Dose to the Patient

Administering a radioactive material to the patient necessarily gives the patient a radiation dose. The organ of interest that takes up the radionuclide (referred to as the source organ) will receive a dose, but it also acts as a source of irradiation for other so-called target organs and tissues in the body. An example of the source and target organs in lung ventilation studies is shown in Figure 8.29.

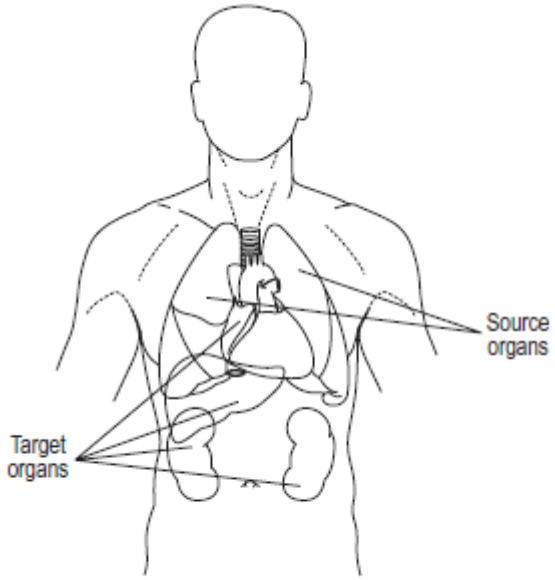

Figure 8.29 How activity in source organs can contribute to patient dose in both source (lungs) and target organs (heart, liver and kidney) in a ventilation study.

Dose to an organ

The absorbed dose delivered to an organ by the activity within it increases in proportion to:

- the activity administered to the patient
- the fraction taken up by the organ
- the effective half-life of the activity in the organ
- the energy (keV) of beta and gamma radiation emitted in each disintegration.

It also depends on how much of that energy escapes from the organ, and so does not contribute to the absorbed dose within the organ but will irradiate other tissues. Almost all the energy of a beta ray is deposited inside the organ, and very little escapes.

Some of the energy of a gamma ray is deposited in the organ and some leaves it, to an extent depending on the size of the organ and how energetic the gamma ray is. The calculation of internal absorbed dose is complicated and often uses Monte Carlo methods (a mathematical technique that considers the fate of individual photons whose behavior is determined in terms of probabilities) and mathematical simulations of patient anatomy based on CT images. It must also take account of the additional dose delivered to the organ by gamma rays coming from activity in surrounding tissues and organs. The American Society of Nuclear Medicine has developed a method to calculate organ dose, which is referred to as the Medical Internal Radiation Dose (MIRD) scheme. This assumes that there are source organs, which accumulate the activity, and target organs, which are irradiated by the source organs. Table 8.3 shows, in the organ dose column, that the three source organs in bone marrow imaging – liver, spleen and red bone marrow – receive the highest doses after a 99Tcm colloidal injection, but there are at least five other target organs that receive significant doses. The calculation is obviously approximate, as uptake depends on body size and weight, disease, age, sex, diet and drugs

Table 8.3 Organ dose and organ-weighted effective dose for bone marrow imaging using a technetium-99m colloidal injection

Main source and target organ(s)	Organ absorbed dose (μGy MBq^{-1})	w_T	Effective dose contributions, organ-weighted using w_T (μSv MBq^{-1})
Spleen	110	0.025[a]	2.8
Liver	66	0.05	3.3
Red marrow	13	0.12	1.6
Stomach	7.1	0.12	0.9
Colon	3.8	0.12	0.5
Lungs	5.7	0.12	0.7
Bone surfaces	9.8	0.01	0.1
Breasts	1.9	0.05	0.1
Other	Various	0.025	0.1
Total effective dose (whole body)	–	–	10.1

[a]Spleen is a remainder organ. For internal radiation dosimetry, the remainder organ receiving the highest dose is assigned half the remainder tissue-weighting factor.

Effective dose to the body

Unlike imaging with X-rays, the dose delivered by a radionuclide examination is unaffected by the number of images taken, neither is it confined to the region of diagnostic interest. After an intravenous injection, most tissues may receive some dose, but the organs of
interest and the organs of excretion generally receive the highest doses.
The distribution of a dose is non-uniform and specific to the examination, but an average dose to the body as a whole can be calculated to give a measure of risk. This is termed the effective dose (E), which has the unit sievert. It is calculated using the differing sensitivities of the various organs and tissues to irradiation, by weighting each organabsorbed dose with a tissue-weighting factor, wT, to produce an equivalent dose. These are then summed to give the effective dose per MBq activity administered. Thus, in Table 8.3, if 400 MBq is the administered activity, the effective dose is 4 mSv.

Precautions Necessary In Handling Radionuclides

When handling radionuclides, in addition to the hazard from external radiation there is also a potential hazard from internal radiation due to accidental ingestion or inhalation of the radionuclide or its entry
through wounds. It is therefore important to avoid contamination of the environment, the workplace and persons, and to control any spread of radioactive materials. Generally, the risk from contamination is greater than that from external radiation.

Segregation

A nuclear medicine facility must have identified and preferably separate areas for:

- the preparation and storage of radioactive materials
  the injection of patients
- patients to wait (to allow uptake of the radiopharmaceutical into the organ of interest)
- imaging
- temporary storage of radioactive waste.

Patients containing radioactivity are a source of external radiation. They should be spaced apart in the waiting area. Departmental layout should make use of the inverse square law to reduce the effect of background radiation from other patients and sources, particularly in the imaging areas.

Personal protection

Use should be made of distance, shielding and time. Staff should enter areas where there is radioactivity only when it is strictly necessary; all procedures must be carried out expeditiously and efficiently. Departmental local rules must be followed. Some general
guidance follows. Radionuclides are contained in shielded generators or in bottles inside lead pots. Where feasible, bottles and syringes are handled with long-handled forceps (tongs). Manipulations, such as the labelling of pharma ceuticals and the loading of syringes, are carried out with the arms behind a lead barrier that protects the body and face, and over a tray, lined with absorbent paper, to catch any drips. Syringes are protected by heavy metal, tungsten or lead glass sleeves (which can reduce radiation doses to the fingers by 75%) and are carried to the patient in
special containers or on a disposable tray. Before injection,syringes are vented into swabs or closed containers and not into the atmosphere

Patient protection

Every radionuclide should be checked for activity before a dministration, using a radionuclide (well) calibrator. The patient's identity must be checked against the investigation to be made and the activity to be administered, and this must be recorded. Particular
care should be taken to avoid contamination during oral administrations. Special circumstances apply for pregnant patients and those with babies whom they are breast feeding