RADIATION AND RADIONUCLIDES IN MEDICINE

A Brief Overview of Nuclear Medicine and Radiotherapy

With the discovery of radiation and radionuclides for use in medicine, doctors now have more diverse and effective prevention, diagnostic and treatment options to offer their patients.
(Photo: D. Calma/IAEA)

In the past two centuries, the field of medicine has seen unprecedented advances. Alongside discoveries like the smallpox vaccine and antibiotics, the discovery of radiation and radionuclides for use in medicine has led to more diverse and effective prevention, diagnostic and treatment options for many health conditions.

Diseases like cancer that were once considered unmanageable and fatal can now be diagnosed earlier and treated more effectively using nuclear techniques, giving patients a fighting chance and, for many, a significant chance for a cure. These methods are more important than ever as high-mortality diseases like cancer or cardiovascular diseases are on the rise and are among the leading health threats globally.

The IAEA has worked for over 50 years to promote the use of nuclear techniques in medicine by collaborating with its Member States and other organizations through projects, programmes and agreements. The Agency's aim is to help build Member States' capacities in this field in order to support the provision of high-quality health care worldwide, particularly in developing countries. Since the IAEA began its work in human health, the use of nuclear techniques in medicine has become one of the most widespread peaceful applications of atomic energy.

The December issue of the IAEA Bulletin focuses on the work of the IAEA in the area of radiation medicine and technology. Before delving into this month's issue, here is an overview of the issue's two main themes: nuclear medicine and radiotherapy.

Nuclear Medicine

Nuclear medicine is a field of medicine that uses a trace amount of radioactive substances called radioisotopes for the diagnosis and treatment of many health conditions such as certain types of cancer, and neurological and heart diseases.

Diagnostic Techniques in Nuclear Medicine

In nuclear medicine, radionuclides are used to provide diagnostic information about the body. The techniques in this field can be broadly divided into two categories: in vitro and in vivo procedures.

A gamma camera traces and detects radiopharmaceuticals inside of a patient in order to produce diagnostic images.
(Photo: E. Estrada Lobato/IAEA)

A radiation therapy machine delivers a beam of radiation in order to treat cancer in a patient.
(Photo: D. Calma/IAEA)

In vitro
In vitro diagnostics procedures are performed outside of the body, such as in a test tube or culture dish. Within the field of nuclear medicine, procedures, such as radioimmunoassay or immunoradiometric assay, primarily focus on identifying predispositions to certain health conditions and early diagnosis using genotyping and molecular profiling for a variety of conditions. This can range from identifying changes in cancer cells and tumour makers, to measuring and tracking hormones, vitamins and drugs for detecting nutritional and endocrinological disorders as well as bacterial and parasitical infections such as tuberculosis and malaria.

In vivo
In vivo non-invasive procedures take place inside the body and are the majority of those done in nuclear medicine. These methods involve using radiopharmaceuticals, which are carefully chosen radioactive materials, that are absorbed into a patient's body and, due to their specific chemical properties, target specific tissues and organs, such as the lungs or the heart, without disturbing or damaging them. The material is then identified by using a special detector, such as a gamma camera, placed outside of the body that is able to detect the small amounts of radiation released from the material. The camera is then able to translate the information into two-dimensional or three-dimensional images of the specific tissue or organ.

Among the more well-known and the fastest growing of these techniques is positron emission tomography (PET). Doctors use special instruments called positron emission tomographs to produce scans in order to track body chemistry and organ function on a molecular level, which allows them to identify more nuanced changes in health in a patient at an earlier stage than many other diagnostic techniques. PET scans can be combined with other scanning techniques such as computed tomography to further enhance the speed, accuracy and usefulness of nuclear medical imaging.

Nuclear medicine techniques like these, unlike a traditional X-ray image which depicts anatomical details, reveal how the body functions: they show important dynamic physiological or biochemical qualities of the targeted body part. The information produced during such diagnostic procedures frequently supplements static X-ray images, helping a doctor to determine the status and function of different organs, which can be useful as a doctor makes critical decisions and tailors treatment to the patient's needs.

Radiation Therapy

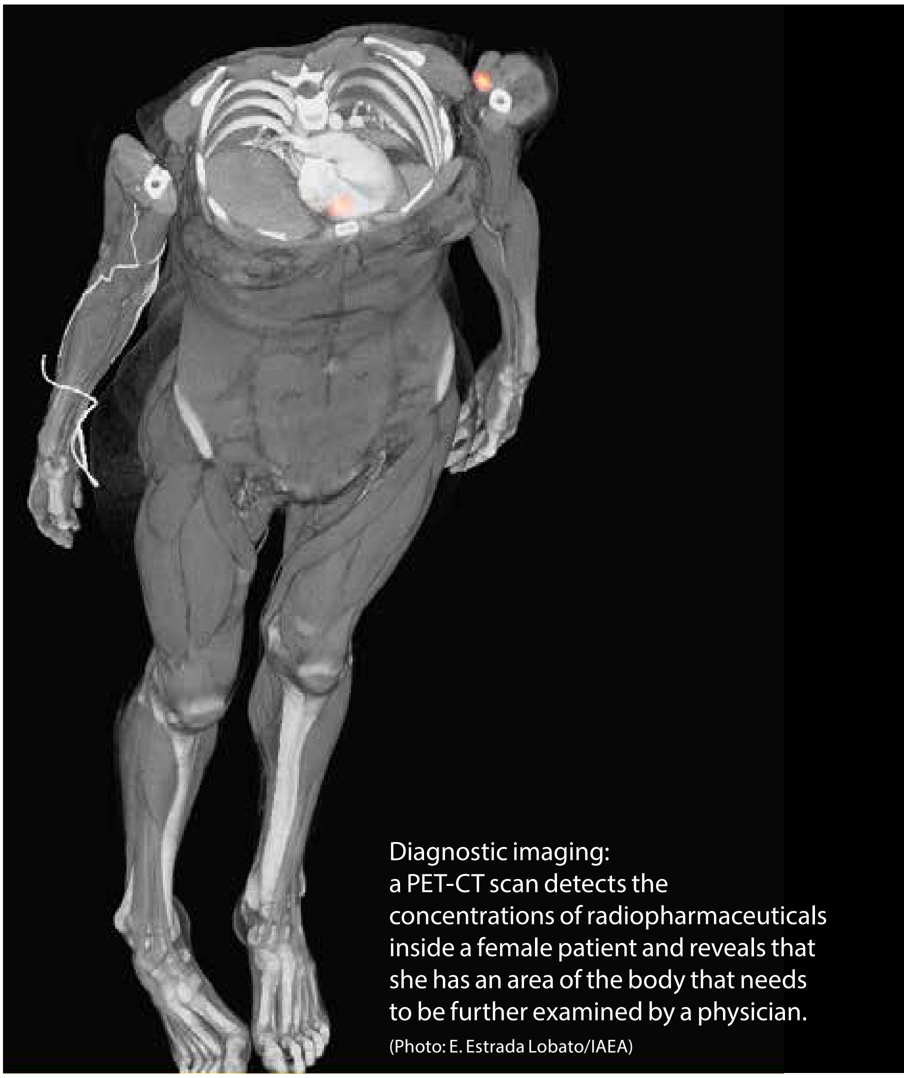
Radiation therapy, or radiotherapy, is a branch of medicine that focuses on the use of radiation to treat cancer. Radiotherapy is designed to use radiation to target and kill cells. In the case of cancer, when the radiation is applied to a cancerous tumour, or a mass of malignant cells, the targeted cells are damaged and killed, leading to a reduction of the tumour size or, in some cases, the disappearance of the mass.

There are primarily three types of radiation therapy treatment options: external beam radiation therapy, brachytherapy and systemic radioisotope therapy.

External beam radiation therapy delivers a beam, or multiple beams, of radiation to target specific areas of a patient's body. The beam is designed to minimize radiation exposure to healthy cells, while controlling or killing the cancer cells. The beams can consist of electrons and/or X-rays, gamma rays or, in the case of particle therapy, protons or carbon ions. In some cases, doctors also use these beams in conjunction with surgery where the surgical procedure is used to uncover the tumour in order to allow the beam to more directly target the mass. This type of procedure is called intraoperative radiation therapy.

Brachytherapy is the placement of radiation sources inside of or next to an area of a patient's body that requires treatment. For example, in the case of cervical cancer, radioactive sources can be placed directly into the uterus in order to target a cervical mass. Unlike external beam radiation, brachytherapy allows for a tumour to be treated with high doses of localized radiation, while reducing the probability of unnecessary exposure to surrounding healthy tissue.

Systemic radioisotope therapy (also known as radionuclide therapy) can be used to address a range of health conditions, such as cancer, blood disorders, or those affecting the thyroid gland. It involves small amounts of radioactive material, such as lutetium-177 or yttrium-90, taken into the body through a body cavity, intravenously, orally or other routes of administration that then target different body parts or organs for treatment. The radioactive material used for treatment is chosen for its isotope properties, or chemical properties, as certain body parts can absorb certain isotopes significantly more effectively than other body parts, which allows doctors to target those specific areas during treatment.



Diagnostic imaging:
a PET-CT scan detects the concentrations of radiopharmaceuticals inside a female patient and reveals that she has an area of the body that needs to be further examined by a physician.
(Photo: E. Estrada Lobato/IAEA)

For example, a patient with a thyroid condition may be treated with radioactive iodine, sodium-iodide-131, therapy. This involves the patient swallowing a small amount of sodium-iodide-131, which is then absorbed into the bloodstream through the gastrointestinal tract and later concentrates in the thyroid gland, which absorbs iodine-131 thousands of times more than the rest of the body. Once in the thyroid gland, iodine-131 begins to destroy highly-active cancer cells in the gland, thus removing those cells causing the health condition.

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