Pearson

20.12: Radioactivity in Medicine and Other Applications

Radioactivity is often perceived as dangerous; however, it is also immensely useful to physicians in the diagnosis and treatment of disease and has numerous other valuable applications. We broadly divide the use of radioactivity in medicine into *diagnostic techniques* (which diagnose disease) and *therapeutic techniques* (which treat disease).

Diagnosis in Medicine

The use of radioactivity in diagnosis usually involves a **radiotracer**, a radioactive nuclide attached to a compound or introduced into a mixture in order to track the movement of the compound or mixture within the body. Tracers are useful in the diagnosis of disease because of two main factors: (1) the sensitivity with which radioactivity can be detected, and (2) the identical chemical behavior of a radioactive nucleus and its nonradioactive counterpart. For example, the thyroid gland naturally concentrates iodine. When a patient is given small amounts of iodine-131 (a radioactive isotope of iodine), the radioactive iodine accumulates in the thyroid, just as nonradioactive iodine does. However, the radioactive iodine emits radiation, which can then be detected with great sensitivity and used to measure the rate of iodine uptake by the thyroid, and thus to image the gland.

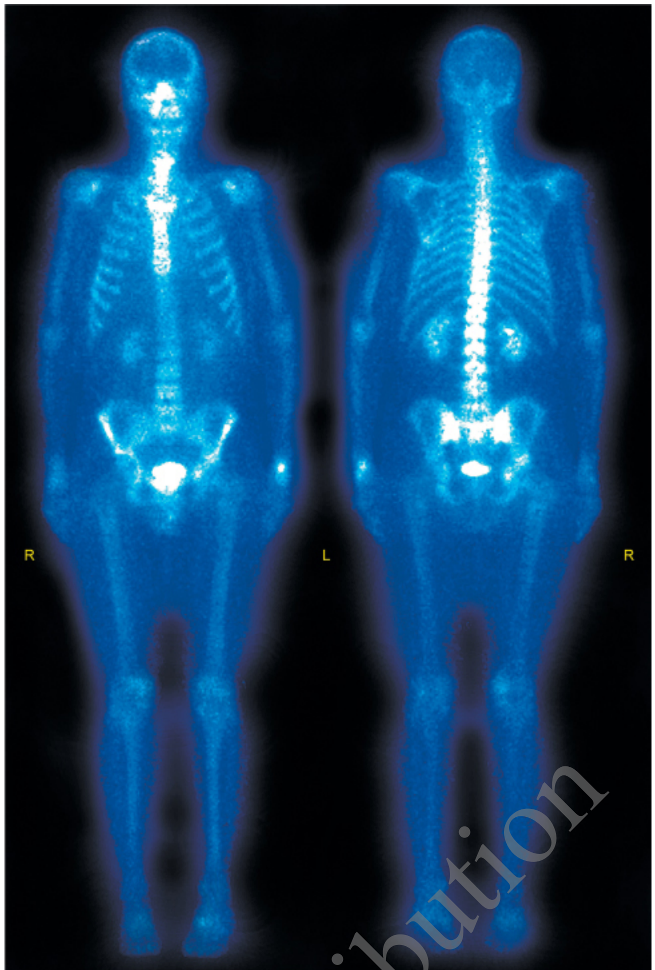
Because different radiotracers are taken up preferentially by different organs or tissues, various radiotracers are used to monitor metabolic activity and image a variety of organs and structures, including the kidneys, heart, brain, gallbladder, bones, and arteries, as shown in Table 20.6. Radiotracers can also be employed to locate infections or cancers within the body. To locate an infection, antibodies are labeled (or tagged) with a radioactive nuclide, such as technetium-99m (where "m" means metastable), and administered to the patient. The tagged antibodies aggregate at the infected site, as described in Section 20.1. Cancerous tumors can be detected because they naturally concentrate phosphorus. When a patient is given phosphorus-32 (a radioactive isotope of phosphorus) or a phosphate compound incorporating another radioactive isotope such as Tc-99m, the tumors concentrate the radioactive substance and become sources of radioactivity that can be detected (Figure 20.17).

Table 20.6 **Common Radiotracers**

Nuclide	Type of Emission	Half-Life	Part of Body Studied
technetium-99m	gamma (primarily)	6.01 hours	Various organs, bones
iodine-131	beta	8.0 days	Thyroid
iron-59	beta	44.5 days	Blood, spleen
thallium-201	electron capture	3.05 days	Heart
fluorine-18	positron emission	1.83 hours	PET studies of heart, brain
phosphorus-32	beta	14.3 days	Tumors in various organs

Figure 20.17 **A Bone Scan**

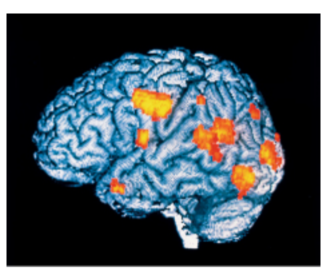
These images, front and rear views of the human body, were created by the gamma ray emissions of Tc-99m. Such scans are often used to locate cancer that has metastasized (spread) to the bones from a primary tumor elsewhere.



A specialized imaging technique known as **positron emission tomography (PET)** employs positron-emitting nuclides, such as fluorine-18, synthesized in cyclotrons. The fluorine-18 is attached to a metabolically active substance such as glucose and administered to the patient. As the glucose travels through the bloodstream and to the heart and brain, it carries the radioactive fluorine, which decays with a half-life of just under 2 hours. When a fluorine-18 nuclide decays, it emits a positron that immediately combines with any nearby electrons. Since a positron and an electron are antiparticles, they annihilate one other, producing two gamma rays that travel in exactly opposing directions. The gamma rays are detected by an array of detectors that can locate the point of origin of the rays with great accuracy. The result is a set of highly detailed images that show both the rate of glucose metabolism and structural features of the imaged organ (Figure 20.18).

Figure 20.18 A PET Scan

The colored areas indicate regions of high metabolic activity in the brain of a schizophrenic patient experiencing hallucinations.



Radiotherapy in Medicine

Because radiation kills cells and is particularly effective at killing rapidly dividing cells, it is often used as a therapy for cancer (cancer cells reproduce much faster than normal cells). Medical technicians focus high-energy photons on internal tumors to kill them. The photon beam is usually moved in a circular path around the tumor (Figure 20.19), maximizing the exposure of the tumor while minimizing the exposure of the surrounding healthy tissue. Nonetheless, cancer patients receiving such treatment usually develop the symptoms of radiation sickness, which include vomiting, skin burns, and hair loss.

Figure 20.19 Radiotherapy for Cancer

This treatment involves exposing a malignant tumor to high-energy photons generated by nuclides such as cobalt-60. The beam is moved in a circular pattern around the tumor to maximize exposure of the tumor to radiation while minimizing the exposure of healthy tissues.

Why is radiation—which is known to cause cancer—also used to treat cancer? The answer lies in risk analysis. A cancer patient is normally exposed to radiation doses of about 100 rem. Such a dose increases cancer risk by about 1%. However, if the patient has a 100% chance of dying from the cancer that he already has, such a risk becomes acceptable, especially since there is a significant chance of curing the cancer.

Other Applications for Radioactivity

Radioactivity is often used to kill microorganisms. For example, physicians use radiation to sterilize medical devices that are to be surgically implanted. The radiation kills bacteria that might otherwise lead to infection. Similarly, radiation is used to kill bacteria and parasites in foods. The irradiation of foods makes them safer to consume and gives them a longer shelf life (Figure 20.20). The irradiation of raw meat and poultry kills *E. coli* and *Salmonella*, bacteria that can lead to serious illness and even death when consumed. The irradiation of food does not, however, make the food itself radioactive, nor does it decrease the nutritional value of the food. In the United States, the irradiation of many different types of foods—including beef, poultry, potatoes, flour, and fruit—has been approved by the U.S. Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA).

Figure 20.20 Irradiation of Food

Irradiation kills microbes that cause food to decay, allowing longer and safer storage. The food is not made radioactive, and its properties are unchanged in the process. These strawberries were picked at the same time, but those on the bottom were irradiated before storage.

Radioactivity is also used to control insect populations. For example, fruit flies can be raised in large numbers in captivity and sterilized with radiation. When these fruit flies are released, they mate with wild fruit flies but do not produce offspring. The efforts of the wild fruit flies, which might otherwise lead to reproduction, are wasted and the next generation of flies is smaller than it would otherwise have been. Similar strategies have been employed to control the populations of disease-carrying mosquitoes, Most recently, Brazil has used this technique to fight the spread of the Zika virus.