
Volume - 5 - Issue 1, 2006 - ECRI Healthcare Product Comparison

Scanning Systems, Positron Emission Tomography PACS Comparison Table

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Scope of this Product Comparison

This Product Comparison covers positron emission tomography (PET) systems capable of whole-body imaging. Combination PET/computed tomography (CT) systems are also included. For more information on CT systems, see the Product Comparison titled SCANNING SYSTEMS, COMPUTED TOMOGRAPHY, FULL-BODY.

For information on gamma cameras capable of performing single photon emission computed tomography (SPECT) and coincidence imaging, see the Product Comparison titled SCANNING SYSTEMS, GAMMACAMERA. The cyclotrons or generators needed to produce the radiopharmaceuticals required for certain PET procedures are not included in this report.

These devices are also called: computerized tomographs, CT/PET combined systems, CT/PET hybrid imaging systems, ECT scanners, isotope scanners, PET scanners, positron cameras.

UMDNS Information

This Product Comparison covers the following device terms and product codes as listed in ECRI's Universal Medical Device Nomenclature System™ (UMDNS™):

- Scanning Systems, Computed Tomography/ Positron Emission Tomography [20-161]
- Scanning Systems, Positron Emission Tomography [16-375]

Purpose

PET systems obtain cross-sectional images of the distribution of positron-emitting radiopharmaceuticals injected into the body, assessing biochemical activity, cellular metabolism, and the physiology and pathology of various organs and tissues. Whereas CT, xray scanning, magnetic resonance imaging (MRI), and ultrasound can only provide images of the anatomic features and some physiologic activity of organs and tissues, PET can measure biochemical and physiologic activity. Data obtained during a PET procedure is functional in nature; images of metabolic processes and blood flow can be acquired, providing information on biochemical activity at the cellular level. Because alterations in biochemical activity can indicate pathologic changes and because biochemical abnormalities precede anatomic changes associated with disease, PET can detect early pathogenesis and follow the effectiveness of therapy. In addition, PET scans can characterize the effects of disease on biochemical processes well before MRI or CT scans reveal any anatomic evidence of disease. PET images can be used in combination with CT or MRI images to view both anatomy and function.

Since the commercial introduction of wholebody PET scanners, their clinical applications in cardiology, neurology, and oncology have expanded to include the following:

- Studying myocardial perfusion and tissue viability
- Evaluating severe left ventricular dysfunction
- Presurgically evaluating and localizing epileptogenic foci
- Characterizing primary brain tumors and differentiating low-grade from high-grade tumors and tumor recurrence from radiation necrosis
- Identifying early Alzheimer's disease, Pick's disease, and Huntington's disease
- Functionally and psychopharmacologically assessing the dopamine system in the normal and diseased brain
- Monitoring metabolic responses to radiotherapy and chemotherapy
- Localizing breast lesions, particularly when mammography is not definitive, such as in patients with radiodense breasts or implants
- Detecting recurrent colorectal and head/neck cancers
- Differentiating benign solitary pulmonary nodules from malignant nodules and determining metastatic involvement of lung cancer
- Performing pretherapy and posttherapy staging of lymphoma
- Detecting malignant melanomas and metastases
- Evaluating residual or recurrent ovarian Cancer

Several studies have addressed the diagnostic usefulness of PET and noted cases in which PET has successfully altered treatment management (Hoffman and Garcia 1995; Conti et al. 1996).

Principles of Operation

PET is a three-dimensional medical imaging technique that combines computerized cross-sectional image reconstruction techniques with the use of radiopharmaceuticals to produce an image. The unique characteristic of

PET coincidence imaging is its use of positron-emitting tracers.

PET Radiopharmaceuticals

The radioisotopes used in PET, which include rubidium-82 (^{82}Rb), fluorine-18 (^{18}F), oxygen-15 (^{15}O), nitrogen-13 (^{13}N), and carbon-11 (^{11}C), are made into radiopharmaceuticals (also called labeled tracers) by a generator or a cyclotron, a fixed-energy accelerator that adds a positive charge to stable isotopes by high-energy proton or deuteron bombardment. ^{82}Rb is 'milked' from a strontium parent and eluted from the generator in an isotonic saline solution. The most commonly used PET radiopharmaceutical, ^{18}F in the form of fluorine-18-deoxyglucose (FDG) — also called fluorodeoxyglucose or fludeoxyglucose — is produced using a cyclotron and a tracer processing system.

The Physics of PET

The radiopharmaceuticals used in PET contain certain isotopes that are unstable because their nuclei have extra protons. To attain a more stable configuration, the nucleus emits a positron (referred to as e^+ or β^+), a positively charged particle with a mass equal to the mass of an electron. (Figure 1a)

After emission, the positron loses energy through dissipation in the patient's tissue and eventually interacts with a free electron after traveling approximately 1 mm. (Figure 1b)

The interaction of a positron and an electron is an annihilation event, and the two particles are converted into electromagnetic radiation in the form of two gamma rays (photons). The initial energies of the emitted positrons typically range from less than 1 MeV to slightly over 3 MeV (Christensen et al. 1995), and the probability of annihilation is greater with decreasing positron energy. Therefore, the electron and the positron will almost always be at or near rest when an annihilation event occurs; consequently, the two created photons will each have an energy of 511 keV, which is the rest mass energy associated with a single electron or positron. To conserve momentum in the annihilation event, the two photons travel in opposite directions (180°) from each other. Figure 1c)

Two detectors within the detector ring encircling the patient register the simultaneous arrival of the paired photons. A 'line of response' (LOR) connects the coincident detection events. An image is gradually built up using the same technique as that in CT (i.e. back projection). A greater percentage of annihilations occurs in more active tissues and parts of organs.

PET Instrumentation

The major components of a PET system include a gantry, a detector assembly, coincidence circuits, a patient couch, and a computer system. The gantry houses the electronic circuitry, the patient positioning lasers, the septal-ring assembly, and the detector assembly.

PET systems use the same basic techniques of detection as those of standard gamma cameras. However, annihilation detection in PET has two significant differences compared to that in standard nuclear medicine.

The first is that the collimation requirements are greatly reduced. All standard gamma cameras rely on lead collimators to allow a meaningful image to be acquired. In PET, collimation is achieved by accepting only coincident events. A short window (approximately 5 to 10 nanoseconds) is preset. Any two events that occur in this window are considered to be true coincident events.

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