WHAT LIES WITHIN

Using Radiopharmaceuticals to Reveal and Target Diseases Hidden Inside the Human Body

A worker looks inside of a shielded container as she prepares radiopharmaceuticals to be packaged into glass vials.
(Photo: D. Calma/IAEA)

The ability to pinpoint the location and size of a cancerous mass hidden inside of a patient's body was unthinkable less than 100 years ago. Today, with the help of special scanning machines, doctors are able to use radioactive drugs known as radiopharmaceuticals to get a glimpse inside the human body, and these pharmaceuticals can even be used in treating many health conditions. In nuclear medicine, radiopharmaceuticals play an essential role for minimally invasive diagnostic, treatment and care management procedures for many diseases, especially cancer, as well as for relieving pain associated with certain cancers.

Inside Radiopharmaceuticals

Radiopharmaceuticals are drugs that contain radioactive substances called radioisotopes. Radioisotopes are atoms that emit radiation as gamma rays or particles. In some cases, radiopharmaceuticals use radioisotopes that emit a combination of these types of radiation.

The radioisotopes used in radiopharmaceuticals can be produced by irradiating a specific target inside of a nuclear research reactor or in particle accelerators, such as cyclotrons[1]. Once produced, the radioisotopes are tagged on to certain molecules based on biological characteristics, which then results in radiopharmaceuticals.

How Radiopharmaceuticals Work and are used in Medicine

When a doctor decides to use radiopharmaceuticals in a patient for diagnostic and/or

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[1] A cyclotron is a complex machine that accelerates charged particles in a vacuum outwards from the centre along a spiral path. During the acceleration process, charged particles gain significant energy. The energized charged particles then interact with stable material that is placed in their path. The interaction transforms stable materials into medically useful radioisotopes that are used to make radiopharmaceuticals.

treatment purposes, the drugs are generally delivered through an injection, orally or introduced in a body cavity. Once inside the body, the different physical characteristics and biological properties of radiopharmaceuticals causes them to interact with or bind to different proteins or sugars inside the body. This in turn means that the drugs tend to concentrate more in specific body parts depending on that area's biological characteristics. Therefore, doctors are able to precisely target areas of the body by selecting specific types of radiopharmaceuticals.

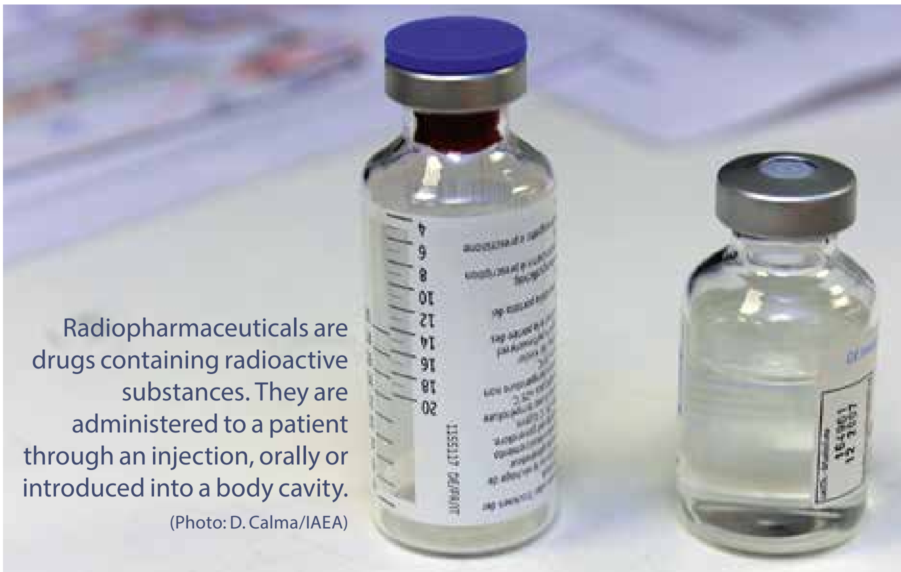
For example, there are currently several radiopharmaceuticals that accumulate preferentially in cancerous tissues making those radiopharmaceuticals effective tools for diagnosing and treating certain types of cancer. This is similarly the case for other radiopharmaceuticals.

Within a few hours to a few days, the radiopharmaceutical dissipates to undetectable levels and/or is eliminated and is no longer found in the body.

For Diagnostic Imaging

When radiopharmaceuticals are used for diagnostic imaging, a doctor will select a radiopharmaceutical containing a radioisotope that emits gamma rays or a particle radiation called positrons, which can be detected using a gamma camera or scanners. These machines can detect where the radiopharmaceutical is concentrating and emitting radiation, translating that information into two- or three-dimensional images that highlight the location and size of the organ or tissue of interest, including cancerous lesions. Diagnostic imaging is widely and routinely used in cardiology and for thyroid disorders, and many other parts of the body (such as the liver, kidneys, brain, skeleton and so on) are also examined using diagnostic radiopharmaceuticals.

In addition to gathering precise information on the size, shape and location of various organs and tumors, radiopharmaceuticals and diagnostic imaging are also used to obtain functional information of various systems in our body. For example, cardiac imaging is used to assess the heart's functions and capacities, to see how blood pumps through the heart, and to examine the heart for any dead or damaged tissue. It is the most commonly used diagnostic test to help cardiac patients receive



Radiopharmaceuticals are drugs containing radioactive substances. They are administered to a patient through an injection, orally or introduced into a body cavity.
(Photo: D. Calma/IAEA)

suitable treatment in a timely manner and to periodically follow up on their health. In the case of cancer patients, imaging is periodically done to assess how the cancer is responding to treatment and to watch over the patient to catch any recurring cancer in order to deliver timely treatment to prevent it from developing further.

Radiopharmaceuticals used for diagnostic imaging emit small amounts of radiation which are considered a net benefit to the patient. The two imaging technologies primarily used with radiopharmaceuticals are the single photon emission computed tomography (SPECT) scanner for detecting gamma rays, and the positron emission tomography (PET) scanner for detecting positrons. When PET and/or SPECT scanners are used in combination with traditional computed tomography, another type of scanning technology, the radiation emitted from the radiopharmaceuticals can be detected to pinpoint accuracy.

The most commonly used radiopharmaceutical for SPECT contains technetium-99m. It is used in more than 80 per cent of all diagnostic procedures in nuclear medicine and is most often used for cardiac and bone scans. Technetium-99m is produced from its parent radioisotope molybdenum-99 through a generator system. Technetium-99m can be tagged to various molecules to produce a number of radiopharmaceuticals designed to target specific organs or diseases.

For PET, the most widely used radiopharmaceutical is fluorine-18 fluorodeoxyglucose (FDG), a glucose analogue that is more readily absorbed by very active cancer cells than by

Doctors administer a radiopharmaceutical to the patient, which is then detected by a scanning machine. The images produced by the scanner are then analysed by the doctors in order to determine the next course of action for the patient.
(Photo: E. Estrada Lobato/IAEA)

healthy cells, and that contains a radioisotope called fluorine-18. Fluorine-18 is produced by bombarding oxygen-18 with high energy protons in a cyclotron, a type of particle accelerator. Fluorine-18 is then tagged to various molecules to produce a number of organ and disease specific PET radiopharmaceuticals.

For Therapeutic Applications

After an illness has been diagnosed, radiopharmaceutical therapy in some cases may be the best course of treatment. Therapeutic radiopharmaceuticals are chosen by doctors because the drugs contain radioisotopes that emit particle radiation that is powerful enough to destroy diseased cells.

The radiation released from a radiopharmaceutical is detected by a specialized machine, which is able to produce images similar to this. This diagnostic image shows the results of a SPECT-CT scan of a female patient that is suffering from a severe inflammation of the left hip due to sclerosis.
(Photo: E. Estrada Lobato/IAEA)

Radiopharmaceutical therapy for managing and treating diseases relies on how effectively the radiopharmaceutical can localize in the tissue or organ to be treated, which in turn depends on how the body interacts with the radiopharmaceutical. Once selected, radiopharmaceuticals are administered in larger doses in order to deliver targeted doses of radiation to problematic areas within the body.

For example, radioactive sodium-iodide-131 in the form of iodine, is a radiopharmaceutical commonly used in the treatment of thyroid cancer as scientists have found that nearly all iodine from the blood accumulates in the thyroid. This means that when a doctor administers a dose of sodium-iodide-131, the thyroid almost exclusively absorbs the drug, leaving the rest of the body virtually unaffected. Once absorbed into the thyroid, the high dose of radioactive iodine releases radiation that destroys the cells of the gland and in turn the cancer cells. There is no conventional treatment that can replace the use of sodium-iodide-131 for the treatment of thyroid cancers or hyperactive thyroid.

Similarly, radium-223, another particle radiation emitter, is successfully used in the form of radium chloride to treat patients with bone cancers due to advanced prostate cancer, which results in improved survival rates.

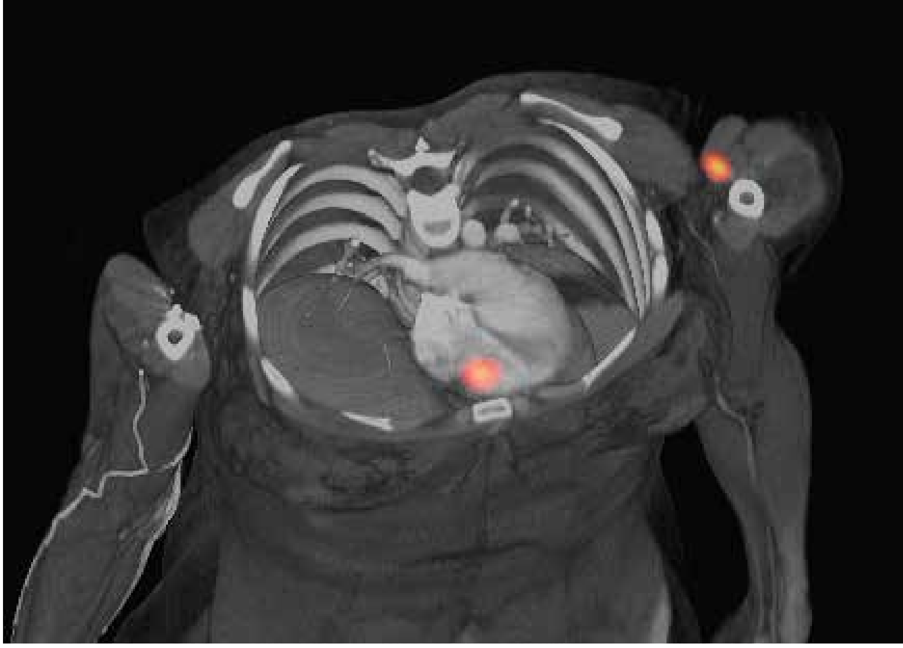
The IAEA and Radiopharmacy

Through projects, programmes and agreements, the IAEA supports its Member States in developing their capacities in the area of radiopharmacy. The IAEA assists with human resources development such as fellowships and expert visits, and provides equipment, technology transfer, training courses and educational tools. The IAEA has also developed guidance documents that detail requirements for establishing radiopharmaceutical production facilities that are safe and reliable. The aim of these activities is to help to ensure that radiopharmaceuticals consistently meet required quality standards for providing reliable and safe nuclear medicine practices.

Research and Development: Through IAEA coordinated research projects (CRPs), Member States are able to further their research and development of radiopharmaceuticals and focus on topics that experts have identified as beneficial. This can help to foster scientific and technical knowledge exchanges as well as stimulate progress in radiopharmacy and, more broadly, nuclear technology and applications.

For example, a CRP on sentinel node imaging has led to a newly developed radiopharmaceutical that has proven to be very effective in tracing the spread of cancer through the lymphatic system. Similarly, a CRP on new radiopharmaceuticals of fluorine-18 and gallium-68 has facilitated collaborative efforts between centres of excellence and centres that are developing such radiopharmaceuticals for the first time. These examples highlight the types of results that can stem from CRPs.

Capacity Building: A major area of the IAEA's focus is helping to build Member State capacities in many nuclear-related areas.



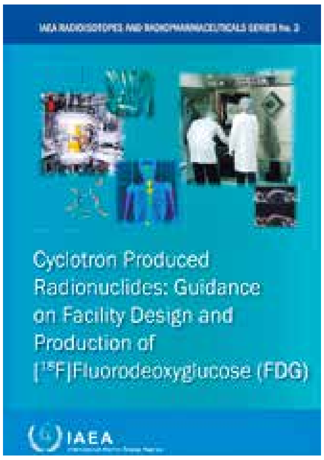
After a radiopharmaceutical is administered to the patient, a PET-CT scan detects the radiation released from the drug and the resulting diagnostic image shows that the male patient suffers from lung cancer and metastases to the lymph node near the heart.

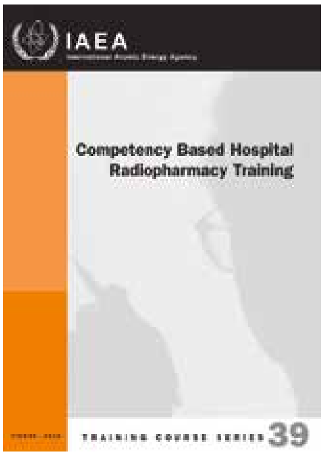
(Photo: E. Estrada Lobato/IAEA)

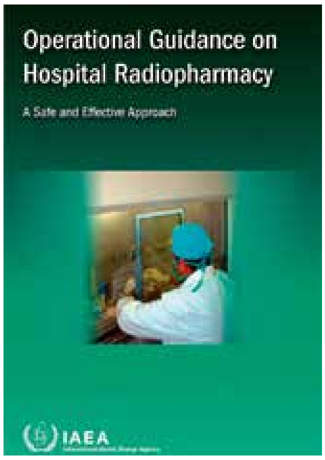
Through the IAEA's technical cooperation (TC) projects, Member States receive expert support for developing their abilities to use nuclear tools, such as radiopharmaceuticals. A recent example is a TC project on establishing a major training programme based on e-learning methods for radiopharmacy technologists and radiopharmacists via coordinating academic institutions and professional scientific organizations.

Safety Standards: For the IAEA, the safety of patients, staff, members of the public and the environment is of the utmost importance. The IAEA has produced several publications and guidelines for Member States that are working in the area of radiopharmacy. The aim is to provide Member States with safety standards guidelines for ensuring the safety, quality and efficacy of radiopharmaceuticals.

Nicole Jawerth, IAEA Office of Public Information and Communication in collaboration with the Radioisotope Products and Radiation Technology Section, IAEA Department of Nuclear Sciences and Applications







The IAEA produces publications and guidelines related to radiopharmacy.