCH (18F-Flurocholine) For cell membrane metabolism.

Radioactive tracer

- It is chemical compound in which one or more atoms have been replaced by a 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 reactant to products.
- It is also called radiotracer or radioactive label.
- The simplest radiotracers used for metabolic imaging are several radioactive isotopes that are administrated as the element without labelling to any compound. These include iodine(123I and 131 I), gallium (67Ga and 688Ga), indium(111In), rubidium(82Rb) and strontium(89Sr).
- In imaging test tracer allows doctor to see how blood flows to tissues and organs. It is injected into blood stream and it emits gamma rays that can be detected by CT scanner.

Characteristics of tracer for molecular imaging

✓Tracer must emit gamma rays of sufficient energy to escape from the body.

✓It must have half –life short enough for it to decay away soon after imaging is completed.

Advantages of using short half life isotopes

- It will be easier and cheaper to dispose of
- High specific activity makes the experiments more sensitive.
- Lower doses likely (e.g., in diagnostic testing of human subjects)

Disadvantages of using short half life isotopes

- Isotopes decays during time of experiment.
- Frequently need to calculate amount of activity remaining
- Cost of replacement for further experiments

Safety aspects

- ✓ Radioisotopes produces toxic ionising radiations.

- ✓ After absorption it causes ionisation and free radicals form that interact with the bio-molecules and causing mutation of DNA and hydrolysis of proteins.

- ✓ The gray (Gy), an SI unit , is the unit used to describe this; 1Gy is an absorption of 1 J/kg of absorber.

- ✓ Gray unit unable to describe the hazard to living organism because different types of radiation associated with different degrees of biological hazards.

- ✓The unit of absorbed dose which takes into account this weighting factor is the Sievert (Sv) and known as equivalent dose. Dose equivalent measured in rem or sievert and expresses damage to human.

- ✓For beta radiation 1Gy= 1Sv
- ✓For alpha radiation 1Gy= 20Sv

- ✓In other words we can say alpha radiation is 20 times as toxic to human as X-rays for the same energy absorbed.

- ✓From the point of view of safety it is advisable to use radioisotopes with low energy wherever possible.

✓The dose limit for workers exposed to radiation is 20mSv/year for whole body. For individual organs such as for hand it is 500mSv/year and for eye lens it is 150mSv/year (mili sievert per year).

✓Toxicity of radiation is depends on

(i) The amount absorbed by the body

(ii) Energy of the absorbed radiation

(iii) Its biological effects

✓Potential of hazard of a radiation directly proportional to the energy of radiation and amount of radiation absorbed by the system.

✓Absorbed dose measured in rad or gray which expressed energy absorbed by any material

Absorbed radiation dose

Absorbed dose from known sources can be calculated if following is known -

- ✓ The decay rate of source
- ✓ The energy of radiation
- ✓ The penetrating power of radiation
- ✓ The distance between the source and the worker

Radiation is emitted from a source in all directions, the level of irradiation is related to the area of a sphere. Thus the absorbed dose is inversely related to the square of the distance (the radius of the sphere) from the source.

$$\mathbf{Dose_1 \times (Distance_1)^2 = Dose_2 \times (Distance_2)^2}$$

For example-

Q. A 1mCi source of ^{125}I gives a dose of 10mSv/h at 1cm.

Calculate the dose rate at 5cm.

Soln.

$$\mathbf{Dose_1 \times (Distance_1)^2 = Dose_2 \times (Distance_2)^2}$$

$$\mathbf{10 \times 1^2 = new\ dose \times 5^2}$$

$$\mathbf{new\ dose = 10/25}$$

$$\mathbf{= 0.4 mSv/h}$$

Dose rate

The rate at which dose is delivered is referred to as the dose rate expressed in Sv/hr.

Total Dose = Dose rate (Sv/h) x time (h)

For example-

Q. if a source delivering 16 mSv/h and a person worked with the source for 7 h what would be the total dose?

Soln- Total Dose = Dose rate x time
= 16 mSv/h x 7
=112 mSv

Annual limit on intake (ALI)

- According to title 10, section 20.1003, of the code of federal regulations (10CFR20.1003) Annual limit on intake (ALI) is the derived limit for the permissible amount of radioactive material taken into the body of an adult radiation worker by inhalation or ingestion in a year.

- It is smaller value of intake of a given radionuclide in a year by reference man that would result in a committed effective dose of 5 rem (0.05 sieverts) or a committed equivalent does of 50 rems(0.5Sv) to any individual organ or tissue.

- It is defined by ICRP in publication 60(ICRP, 1991B, paragraph S30) and expressed in units of activity (becquerels or curies)

Derived air concentration (DAC)

✓Derived air concentration (DAC) is the concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2000 hours under conditions of light work (with an inhalation rate of 1.2 cubic meters of air per hour), results in an intake of one annual limit on intake (ALI).

✓Derived air concentration equals to the annual limit on intake (ALI) divided by volume of air inhaled by a reference person in a working year (2.2x $10^3 m^3$). The DAC is the average airborne concentration that a radiation worker may be exposed to for 40 hours/week, 50 weeks/year.

✓The unit of DAC is Bq/m^3

ICRP

- The international commission on radiological protection (ICRP) is an independent , international , non governmental organization with the mission to provide recommendations and guidance on radiological protection concerning ionisation radiation.
- It was established in 1928 at the second international congress of radiology to respond to growing concerns about the effect of ionizing radiation being observed in the medical community.
- At that time it was called the international X-ray and radium protection committee.
- It was restructured to better take account of uses of radiation outside the medical area and given its present name in 1950.

Management of radiation protection

- ✓ It is similar in most countries
- ✓ In USA, there is a Code of Federal Regulations
- ✓ In UK, there is the Radioactive Substances Act(1993) and the Ionising Radiations Regulations (1999).

  Every institution requires certification (monitored by the Environmental Protection Agency in the USA or the Environment Agency in the UK) and employs a Radiation Protection Advisor

Before using radioisotopes consider it

- ✓ If any other methods is exist which fulfil your query than use those method

- ✓ If it is necessary than use isotope with lowest energy that can deliver your needs

ALARA

- ALARA (As Low As Reasonably Achievable) is a safety principle designed to minimize radiation doses and releases of radioactive materials.

- More than merely best practice , ALARA is predicted on legal dose limits for regulatory compliance, and is a requirement for all radiation safety programs.

- There are three major principles that assist in maintaining ALARA and can help prevent both unnecessary exposure and over exposure: time, distance and shielding.

Time : minimize the time spent near a radiation source to only what it takes to get the job done.

Distance: maximize your distance from a radiation source as much as you can.

Shielding: put something between you and the radiation source.

Rules for handling radioisotopes

- ✓ Wear protective clothing , gloves and glasses.
- ✓ Use smallest amount possible.
- ✓ Keep materials safe, secure and well labelled.
- ✓ Monitor working area frequently.
- ✓ Avoid foods and drinks in laboratory.
- ✓ Wash and monitor hands after experiment.

✓Follows all local rules such as for the dispensing of stock and the disposal of waste.

✓Do not create radioactive aerosols or dust and for penetrating radiations(32P).

✓Maximise the distance between source and you.

✓Minimise the time of exposure.

✓Maintain shielding at all times.

Thank you