Introductory Medical Radiation Science

Radiopharmaceutical Revision

What is a Radiopharmaceutical?

A radiopharmaceutical is a compound (radioactive drug) used in diagnosis and therapy. They are sterile and pyrogen free. It may be referred to as a radiotracer or just a tracer. There are 2 parts to a radiopharmaceutical:

- A radionuclide
- A pharmaceutical

The usefulness of the radiopharmaceutical is dictated by the characteristics of these 2 components.

Ideal Characteristics of Radiopharmaceuticals

The ideal characteristics of a radiopharmaceutical for diagnostic imaging include:

- Readily available and easily produced and cheap
- Short effective half-life
- Suitable half-life in consideration of transport times
- No particle emissions due to their high linear energy transfer (LET) and radiation dose.

Components of a Radiopharmaceutical

- Ligand → Pharmaceutical
- Chelate → Radionuclide
- Reductant → This controls the oxidative state of the chelate
- Antioxidants → The prevent oxidation of the radiopharmaceutical post reconstitution
- Buffers → Creates the ideal pH for reconstitution
- Catalyst → This is a weak ligand that binds the chelate in order to maximise the yield of the target complex (ligand exchange with target ligand)
- Accelerator → This increases the rate of the complex formation
- Surfactants (solubilising agents) → These are used for lipophilic compounds to be aqueous soluble and to prevent particle aggregation
- Inert Fillers → These cause more rapid dissolution of solids

The first five are the most important.

Radiolabelling

Radiolabelling is a technique for tracking the passage of a sample of a substance through a system. The substance is labelled using radionuclides in its chemical composition. As the radio-nucleotides decay, their presence can be tracked by detecting the minute amounts of radioactivity emitted. The substance is 'labelled' by replacing specific atoms by their isotope.

Mechanisms of Localisation

Nuclear Medicine is based on its ability to specifically localise the radiopharmaceutical in the target organ. The primary objective is selective accumulation in the target organ.

Interactions with Matter

Charged Particles (10 kEv to 10 MeV)

A charged particle will interact with a negatively charged electron and a positively charged nucleus of atoms with matter.

The deposition of energy causes ionisation or excitation. Most of these interactions cause ionisation, as they are high energy particles between the range of 10 keV to 10 MeV.

Excitation and Ionisation

Excitation is the absorption of small amounts of energy from a passing charged particle or from an interaction with electromagnetic radiation. Usually, an outer electron will transfer to a slightly higher energy level. As there is no ionisation, the atom gives up and releases the additional energy as electromagnetic radiation.

Ionisation is an effect of radiation "collision" with the electron structure. For ionisation to occur, the energy level must be much higher than that of the binding energy, and this will completely remove the electron from its orbit.

Passage Through Matter

The manifestation and behaviour is different for all charged particles. Small particles (like electrons) tend to deflect in a zig-zag pattern at a large deflection angle. They also have the tendency to produce a secondary electron due to the energy they have absorbed from the inelastic collision.

Larger particles (like protons or large alpha particles) tend to have less of a deflection angle and more of a direct path, with a shorter range.

Range of a Charged Particle

Particles loss energy as they interact with mater and almost come to rest. The range of a charged particle is described by the depth in matter in the plane of the incident angle.

Larger particles tend to have a maximum distance that is measured in a straight line. Smaller particles are considerably shorter than the distance actually travelled (zigzag).

There are a number of factors that determine the range in matter of a charged particle:

- The range increases with initial energy
- The range increases with decreasing mass
- The relationship of the mass, energy and the velocity increases with increasing initial velocity
- The range increases with decreasing charge
- The range decreases with increasing density of the matter through which the charged particle is passing