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Role of PET and SPECT Scans Functional Imaging Technique in Radiological Diagnosis

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Abstract

In the medical imaging field, nuclear medicine employs a variety of image analysis methodologies, including single-photon emission computed tomography (SPECT) and positron emission tomography (PET). These techniques offer the radiologist supplementary information that aids in the precise analysis and diagnosis of various diseases. A PET system is a functional imaging technique that relies on the capture of two gamma photons from a radioisotope that has accumulated in a target, whereas a SPECT scan is a functional imaging technique that relies on the capture of a single gamma photon from a radioisotope within a target. Radiopharmaceutical materials are indispensable for PET and SPECT examinations. In order to determine the localisation and distribution of radioisotopes within the body, they are designed as molecules that transport radioisotopes to the target. In summary, the primary distinction between SPECT/CT and PET/CT imaging techniques is the manner in which they detect the photons emitted by radiopharmaceuticals that have been loaded with radioisotopes after being absorbed by the body. The selection of radioactive material and radiopharmaceuticals is contingent upon the target's metabolism process within the body, the radionuclide's physical half-life, and the molecule's size.

Introduction

In nuclear medicine, a diverse range of image analysis methodologies are currently implemented within the field of medical imaging, providing the radiologist with additional information to facilitate the accurate analysis and diagnosis of diseases. Consequently, the radiologist is now capable of identifying abnormalities in the body with a significantly higher degree of precision. Therefore, functional imaging techniques, such as PET and SPECT, have become indispensable to clinical

decisions in numerous medical specialties. As a result, hybrid imaging, which integrates with computed tomography (CT), PET/CT or SPECT/CT, or with magnetic resonance imaging (MRI), PET/MRI or SPECT/MRI, has enhanced diagnostic accuracy by utilizing the combined functional and anatomical information from PET and MRI scans, as well as correcting for attenuation [1]. PET/MRI and SPECT/MRI have been shown to be superior to PET or SPECT alone. However, the approach that will ultimately dominate nuclear imaging techniques remains unclear.[2] Radiopharmaceutical materials are essential to PET and SPECT examinations [3]. They are designed as molecules capable of delivering radioisotopes to a given target in order to ascertain the localisation and distribution of radioisotopes within the body [4]. A variety of radiopharmaceuticals are used in the SPECT and PET imaging techniques to support clinical decision making. For example, 99mTc-sestamibi and 99mTc-tetrofosmin are used in SPECT scans to find heart ischaemia, and 18-fluorodeoxyglucose (FDG) is used in PET scans to find breast cancer [5]. Malignant cells have a greater metabolism than normal cells, so they uptake radioisotopes more rapidly than healthy cells. This means that the targeted tissues absorb these materials to a faster and greater extent than the surrounding tissues [6]. Although radiopharmaceuticals are considered safe medical products [7], side effects should not be ignored, which include effects on bone health due to radioactive materials [8-10]. The progress of radiopharmaceuticals associated with diagnosis and therapy protocol In order to carry the radioactive material to the target [4]. The main aim of the article is to explain the role of functional imaging techniques (PET and SPECT scans) in the radiological diagnosis of various diseases, as well as the impact of radiopharmaceuticals in diagnosis.

Positron Emission Tomography (PET) scan

A PET scan is a functional imaging technique that detects two gamma photons emitted in opposing directions (180º), each with energy of 511 keV, due to the annihilation of a radioisotope concentrated in the target organ. This technique observes metabolic activities within the human organism [11]. Consequently, it is possible to ascertain the position of a source along a line of response (LOR) [12]. A multitude of detectors encircles the patient in a PET system, capturing gamma rays emitted from the target which are utilised to create two-dimensional pictures. The software subsequently reconstructs these images to generate three-dimensional representations of the radiopharmaceutical concentrations within the target [13]. PET scans can visualise certain diseases, including neurological and cardiovascular ailments. PET scans utilising diverse radiopharmaceuticals provide dependable insights into dementia, assisting radiologists in diagnosing distinct dementia-related illnesses [14,15]. In practical applications, PET can differentiate between benign and malignant solitary pulmonary nodules measuring between 0.6 and 3 cm when X-ray findings are ambiguous

[16]. The PET technique is predicated on the capture of photons emitted from a radioisotope, which is typically administered via intravenous administration [17]. The PET imaging technique is most frequently employed to assess the rate at which glucose is utilized in various regions of the body by utilizing the accumulation of the radioactive glucose analogue 18-fluorodeoxyglucose (FDG), which is considered the gold standard PET radiopharmaceutical [18]. This technique is employed for whole-body scans to stage and position tumours, as malignant tumours metabolize glucose at a faster rate than benign ones [19]. Additional applications of PET scans include the monitoring and diagnosis of Parkinson's disease, the assessment of myocardial viability in cardiology, and the monitoring of blood flow and oxygen utilization in the brain [20].

Single-Photon Emission Computed Tomography (SPECT) scan

SPECT scans use target-emitted gamma photons for functional imaging. SPECT systems can use one or more gamma cameras on a gantry to record images from a range of viewing angles and similar time intervals around the body [21]. Gamma camera heads rotate around the subject to evaluate organ function. Two cameras require simultaneous 180° coverage, though triple-head cameras with 120° coverage can also be employed, while a four-headed system needs only 90° coverage [22]. Multiple heads boost sensitivity by covering the solid angle for the targeted tissue, lowering gamma-ray attenuation, and minimising the angular range of motion required to gain complete target data. Thin slices along any imaging axis of the target illustrate the radioisotope's distribution [23]. SPECT imaging is performed by administering a radiopharmaceutical [24]. The administered radioisotope concentrates in particular regions of the human body, depending on the type of examination conducted; for example, it will highlight the gallbladder and bile duct during a hepatobiliary scan, and bone during a bone scan. In most instances, a complete 360° rotation is employed to provide comprehensive images of specific tissues. The image acquisition duration varies between 15 and 30 minutes [25].

Comparison between PET vs SPECT scan

PET technology provides superior resolution, reduced attenuation (high photon energy), and fewer scatter artifacts, hence improving diagnostic capabilities relative to SPECT [10]. PET is a potent and versatile instrumenting applicable in both clinical and research fields. Its superior sensitivity and adaptability as a tracer are its key advantages over SPECT [26]. However, the use of PET imaging is somewhat restricted by the substantial cost associated with its use. The nuclear medicine department of the hospital is obligated to synthesize the majority of positron-emitting radioisotopes using cyclotrons due to their brief half-lives [27]. One of the advantages of SPECT imaging is that radiopharmaceuticals are easier to provide than those required for PET scans [28]. SPECT has targeting capabilities for active tissues due to the single photon emitters, facilitating the precise

characterization of biological processes within the human body, which occur within many hours after the administration of the radioactive compound. Positron emission tomography (PET) is used with short physical half-life isotopes, including carbon-11 (20.4 min) and fluorine-18 (109.7 min), to measure biological processes within the body [29]. Additionally, it is widely used as a tool to detect specific molecules within the body. Radiopharmaceuticals were recognized in the 1960s with regard to their utility in in vivo diagnostic and therapeutic applications [30]. Single-photon emission computed tomography (SPECT) constitutes nearly 80% of all nuclear medicine scans conducted globally [31]. PET offers the benefit of increased resolution and sensitivity; however, SPECT is cheaper and more readily accessible [32]. In clinical trials, a diverse array of radiopharmaceuticals has been tested and evaluated that are now used in the diagnosis of a broad spectrum of diseases, they are all required to achieve the same criteria as imaging agents: high specificity, low toxicity, stability, rapid clearance from non-targeted tissue, and be low-cost [11]. To be suitable for a specific biological target, there are several factors that should be considered when dealing with radiopharmaceuticals; for instance, the radionuclide must have an acceptable half-life, the length of which is dependent on the intended application. The size and amount of the radiopharmaceuticals is directly related to the specificity of the biological target, which is in turn dependent on the metabolism and tissue components of the target, the body mass index of the patient, and the size of the target's cells. Therefore, quality control studies require consideration of physical, chemical, radiological, and biological properties [33, 34]. As medical applications that employ ionising radiation, the advantages of PET and SPECT procedures must be assessed in relation to the potential risks to patients. The procedure entails the administration of a suitable quantity of radioactive material to generate high-quality images that provide the requisite clinical information while simultaneously minimising the patient's exposure to radiation [35]. Therefore, the dose administered must be established by evaluating several pertinent factors, including the configuration of the imaging equipment utilized for the diagnosis, the target's location, and the body's metabolism [36]. The effective dose for functional imaging scanning can be up to 20 mSv, with SPECT scans requiring lower effective doses than PET scans [37]. This is primarily due to the characteristics of the radioisotopes used with PET and SPECT scans. The average dose that works for a 99mTc(I)-sestamibi SPECT scan with 1500 MBq of activity is 12.8 mSv during a cardiac scan. On the other hand, the effective dose for an FDG PET scan with an administered activity of 740 MBq is 14.1 mSv [38]. The integration of a CT scan in hybrid systems leads to heightened radiation exposure. The increased radiation dose is contingent upon whether the CT scan is being employed for diagnostic acquisition, localisation, or attenuation correction [39]. The primary limitation of PET and SPECT scans, which is the localisation of uptake, can be addressed via hybrid imaging (PET/CT and SPECT/CT scans) [13]. The creation of new PET radiopharmaceuticals is currently considered extremely important because PET/CT imaging is now

seeing widespread use in clinical settings. Nevertheless, SPECT remains a significant component of nuclear medicine imaging, as discussed in recent reviews [3].

Conclusions

The basic distinction between the SPECT/CT and PET/CT imaging techniques is based on the manner in which the radiopharmaceuticals loaded with radioisotopes are absorbed by the body. Consequently, SPECT/CT and PET/CT scans will retain the benefit of imaging patients in which the radiopharmaceuticals are absorbed over an extended duration. Moreover, advancements in this technology are expected to enhance scan quality, minimise patient exposure to radiation from the radionuclide (SPECT or PET) and X-ray emissions from CT scans, and reduce scan duration.

The selection of appropriate radiopharmaceuticals and radioactive materials for use in such scans is dependent on the target's metabolism, the radionuclide's half-life, the molecular size, the composition of the targeted tissues, the purpose of the scan, and the patient's mass and height.

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