Nuclear medicine for diagnosis and treatment

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Nuclear medicine is constantly expanding through the introduction of new radiopharmaceuticals and new instruments. Special radiotracers, for instance, are making it possible to study fatty acid metabolism in the heart muscle.

Nuclear medicine is the application of tracer technology to medicine. Chemical compounds labelled with a radioisotope, which are called radiopharmaceuticals, are either administered to patients (in vivo studies) or labelled compounds are mixed with other reagents in test-tubes to measure minute quantities of hormones, certain drugs, and other substances. The amount of radiopharmaceuticals and labelled reagents is so small that it does not interfere with the natural behaviour of the target substance in the body or with biochemical or immunological reactions in test tubes.

After an intravenous injection of such a compound, the patient just lies on the bed while a scintillation detector, called a gamma camera, measures the radioactivity to record multiple images of the organ concerned from different angles. These images are then interpreted by a computer and the tomographic images serve to detect the location of any abnormality. Such in vivo procedures can detect a diseased organ by measuring the localized physiological and metabolic function in a tissue, organ or lesion which can be displayed as a functional image. Each radioisotope has a characteristic half-life, the time taken for any amount of radioactivity to be reduced to half that amount by radioactive disintegration. Those now used in nuclear medicine have a half-life as short as six hours, with very little radiation exposure for patients.

How it began

Shortly after Röntgen’s discovery of X-rays, the experiments of Henri Becquerel led to the discovery of what was later named “radioactivity” by Marie Curie. Further studies by Marie and Pierre Curie, Ernest Rutherford and Frederick Soddy opened the door to the medical applications of radioisotopes emitting β- and γ-rays.

George von Hevesy was the first to use radioisotopes to trace the behaviour of a substance in plants and animals by monitoring the radioactivity. This tracer principle was first applied to human beings by Hermann Blumgart and Soma Weiss in the late 1920s to measure the speed of the bloodstream. They injected a radioisotope into a vein of the arm and measured the time it took for radioactivity to reach the other arm.

The discovery of artificial radioisotopes in 1934 by Irène Curie and her husband Frédéric Joliot gave a boost to the application of
the tracer principle. The medical application of substances labelled with radioisotopes was accelerated after radioisotopes were made available to the private sector in 1946 in the USA. Measurement of insulin levels in human blood was first reported in 1959 by Solomon Berson and Rosalyn Yalow. This new technique was named radioimmunoassay (RIA) and opened up a new horizon for the diagnosis of hormonal disorders.

**Diagnostic tests**

In Japan, about 6600 *in vivo* studies are performed every day in some 900 nuclear medicine facilities in hospitals. The most frequently performed diagnostic tests are bone scintigraphy using labelled phosphate compounds – the most sensitive test for detecting bone metastasis – followed by tumour scintigraphy, myocardial scintigraphy and brain perfusion scintigraphy.

Radiopharmaceuticals are also used for therapy. In 1992, for example, 2000 Japanese patients with hyperthyroidism and 1000 thyroid cancer patients with metastasis were treated. Therapeutic use of unsealed radioisotopes has been playing an increasingly important role since the introduction of monoclonal antibodies labelled with β-ray-emitting radioisotopes, which bind to tumour-related antigens produced by the cancer and irradiate the cancer tissues locally. Similar substances have been used for the effective control of intractable bone pain caused by bone metastasis.

Nuclear medicine is constantly expanding through the introduction of new radiopharmaceuticals and new instruments. In cardiac nuclear medicine, for example, new myocardial perfusion agents labelled with special radioisotopes have been available for the past few years, making it possible to study fatty acid metabolism in the heart muscle. Labelled monoclonal antibodies have been attracting great interest and are the subject of vigorous research for use in both diagnosis and therapy.

An imaging instrument called positron emission tomography (PET), in combination with a small in-house cyclotron, can produce radioisotopes which decay very rapidly with half-lives as short as two minutes. This has excited clinical research workers in nuclear medicine, since with PET we can evaluate regional tissue metabolism, which reveals tissue consumption of oxygen, glucose, amino acid and fatty acid. Moreover PET can visualize activated nerve cells, which will make it possible to study higher brain functions such as speech, cognition, thinking and emotion. The use of nuclear medicine to help us to understand human behaviour will thus play an important role in evaluating psychiatric patients, including those with dementia.

It will also be possible to visualize the sites of drug action in individual patients and measure their sensitivity to it. The therapeutic drug regimen can then be precisely tailored to suit the individual's need.

Nuclear medicine is the result of collaborative efforts in physics, chemistry, computer science, physiology, clinical medicine and, recently, immunology. Its applications, in some instances, may need support by a national health care system because of the high cost. The development of relatively inexpensive devices and radiopharmaceuticals is therefore important if nuclear medicine services are to be available to all who need them, including patients in developing countries.