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PET IS A NEW DEVELOPMENT IN MEDICINE AND ITS ADVANTAGES AND OPPORTUNITIES

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Annotation. Positron emission tomography (PET) uses small amounts of radioactive materials called radiotracers or radiopharmaceuticals, a special camera and a computer to evaluate organ and tissue functions. By identifying changes at the cellular level. PET may detect the early onset of disease before other imaging tests can.

Keywords: PET, positron, electron, radionuclide, positron, radiotracer..

In PET imaging, a molecular substance required for metabolism in the body is labelled with a positron-emitting radionuclide, which releases positrons as it decays. The positrons then interact with free electrons in the body to generate annihilation radiation, emitting two γ photons with the same energy (511 keV) in opposite directions. The PET scanner detects the pair of γ photons within a specific time frame (i.e., the coincidence time window) to confirm the occurrence of an annihilation event between the two detectors, and the event is recorded as one event. Since γ photons have a certain level of penetrating power, PET detects γ photons outside of the body to obtain the tomographic distribution of positron emitting radionuclides for imaging. The PET detector is ring-shaped, and volume data are obtained by detecting the resulting γ photon pairs from annihilation events in any direction within the detector.

Patients must fast for at least 4 h before the scan, although they can drink sugar-free water during this period, and they must also avoid exercising vigorously or for an extended period of time the day prior to the scan. Diabetic patients should maintain their blood glucose concentration at a recommended level of ≤11.1 mmol/L. Patients should disclose their current medication regimens and be accompanied by a family member on the day of the scan. The attending physician obtains a detailed medical history, verifes the patient's order, and confirms the patient's general information, reason for the examination, and scan protocol. The physician also verifes that the patient has no contraindications to MRI, and informs the patient of the scan procedure, precautions, and expectations. On the day of scan, the patient's height, weight, and blood glucose are measured, and venous access is established. The injection dose is calculated based on body weight, which is 3.7 MBq/kg for the conventional tracer 18F-fuorodeoxyglucose (18F-FDG), and 0.1 mL/ kg body weight (0.1 mmol/kg) for the contrast agent. For patients undergoing static imaging, all audiovisual stimuli are blocked out after the radioactive tracer (e.g., 18F-FDG) is injected, the room lights are dimmed, and the temperature is maintained at approximately 22 °C. The patient is asked to keep their eyes closed for 40–60 min while lying on the examination table, during which they should avoid talking, eating, or chewing. For patients undergoing dynamic imaging, a bolus injection of the radioactive tracer is performed with the patient on the scan table, and the technologist begins image acquisition before the injection. Patients receiving dual radioactive tracers are first injected with the tracer with the shortest half-life. They are scanned, and then asked to rest on the scan table with their eyes closed for ≥10 half-lives, after which they are injected with the tracer with a longer half-life. Patients receiving both a radioactive tracer and a contrast agent are injected via two separate intravenous (IV) catheters, so as to prevent the accumulation of radioactive tracers in the IV catheter from affecting image quality. Patients are required to

change into hospital provided clothes for the examination; prior to entering the scan room, the patient and their family member/friend must remove all metallic objects from their bodies. Wheelchairs, stretchers, hospital beds, oxygen tanks, monitoring equipment, and other equipment are all strictly prohibited from entering the examination room. Patients requiring oxygen therapy are given MRI-safe oxygen equipment. Patients with limited mobility should use MRI-safe wheel chairs or beds. Nurses are strictly prohibited from bringing any metallic items into the scan room.

PET imaging of the brain consists of a single scan position, and the scan range includes the entire brain. The midline of the scan position is the center of the brain. Acquisitions can either be considered static or dynamic. The scanning mode is set to volume scan, which covers the entire brain. The dynamic scan time begins after the injection of the radioactive tracer with the patient on the scan table, and ends when drug metabolism stabilizes, which generally takes around 60 min. The scan time can be selected based on the characteristics of the tracer used. Static scans generally last 8–10 min, or are performed simultaneously with the MRI scan. The scan parameter settings (based on the GE PET/MR) are as follows: TOF and point spread function (PSF) technology; slice thickness = 2.78 mm; feld of view (FOV) = 35 cm; number of iterations = 8; valid subset = 32; matrix size = 192 × 192; full width at half maximum = 3 mm; and MRAC based on the Dixon sequence. The list mode is selected in dynamic scanning for segmenting in chronological order, which is necessary for image reconstruction.

PET imaging involves the detection of a radiotracer labelled with a positron-emitting nuclide within the body. When the radionuclide containing tracer is injected into the body, the radionuclide bound to the tracer accumulates in the target organ(s), from which it emits positrons. Each positron travels approximately 1–3 mm and then collides with a random body tissue. This collision generates annihilation radiation, producing a pair of 511 keV gamma (γ) photons that travel 180° relative to each other. By placing a pair of detectors in the direction of fight for the photon pair, the two photons can be captured simultaneously. The line connecting the two detectors receiving the photon pair is known as the line of response (LOR) and implies that the annihilation event must lie somewhere along this straight line. Therefore, by arranging multiple sets of detectors in a 360° ring, we can obtain one-dimensional information about the lines connecting multiple detector pairs. These signals are then subjected to back-projection and mathematical processing, to obtain a tomographic image of the distribution of the radiotracer. The positron-emitting radionuclides involved in the process of the generation of annihilation radiation are generally proton-rich nuclides that emit positrons when they decay. The proton in the nucleus decays into a neutron, while also releasing a positron and a neutrino, as shown in Eq. (2.1): P n → + ++ β υ (2.1) where P is the proton, n is a neutron, β+ is a positron, and υ is a neutrino. A positron has the same mass as an electron, and the same magnitude of electric charge like an electron, but positive rather than negative. Positron emission (or β+ decay) generally occurs in artifcial radionuclides. The preparation of PET radiotracers requires the generation of radioisotopes by bombarding a target with a proton beam in a cyclotron. Currently, the most commonly used PET radionuclide is 18F, which has a half-life of approximately 110 min. In comparison, other PET radionuclides (11C, 13N, and 15O) have shorter half-lives (20, 10, and 2 min, respectively). Radionuclides commonly used in neuroimaging include 11C, 18F, and 15O.

PET image acquisition can be categorized into two types: emission scanning and transmission scanning. Emission scanning can further be divided into the following categories: 2D, 3D, static, dynamic, gated, local, and whole-body acquisition. When positron-emitting nuclides enter the human body and decay, they each emit one positron, which travels a very short distance, 1–3 mm, through the nearby body tissue. Once its kinetic energy disappears, the positron collides with an electron to generate annihilation radiation, thus creating two γ photons (both with an energy of 511 keV) that travel in opposite directions. The process by which the PET scanner collects information about these photon pairs to determine the location and quantity of the radiotracer is known as emission scanning.

2D and 3D Acquisition. A 2D acquisition involves the placement of shields (known as septa)

between the individual detector rings. During 2D acquisition, the septa block photons from interacting with other detector rings and allow the detection of photon pair signals only within the same ring. Threedimensional acquisition is a rapid mode in which the septa are removed, and the detectors can detect photon pair signals from other detector rings, expanding the detection range to the entire axial FOV. The intensity of photon pair signals detected in 3D acquisition is 8–12 times higher than that of 2D acquisition, which also signifcantly enhances sensitivity. However, this also implies that there is a marked increase in scattered and random coincidences in 3D acquisition, leading to a low signal-to-noise ratio and necessitating scatter and random coincidence correction. Three-dimensional acquisition is currently widely used in clinical practice.

Conclusion, the creation of this technology has given a unique look to modern medicine. With the help of this technology, it has become possible to detect even small changes in tissues and even nerves early and effectively. The result of this is very important for early detection of the disease and increasing the effectiveness of its treatment.

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