Chapter 3

RADIONUCLIDES AS TRACERS

R.D. Ganatra

Nuclear Medicine is usually defined as a "clinical speciality devoted to diagnostic, therapeutic and research applications of internally administered radionuclides.". Diagnostic implies both in vivo and in vitro uses. In modern times, there is hardly any medical research, where a radioactive tracer is not used in some form or other. Normally basic medical research is not considered as nuclear medicine, but clinical research applications of radioisotopes are considered as an integral part of this speciality.

Radioisotopes are elements having the same atomic number but different atomic weights. For example, ^{131}I, ^{125}I, ^{123}I are all isotopes of the same element. Their chemical and biological behaviours are expected to be identical. The slight differences in the weights, that they have, is due to differences in the number of particles that they hold inside the nucleus. Some isotopes are perturbed by this kind of change in the nuclear structure. They become unstable, and emit radiation till they reach stable state. These are called radioisotopes. Radioisotopes have few immutable characteristics: they are unstable, they all disintegrate at a specific rate, and they all emit radiations, which have a specific energy pattern.

Importance of radioisotopes in medicine is because of their two characteristics: their biological behaviour is identical to their stable counterparts, and because they are radioactive their emissions can be detected by a suitable instrument. All isotopes of iodine will behave in the same way and will concentrate in the thyroid gland. There is no way of detecting the stable, natural iodine in the thyroid gland, but the presence of radioactive iodine can be detected externally in vivo by a detector. Thus, the radioactive iodine becomes a tracer, a sort of a spy, which mimics the behaviour of natural iodine and relays information to a detector.

The radioactive tracers are popular because of the ease with which they can be detected in vivo and the fact that the measurement of their presence in the body can be in quantitative terms. The measurement can be very accurate and sensitive. Whenever the measurements can be done in vivo, the information is obtained in dynamic terms, as it is happening, as if the physiological events become transparent.

The radioisotopes are physical entities and their radiations and measurements are characterized by laws of physics. It is, therefore, essential to learn some nuclear physics for practising Nuclear Medicine. It is no more or no less than learning the morphological and biochemical characteristics of microorganisms. Doctors are used to learn as much as possible about the tools of their trade.

The older textbooks of nuclear medicine started with a heavy bitter dose of nuclear physics. Now that the nuclear medicine has developed as a clinical discipline, the amount of physics in a nuclear medicine textbook is becoming less and less and is mostly on the need-to-know basis. It is like learning anatomy. One can memorize a large number of facts, but use only very few of them in clinical practice. Same thing holds true for nuclear physics in relation to the practice of nuclear medicine. The approach in this Handbook is also to give few salient facts, which one needs to know, in actual day-to-day practice of nuclear medicine.

The radioactive tracers can be of three types:

(a) where a radionuclide itself is a biologically important substance e.g. iodine,

(b) where a radionuclide is an integral part of a biological molecule, e.g. radio-cobalt in Vitamin B_{12}, and

(c) a radionuclide is welded chemically to a substance of biological interest e.g. radio-iodinated albumin.

An ideal tracer should have the following properties:

(a) the radionuclide should be firmly attached to the biological substance. It should not get dissociated in transit through the body.

(b) the biological behaviour of the tracer should be identical to its stable counterpart.

(c) the tracer should mix intimately with the tracee in all body compartments.

(d) radioactive tracer by itself should not pose any hazard, because of its radioactivity, nor should its chemical nature produce any pharmacological effect.

One other concept should also be understood when working with radionuclides. They emit radioactivity till they transmute themselves to a stable element. Their radioactivity has a life span and it is measured in terms of half life. This is the time period in which the radioactivity is reduced to half. For example, 100 units becomes 50 in eight days, in case of ^{131}I; it will become 25 after another eight days and so on. It is not a linear progression, but an exponential decay. The half life is a physical property of an element, which can not be altered by any external factors. There are some formulas and mathematical expressions to describe this function. They will be described in a later Chapter.

RADIONUCLIDES AS TRACERS

The way the radionuclides are produced in the reactor, every atom does not become radioactive. Non-radioactive tracer component is called a carrier. One must be conscious of the carrier amount in any radioisotopic preparation. Ideally the tracer should be carrier-free. The amount of carrier, if too large, can upset the physiological balance, and may even produce pharmacological effects.

When we detect radioactivity, there is some component of it, which is arising from the background radiation. This comes from cosmic rays, naturally occurring radioactivity in building material, radioactive ^{40}K in the human body. etc. The signal produced by the tracer should be several folds higher than this background noise.

When we have an ideal tracer and a well defined physiological concept, it is possible to ask several basic questions:

Where is the tracer going?

How much of the tracer is going where?

At what rate it is going there, and at what rate it is leaving the organ?

Procedures designed to answer these questions with the use of radioisotopes form the basis of Nuclear Medicine.