What are nuclear medicine and molecular imaging?

Conventional structural images such as radiography and computed tomography (CT) produce primarily anatomical information. Nuclear medicine and molecular imaging, on the other hand, visualise the functionality of the human body at the cellular and molecular level. As disease is first visible by microscopic cell variations, molecular imaging has the potential to identify diseases at an earlier and more treatable stage.

In nuclear medicine, radioisotopes are mostly attached to chemical drugs to form radiopharmaceuticals, which are then delivered to a target organ or specific tissues in the body. In diagnostic applications, the radioactive material attached to the pharmaceutical is administered in a small amount to evaluate the physiological behaviour of the target. The imaging agent, called a radiotracer, is a compound containing radioactive atoms that produce signals that are detected by gamma cameras, single emission computed tomography (SPECT) or positron emission tomography (PET) scanners. Besides diagnostics, nuclear medicine treatments are used for therapeutic purposes in radiopharmaceutical therapy.

SPECT imaging

SPECT is a widely used diagnostic imaging procedure that involves injection of a radiotracer into a patient's bloodstream, which then travels to and through target organs, or attaches to specific cells. Thereby, SPECT images are acquired at multiple angles, creating different bodily cross sections for the construction of three-dimensional images of radiotracer bio-distribution. This provides necessary information on blood flow and organ functionality, leading to a diagnosis. The most common applications of SPECT examinations are diagnosis of brain abnormalities, heart function and bone disorders.

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PET imaging

PET imaging is a valuable diagnostic technique for early detection of cancer with the same mechanism as SPECT, but instead radioisotopes emit two coincident detectable photons that move in opposite directions. The unique configuration of a PET scanner enables a more precise (higher contrast with less noise) 3D reconstruction of radiotracer bio-distribution, which increases diagnostic precision. Fluorodeoxyglucose (FDG), a compound similar to sugar, is one of the most significant diagnostic imaging tracers. FDG is injected into a patient's vein and downstream to the organs with higher metabolism. Imaging of the target field of view after injection of FDG creates images that visualise the distribution of the radiotracer throughout the body, which enables physicians to detect any present abnormalities.

Targeted radiopharmaceutical therapy

Radiopharmaceutical therapy, also called molecular radiotherapy or radionuclide therapy, involves a radioactive atom attached to a chemical drug that targets specific cancer cells. Radiopharmaceuticals typically consist of a cell-targeting molecule that recognises and latches onto cancer cells combined with radioactive atoms that release decay products to kill tumorous cells. When injected into the patient's bloodstream, the radiopharmaceutical travels to and delivers radiation directly to or near cancer cells. This technique is defined as targeted because its effect is primarily on cancer cells, minimising radiation exposure to normal tissues. Molecular radiotherapy demonstrates promising results for personalised cancer treatment to improve clinical outcomes.

Some radioisotopes have the ability to target specific cells on their own, such as radioactive iodine, which has been used for thyroid cancer treatment since the 1940s. More recently, applications of molecular radiotherapy for the treatment of neuroendocrine tumours, lymphoma, prostate cancer and bone metastasis, among others, have become clinically available.

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Are nuclear medicine procedures safe?

Nuclear medicine and molecular imaging procedures are non-invasive (painless), safe and always carry low risk (e.g., in case of extravasation). For diagnostic examination small amounts of radioactive materials, (nearly the same order of natural background activity) are utilized. Hence, the benefits outweigh the radiation risks attributed to such procedures.

The principle As Low as Reasonably Achievable (ALARA) is implemented in nuclear medicine examinations to optimise the radiation exposure required to create an accurate diagnostic marker. The injected radioactive dosage is determined by the patient's body weight, purpose of examination or diagnostic task, and body region of interest. In addition, software and hardware are constantly updated to reduce the radiation dose to patients without hindering the image quality. A notable achievement is that nuclear medicine procedures have been performed on adults and children (enfants) for over 40 years without any known adverse effects.

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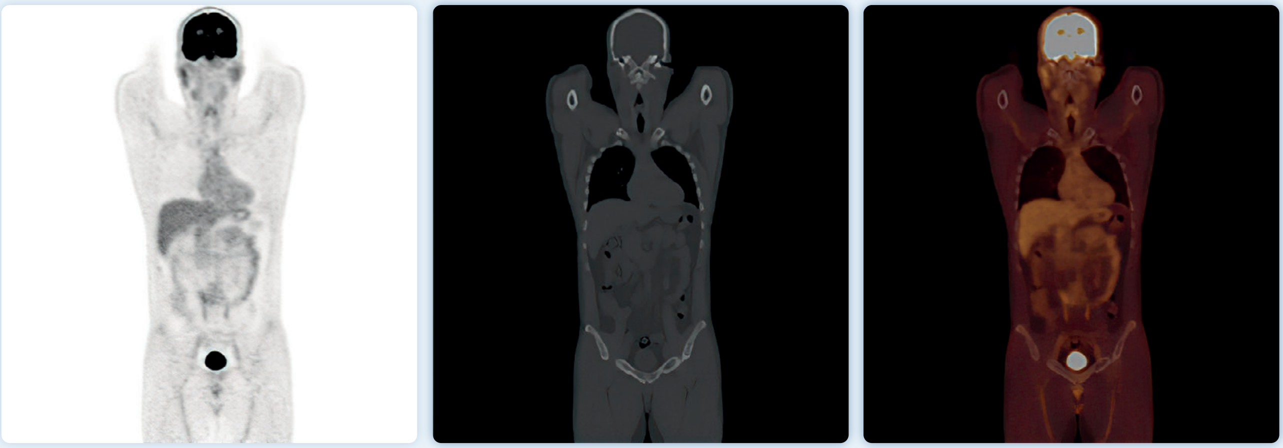
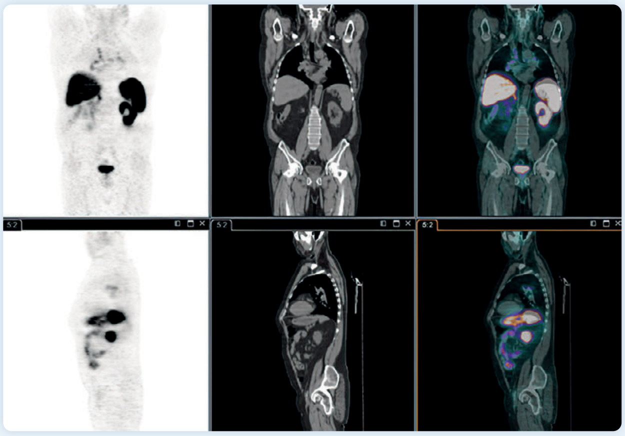
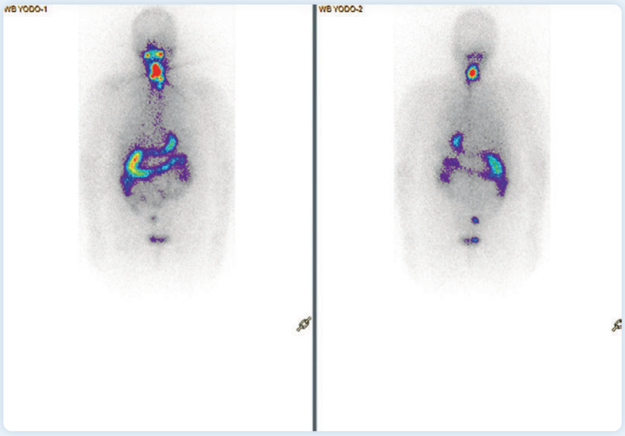


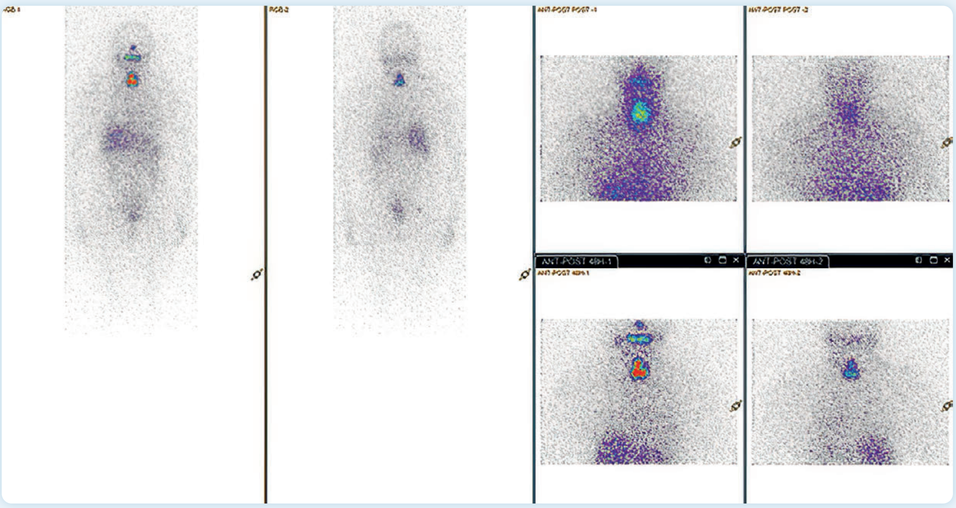
PET-CT with FDG performed on a patient with lymphoma. The PET functional image (left) is supported by CT anatomical image (middle) in order to identify more clearly the highlighted organs (SINFONIA lymphoma patient).



PET-CT with ^{68}Ga. Neuroendocrine tumour of unknown origin (SINFONIA ^{68}Ga patient)



Scintigraphy test after iodine treatment for thyroid cancer (SINFONIA ^{131}I patient)



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