Nuclear Medicine and Radiation Protection CE

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ABSTRACT: **Nuclear medicine and molecular imaging procedures play an important role in the diagnosis, assessment, and treatment of many diseases. These include diseases of the heart, skeleton, brain, and kidneys as well as applications in oncology. The following article discusses various nuclear medicine diagnostic and therapeutic applications, and the technology behind them. Finally, radiation safety in the context of nuclear medicine will be discussed. It is important that all members of the nuclear medicine team are equipped to provide an appropriate discussion of the benefits and risks of nuclear medicine to our patients and their families. (J Radiol Nurs 2016;35:5-11.)**

KEYWORDS: **Nuclear medicine; Isotopes; Radiation safety; SPECT; PET/CT.**

INTRODUCTION—WHAT IS NUCLEAR MEDICINE?

Nuclear medicine and molecular imaging procedures play an important role in the diagnosis, assessment, and treatment of many diseases. These highly effective, safe, and painless methods involve the administration of a small amount of a radioactive tracer or radiopharmaceutical to the patient to allow health care professionals to examine molecular and physiologic processes within the body. These studies have been used for >60 years to evaluate practically every human system, including the heart and brain, and to image many types of cancer. In addition to diagnostic imaging procedures, radiopharmaceuticals can be given to the patient for therapeutic purposes such as the use of radioactive iodine to treat thyroid disease. This article addresses diagnostic nuclear medicine procedures exclusively and will not discuss the therapeutic aspects.

Nuclear medicine is unique in that it provides information about a patient's condition that may not be readily obtained or is not obtainable at all with other diagnostic imaging methods. This is because nuclear medicine examines function, rates of metabolism, and various other physiological activities within the body, rather than focusing primarily on anatomy and structure. In many disease states, functional changes occur long before anatomical changes occur or become visible. Thus, nuclear medicine can often provide critical information to the clinician such as early detection and extent of disease, whether the disease is progressing or if a current treatment is working.

Nuclear medicine procedures are physiological, sensitive, minimally invasive, and safe. Overall, radiopharmaceuticals contain only trace amounts of material and are

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nontoxic and nonallergenic (Treves & Fahey, 2014). The total mass and volume of material administered is very small (typically <1.0 mL), significantly lower than the usual amount of magnetic resonance imaging (MRI) and computed tomography (CT) contrast agents. Therefore, their administration does not produce hemodynamic overload or osmotic effect. For example, a patient who is allergic to iodine can receive ^{123}I-NaI or ^{123}I metaiodobenzylguanidine (MIBG) without fear of an allergic reaction because the actual mass of iodine that is administered is exceedingly small and well below the threshold needed to trigger this adverse response. However, in some instances, nonradioactive iodine may be given to the patient beforehand to limit the uptake in the thyroid of radioactive iodine and thereby the radiation dose from radiopharmaceuticals such as iodine-labeled MIBG.

DIAGNOSTIC PROCEDURES

Diagnostic nuclear medicine procedures involve the administration of a small amount of a radioactive tracer to image various physiological processes of certain organs. These methods allow for early detection of disease, assist in patient management and therapeutic decisions, and provide an important tool to follow the effectiveness of therapy or to assess progression of disease. There are numerous beneficial clinical applications of the use of nuclear medicine. Some examples include myocardial perfusion imaging, tumor imaging, imaging of bone metabolism, detection of regional and relative renal function, and brain imaging to detect and localize epileptic foci and determine activity of brain tumors. Table 1 shows several radiopharmaceuticals and their routine clinical uses (Gelfand, Parisi, & Treves, 2011).

NUCLEAR MEDICINE TECHNOLOGY

After the administration of the radiopharmaceutical, typically by intravenous injection, the tracer travels to the area of the body of interest. Different radiopharmaceuticals will go to different types of tissue (Table 1). The radiopharmaceutical typically consists of a radionuclide (e.g., ^{99m}Tc, ^{123}I or ^{18}F) and a pharmaceutical part. The radionuclide portion of the tracer emits some form of radiation, typically gamma rays, beta particles, or positrons. For example, ^{99m}Tc and ^{123}I primarily emit gamma rays, whereas ^{18}F emits positrons. These tracers have relatively short half-lives (^{99m}Tc and ^{18}F have half-lives of 6 and 2 hr, respectively), which allow for enough time to perform the study, yet minimize radiation exposure to the patient. The pharmaceutical part of the tracer defines where the radiopharmaceutical will concentrate within the body. For example, ^{99m}Tc medronate (MDP) will localize in the skeleton, whereas ^{99m}Tc dimercaptosuccinic acid (DMSA) will concentrate in the kidneys. ^{18}F fluorodeoxyglucose (FDG) is a glucose analog and thus distributes in the body according to glucose metabolism. In some cases, imaging occurs immediately after the radiotracer administration, such as ^{99m}Tc mercaptoacetyltriglycine (MAG3) kidney and ^{99m}Tc-labeled red blood cells studies. For other radiotracers, such as ^{99m}Tc DMSA, ^{99m}Tc MDP and FDG, there are waiting periods between the administration of the tracer and when the images are taken (from 1 to 3 hr) so that the agent can distribute to the tissue of interest and to clear from the blood or neighboring tissues. Certain cases, such as a ^{99m}Tc MDP bone scan, may require initial imaging and later imaging.

The scans can be dynamic, meaning that they measure the radioactivity in the tissue over time (e.g., an image every minute for 30 min). Several frames are collected during this interval that can be displayed as a video recording of the movement. An example of a dynamic scan would be the acquisition of a "renogram" using the radiopharmaceutical ^{99m}Tc MAG3. In this study, an image of the agent in the kidneys is acquired every minute or so for around 30 min. The early images or "frames" show the perfusion and uptake of the agent by the kidneys, whereas the later frames demonstrate the rate of clearance from the kidneys.

Table 1. Common clinical uses for various radiopharmaceuticals

Radiopharmaceutical	Common clinical imaging use
^{18}F fluorodeoxyglucose (FDG)	Tumors, inflammation, and myocardial viability
^{99m}Tc sestamethoxyisobutylisonitrile (MIBI)	Myocardial perfusion
^{123}I metaiodobenzylguanidine (MIBG)	Neuroendocrine tumors
^{99m}Tc medronate (MDP)	Bone metabolism
^{99m}Tc dimercaptosuccinic acid (DMSA)	Detection of acute pyelonephritis and chronic renal scarring
^{99m}Tc mercaptoacetyltriglycine (MAG3)	Renal function
^{99m}Tc mebrofenin or disofenin	Hepatobiliary system
^{99m}Tc-macroaggregated albumin (MAA) and labeled aerosols	Lung perfusion and ventilation
Ethyl cysteinate dimer (ECD) or ^{99m}Tc hexamethylpropyleneamine oxime (HmPAO)	Regional cerebral perfusion
^{99m}Tc-labeled red blood cells (RBCs)	Gastrointestinal bleed−spleen imaging
^{99m}Tc sulfur colloid (SC)	Gastric emptying, lymphatic flow