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# Introduction To The Factors Of Acquisition Of Positron Emission Tomography PET-CT

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**Abstract**

The results of Positron Emission Tomography (PET-CT) are qualitative and quantitative. The observation of uptake images brings along the quantification of metabolism. Healthcare professionals should understand the factors that can alter this outcome. This review is descriptive with an analytical discussion of the current practices in Nuclear Medicine. We present a literature review of the factors that can alter the results from this imaging technique and a critical analysis of its clinical significance and relevance. PET-CT is a hybrid technology and it is important to have a basic understanding of how deviations in acquisition processes can affect the resulting images. It is important to understand the type of radiation protection that is applicable to patients and healthcare workers in PET-CT.

**Keywords:** nuclear medicine, PET-CT, factors, acquisition

## 1. Introduction

Positron Emission Tomography (PET) is part of the field of Molecular Imaging and allows you to visualize non-invasively the molecular processes in living organisms. This technological advance is the product of several disciplines including physics, engineering, pharmacy and medicine. Since its invention up to the present date, PET CT has undergone several changes in instrumentation as well as in radiopharmacy and clinical applications (Liu et al., 2010; Mettler & Guiberteau, 2012).

It is very important to treat the technology, PET CT as a clinical tool to reach diagnoses more quickly and accurately. At the same time, you must take into consideration that the results of this mode are semi-quantitative and dependent on care, analysis, and maintenance of measuring equipment. To understand the limiting factors of the technology and the team is a task that expands to the team of professionals including medical doctors, physicists and technologists.

In this article we review topics that cover the principles and factors of the SUV, the importance of the quality controls of the equipment and radiation protection in PET CT (Mansi, 2019). This review is addressed to health care professionals including, but not limited to, medical doctors, physicists and technologists, as a material for education and reference. This article is a supplement to the “Basic Principles of Positron Emission Tomography PET/CT for health professionals” published by the same authors.

## 2. Materials and Methods

The present work is a review of the descriptive with a discussion of analytics of the factors that alter the resulting images of the PET-CT as well as the type of radiation that is handled in this image area. This study corresponds to the query and critical discussion of primary and secondary sources obtained from technical documents, research books and scientific journals indexed, with relation to the subject of research. The classification documentary of the process of analysis was identified and sorted by classes, defined according to the content of the document itself and the experience of the authors.

## 3. Contents

### 3.1 Concept of the SUV

In computed tomography, the pixels are assigned with values of Hounsfield Units (HU) which is an index semiquantitative of attenuation. In PET, they can be assigned values of accumulation of uptake, called the SUV (Standardized Uptake Value) or Value of Uptake Standardized. The use of this value removes variability introduced by differences in patient size and the injected dose. (Mansi, 2019; Liu et al., 2010).

$$\frac{\text{Activity of the Region of Interest (mCi/mL) x patient Weight (g)}}{\text{injected Dose (mCi)}}$$

If the dose was distributed homogeneously in the body, the value of the SUV would be 1.0. The SUV has no units, since it works by assuming that 1 ml of tissue weighs 1 gram. The data for the calculation of the SUV are manually inserted into the computer of PET-CT before starting the test (Fanti et al., 2009; Mettler & Guiberteau, 2012; López-Durán et al., 2007; Keyes, 1995).

### 3.1.1 Factors that alter the SUV

It is important to emphasize that the SUV is not an absolute value and accurate. There are several points of bias and variance are introduced to measure this value. In clinical practice, the value SUV allows an assessment of uptake relative. The use of threshold values of SUV for diagnosis is not a widely accepted practice (Keyes, 1995); for two main reasons: i) The staging and diagnosis should not rely on calculations accurate, as the appearance of the image is sufficient for such purposes; ii) The value SUV has a high degree of variability. It is a very common practice to report values SUV tumor (Kinahan & Fletcher, 2010; Oliva González et al., 2017), so it is recommended that the professionals using this value as part of the reports and clinical decisions are made aware of the contribution and the limitations of this value is useful especially to compare when you have studies pre-or basal and by which we can assess the improvement or progression of tumor diseases.

Among the technical factors that can affect the calculation of an SUV, it includes the counting statistics of events for the image, the parameters of reconstruction, the creation and the definition of volumetric regions of interest, calibration of the equipment. Images obtained with short times of image, or with very low doses of radiopharmaceutical do not have the amount of information required to determine the SUV with a low margin of error. The way in which the system quantifies the information of the image within an area of interest outlined may vary (Sciagrà et al., 2021; Protección radiológica y seguridad en medicina, 1996).

The physiological factors that affect the calculation of the SUV, which include the injection time-measurement, levels of glucose in the blood, infiltration of dose during the injection, among others. In terms of the time of measurement, the uptake of FDG in lesions increases rapidly during the first two hours. Take into account that as you increase the time from the injection to the acquisition of images, the greater will be the values of the SUV in malignant cells. In some cases, this feature helps to differentiate in images late lesions with catchments suspicious in the first image. The main reason for fasting in patients is to reduce the glucose in the blood so that it does not compete with the uptake of FDG (Caldwell et al., 2003).

It is important to analyze the relevance of the use and accuracy of values of SUVS on the images PET. The precision is presented with constant values on several occasions in which to measure something. It is possible to obtain values of the SUV accurately in the case of known or to maintain constant sources of error and variance introduced in the procedure. The first category that benefits from this type of measurements spanning clinical research, clinical trials and development of new medicines. The second category of priority is the evaluation of the response to treatment of oncological diseases. In this case, PET/CT has the added value of the metabolic rate to measure only the dimensions of the tumor. The third category is the clinical practice of day-to-day. The

SUV is a value that is added to the interpretation of the images without being a determinant sole and absolute clinical decision (Kinahan & Fletcher, 2010; Caldwell et al., 2003).

### 3.2 Importance of quality controls

The images of the PET / CT are unique in their ability to quantify the distribution of the radiotracer. For this reason, it should be noted that the performance of a system PET / CT has a direct influence on the clinical outcome. It is recommended to follow a complete program, and continuous quality control to systems, PET / CT to establish a performance baseline to then perform periodic evaluations annually, semi-annual and daily. Users can avail of the recommendations of the manufacturer as well as review other recommendations implemented by international agencies. All the evidence suggested can be accomplished with the numerous platforms of PET commercially available (Sciagrà et al., 2021, Bebbington et al., 2019). Below is a brief explanation of the most well-known and its clinical impact.

#### 3.2.1 Alignment of PET images and CT

One of the most important features of these studies is the fusion of the images and metabolic imaging morphology. In clinical practice there are certain faults in the fusion of images, especially when the patients have changed their position between parts of the study. In these cases, the user can identify the fault in the fusion of images very easily. It is also necessary to do a quality control check for the alignment of images of PET and CT, without having the variant of the patient. These measurements can be performed with the use of a fantoma with radioactive sources and markers of high density in various places. Then by the exploration of the fantoma with both modalities, we can quantify the registration of the two images on an annual basis and on its installation.

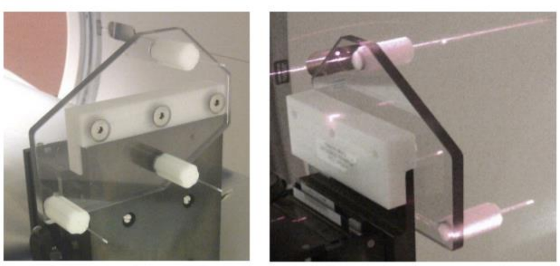

**Figure 1.** Use of capillary tubes with a radiotracer in a fantoma GE for the verification of the alignment of images of PET and CT.

**Source:** PET/CT Acceptance Testing and Quality Assurance. American Association of Physicists in Medicine. 2019.

#### 3.2.2 Spatial Resolution of PET

The spatial resolution of a system refers to the fineness of detail that can be seen in a reconstructed image. Usually, it is defined as the full width at half-maximum (FWHM) of a point spread function (PSF) and is calculated from the profile of a reconstructed image from a radioactive source. The values of follow-up must be within ± 5% of the reference values. The evaluation of the spatial resolution is very important because it allows the user to recognize what is the size of the lesion smaller than that of the PET can detect (Organismo Internacional de Energía Atómica, 2009; Bebbington et al., 2019; Mansi, 2019).

### 3.2.3 Sensitivity of the computer

The sensitivity is a measure of the number of detected events per second per unit of activity in the field of view of the PET scanner. In the clinical aspect, the more sensitivity you have to the equipment, the image will have more events of annihilation registered and more information, which is equivalent to a good quality image.

The test is conducted with the levels of very low to decrease the losses of dead time and random coincidences. The sensitivity of a PET scanner should not vary substantially during the useful life of the scanner at least that there is a fault or update of a component that affects the sensitivity. However, we expect a gradual decrease in sensitivity due to the deterioration of the crystals with age. The values of tracking sensitivity should be within ± 5% of initial values (Avramova-Cholakova et al., 2015; Lopez et al., 2021).

**Figure 2.** Example of a fantoma sensitivity for PET with various sizes of tubes with different activities.

**Source:** PET/CT Acceptance Testing and Quality Assurance. American Association of Physicists in Medicine. 2019.

### 3.2.4 Measurement of the SUV

The performance measurement of the count rate is used to evaluate the losses of system events with varying amounts of radioactivity. The methodology NEMA NU 2 requires a fantoma special of 70 cm with a line source of radioactivity, access to the analysis of sinogrammes PET to calculate the rates of the different types of events, and the noise as a function of activity concentration. The clinical significance of this test is that it can affect the measurements of values, SUV (Lopez et a., 2021).

This test measures the accuracy of the SUV in a fantoma based PET reconstructed. The fantoma proper is filled with water and F-18. When the activity is distributed in a uniform manner, the SUV is 1.0. You can also measure the phantoms with other concentrations of radioactivity, and to compare with the calculated value.

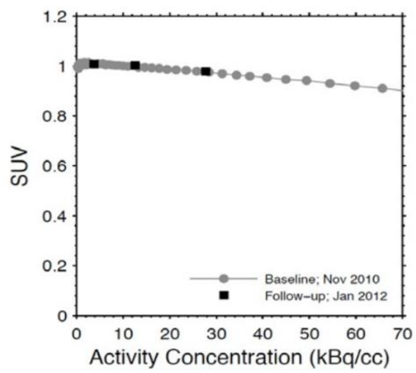


**Figure 3.** Measurements base and monitoring of values in SUV in function of the concentration of activity on the same computer. Time between measurements: 14 months.

**Source:** PET/CT Acceptance Testing and Quality Assurance. American Association of Physicists in Medicine. 2019.

### 3.2.5 Evaluation of the correction of the attenuation and the contrast of the image PET

The purpose of this test is to evaluate the image quality of PET in clinical conditions. It can be performed with a fantoma special, usually the fantoma ACR that contains four cylinders of different diameters and with different levels of activity and three cylinders of materials of different density. The user can measure the values of a SUV and the attenuation that represent the different regions of teflon, air, and water. This test verifies that the image fusion between PET and CT and attenuation correction are correct (Lu Zhang et al., 2021).

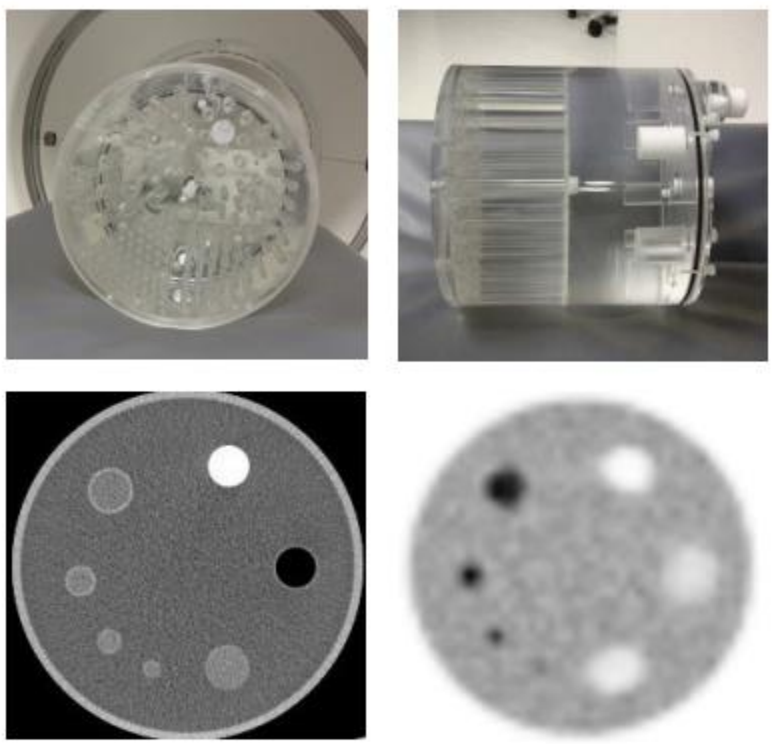

**Figure 4.** Fantoma PET of the American College of Radiology. Above you can see the blood phantom in its physical form. Below are the images of CT (left) and PET (right). The CT images show multiple cylinders of materials such as air, water, and teflon. Image of PET shows the attenuation given by these cylinders.

**Source:** Organismo Internacional de Energía Atómica (2009).

### 3.2.6 Evaluation of the uniformity of the image of PET

The purpose of the evaluation of the uniformity of the image is to provide a measure of the deviation in the concentration of activity within a court (López-Durán et al., 2007). This prevents the misinterpretation of images due to artifacts caused by the scanner or by faults in the detector PET. Usually this test can take the place of phantom acrylics, which have to be filled with a small activity of radiotracer diluted in the water volume.

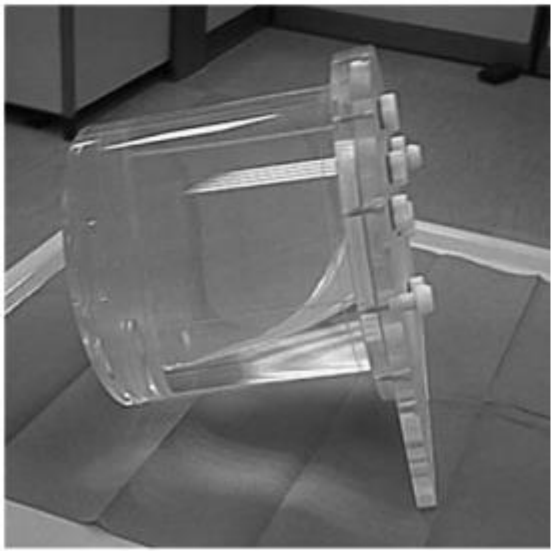

**Figure 5.** A fantoma cylindrical uniformity to be filled with a solution of F18.
**Source:** Organismo Internacional de Energía Atómica (2009).

### 3.3 Radio proteccion PET-CT

#### 3.3.1 General precautions

The radiosafety in PET-CT with open source is similar to that which is put in practice in the area of Nuclear Medicine. Radiopharmaceuticals for PET-CT emit photons with higher energies (511 keV) of Technetium-99m (140 keV), but with a duration or half-life significantly shorter (Cherry et al., 2012). You should also take into consideration the existence of the ct scanner and the additional measures of radio safety for users and patients. According to the International Commission on Radiological Protection (ICRP for its acronym in English), there are three fundamental concepts in radiation protection: justification, optimization and dose limitation.

#### 3.3.2 Justification

To justify the use of PET/CT in a patient, one must examine the relationship of risk-benefit tests. The benefit of the examination must be greater than the risks that it implies, according to the circumstances of each patient. In new techniques, more than to take this justification, the decisions should be supported by literature. The International Commission on Radiological Protection (ICRP) has adopted an approach of several steps for the justification of the examination. Once you have identified a new practice, it reviews the results reported in the literature which provides a rationale and preliminary generic. Much more research work is needed for other diagnoses other than cancer and is just in need of a justification of the exposure and the needs of the particular patient.

Agencies and health institutions around the world perform systematic evaluations independently that support the use of PET-CT under certain conditions. There may also be specific scenarios where the evidence from the literature is not so strong or is scarce but there is a strong logic in which the test can help in a positive way to the patient. The team of doctors who observes the patient is the best knower of the benefits of the different technologies in health.

For all patients arriving for your exam, PET-CT, there must be knowledge of the history, including but not limited to: surgery, chemotherapy, radiation therapy, medical problems, recent, drug, and finally other diagnostic tests recently conducted or to be conducted in the future.

### 3.3.3 Optimization

The optimization level of radiation protection is based on the principles of ALARA (As Low As Reasonably Achievable), an acronym that translates to "how low is reasonably possible". Exposure to patients is directly proportional to the administered activity. While most activity is administered, the greater the dose of radiation to the patient. The activity of the radiopharmaceutical administered depends on the material of the detectors (crystals, BGO, GSO, LSO), the count rate of the scanner, the mode of acquisition of images (2D, 3D, Time of Flight) and the weight of the patient. It is not possible to sacrifice the quality of images at the cost of very low doses of radiopharmaceutical, but if it is feasible to find a balance between the two factors.

The exposure to the patient is kept as low as possible to obtain a good image quality according to the available resources. Over the years, there are better teams detectors with more sophisticated than ever require less dose to the patient to give results of excellence.

### 3.3.4 Radiation protection for Patients

Like any other diagnostic test that uses ionizing radiation, PET-CT is not suitable for pregnant women. For the patient there are two types of radiation exposure: exposure of internal and external. The internal exposure to the patient is given for the dose that is injected intravenously. Assuming that F-18 FDG is the radiopharmaceutical of use, in a normal metabolism, the bladder is the organ that receives more radiation because the compound is excreted through the urine.

Among the precautions to reduce this accumulation of radiotracer, is giving water to drink to the patient and that the patient empty their bladder when possible (Fukukita et al., 2014; Boellaard et al., 2010). Other ways to decrease the internal exposure include the administration of additional doses by weight. The external dose to the patient comes in most of the study of ct scan done at the beginning of the review of PET/CT. The dose to the patient may vary according to the study that is being carried out. Originally, the part of the CT scan in an exam PET/CT exists for reasons of attenuation correction of the picture PET and correlation of the catchments with its anatomical location (Harrison & Marsh, 2020; Brix et al., 2005).

According to the ICRP, the dosage of a ct scan of a low dose is used only for attenuation correction varies between 2 and 4 mSv, while the dose of a ct scan of diagnosis that may or may not include contrast varies between 2 and 20 mSv (Fahey, 2009). Dosimetry of Pediatric PET/CT. On the average, the use of tomography of low dose for attenuation correction reduces the dose by a factor of 2 to 3 (Harrison & Marsh, 2020). The tomography verification of attenuation technically does not qualify as a diagnostic study by itself, unless the institution has the appropriate modifications in the configuration of the scanner to obtain images of diagnostic quality and suitable personnel to perform and interpret CT imaging. It is important to ensure that the different parameters are covered by the algorithms of checking for attenuation. There are differences between the practices of institutions and in different countries.

### 3.3.5 Radio protection for Personal Work

The staff work area should take precautions similar to those taken in Nuclear Medicine to lower the risk of receiving high doses of radiation. The personnel shall maintain the most important concepts and basic radiation protection: distance, time and shielding. It has been estimated that around 59% of the dose received by the staff is due to the direct handling of the radiopharmaceutical with F18 and 41% comes from the interactions with the patient (Alenezi, & Soliman, 2015; Keyes, 1995). The use of the ct scanner adds a minimal dose as long as they follow universal precautions and shields appropriate (Introduction to the special issue of Radiation Protection Dosimetry, 2016; Valentin, & International Commission on Radiation Protection, 2007).

The staff always need to bring out the dosimeter for the estimation of doses received during their work. When handling radioactive compounds, to more than use the armor necessary, the use of gloves prevents inadvertent contamination with radioactive materials. You should use whenever possible the automated systems and armored for the handling of radioactive substances. The shield to be used with positron emitters will be directed to agents used in PET which are usually coatings made of titanium for the syringes and vials. The use of titanium significantly decreases the weight of the armor required to 511 keV. In a study conducted in Belgium, workers were monitored for one year to estimate the dose to your upper extremities. The dose to the skin highest was obtained in the left hand, which is used to support the syringe and the needle. The activity that resulted in increased exposure was the dispensing or dosing F18 FDG. The dose is monitored at the tips of the fingers, exceeding easily to that of the middle finger of the right hand, where usually placed the rings detectors (Kaushik et al., 2015). In other studies, it has been estimated that the use of an automatic infusion can be decreased up to 10 times the exposure of the whole body and limbs of the staff (Nassef & Kinsara, 2017).

## 4. Conclusion

In the same way that it's important to the training in the interpretation of images, it is also imperative to the understanding of the basic operation of this technology. This theoretical basis can help staff to know the limits of detectability and quantification of lesions of the scanner and to reduce the number of false negatives. While it is true that PET/CT is a very useful tool in the clinical management in oncology and other fields, this technology has its limitations, which can be overcome with the concurrent use of other imaging modalities.

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