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Influence of the resolution mode on mean and maximum SUV for PET images acquired by a LabPET SOLO 4 scanner

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ABSTRACT

In preclinical PET, SUV (standardized uptake value) is a robust quantifier that can be used to analyze PET images. Several factors – biological or technical – can affect SUV determination. Among technical factors, it is possible to cite the reconstruction protocols of PET images. This work evaluated the influence of two resolution modes – standard and high – on mean and maximum SUVs. The PET image of a mouse with a tumor in left flank was chosen from a PET image bank and reconstructed using two different protocols varying the resolution mode. The post-processing of images was performed using AMIDE software and eight volumes of interest (VOIs) were defined. Qualitatively, there was light improvement in structures definition in high-resolution image compared to standard resolution image. At the semiquantitative analysis, image reconstruction protocols using high-resolution mode did not significantly improve the recuperation of radiopharmaceutical uptake into analyzed tissues.

Keywords: **LabPET SOLO 4, Resolution Mode, Standardized Uptake Value.**

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1. INTRODUCTION

Positron Emission Tomography (PET) is used for generating molecular images applied to biochemical, metabolic and functional investigation of organs and tissues [1]. In the last years, small animal PET has become a valuable resource in noninvasive animal-based biomedical research, contributing to drug development, evaluation of new PET tracers and in vivo therapy monitoring [2].

In the preclinical routine, PET studies of small animals include three steps: images acquisition, reconstruction and post-processing. The LabPET SOLO 4 platform permits the use of different image reconstruction protocols, varying the reconstruction algorithm (FBP, MLEM-3D or OSEM-3D), the resolution mode (standard resolution or high resolution) and the number of iterations.

In a previous work realized by our group [3], the Image Quality (IQ) phantom recommended by NEMA NU-4/2008 publication [4] was used to determine the standard PET image reconstruction protocol to LabPET SOLO 4 scanner in the Molecular Image Laboratory (LIM) of the Nuclear Technology Development Center (CDTN) for the isotope F-18. This protocol is presented in Table 1.

Table 1: Standard image reconstruction protocol* for F-18 PET images.

Algorithm	Resolution Mode	Number of Iterations
MLEM-3D	Standard	20

* LabPET SOLO 4 at LIM/CDTN

It was observed that the use of the standard resolution mode did not show significant differences when compared to high resolution mode [3]. In the preset study, our objective is to verify if this finding also applies (or not) to PET images of small animals, which have more complex internal structures than those of the IQ phantom. In this sense, we analyzed standardized uptake values (SUV) for small animal PET images reconstructed with two different protocols, where it was varied only the resolution mode.

SUV is a robust quantifier that can be used to analyze PET images. In preclinical PET, SUV can be defined as a ratio of tissue radioactivity concentration (kBq/mL) and administered dose divided by animal body weight (kBq/g) [5], presented in Equation 1.

$$SUV = \frac{Activity\ concentration\ in\ a\ volume\ of\ interest\ \left(\frac{kBq}{mL}\right)}{\left(\frac{Injected\ activity\ (kBq)}{Body\ weight\ (g)}\right)} \quad (1)$$

The literature [6, 7, 8] shows that several factors – biological or technical – can affect SUV determination. Biological factors like the animal weight, the blood glucose level and respiratory movements can be cited as well as technical factors and acquisition parameters like uptake time, lacking correct decay correction, inaccurate calibration of the small animal PET scanner or use of contrast agent in PET/CT.

Additionally, at laboratorial practice different methods of SUV calculation are used in PET image analysis [7], including mean SUV (SUV_mean) and maximum SUV (SUV_max) variations. SUV_mean corresponds to the average SUV in a region of interest (ROI) while SUV_max assesses the maximum voxel value representing the highest metabolic site.

2. MATERIALS AND METHODS

Initially, a PET image (13,6 kBq; 20 min; three bed positions) of a mouse with a tumor implanted in left flank was selected from our ^{18}F-FDG/PET image bank. This bank collects images acquired using LabPET SOLO 4 scanner of LIM/CDTN. Table 2 presents some scanner specifications. More details are presented in a previous paper [2].

Table 2: Summary of LabPET 4^{TM} technical specifications [2].

Parameter	Specification
Detector Crystal Material	Phoswich pair of LYSO and LGSO
Crystal Dimension	2.0 x 2.0 x 14 mm^3
Number of detector rings	24
Crystals per ring	64
Number of Crystals	1536
Axial field-of-view	37 mm

The image acquisition file was reconstructed with two different protocols where the reconstruction algorithm MLEM-3D and the iteration number (20 iterations) were fixed, and the resolution mode were varied between standard resolution (SR) and high resolution (HR). For SR and HR modes the voxel sizes are 0.50 x 0.50 x 0.50 mm and 0.25 x 0.25 x 0.50 mm respectively. The software LabPET 1.12.1 provided by the scanner manufacturer was used for image reconstructions. Table 3 summarizes the protocols used in this study.

Table 3: PET image reconstruction protocols.

Algorithm	Resolution Mode	Number of Iterations
MLEM-3D	Standard	20
	High	

No attenuation or scatter corrections and no post-filtering are applied. After reconstruction, the post-processing of images was performed using AMIDE software and eight volumes of interest (VOIs) were defined. For VOIs definition, we use simple geometrical shapes (ellipsoid or cylinder) positioned in the inner of the animal organs and the center of each VOI coincided with the highest uptake region of the organ /tissue. This choice was due to the fact that the LabPET SOLO 4 scanner is a single modality scanner without the Computed Tomography (CT) coupled. In this sense, anatomic/morphological information of the animal organs are not available. The VOIs used are presented in Table 4.

Table 4: Volumes of interest (VOIs).

Organ/Tissue	Geometry*	Volume (mm^3)
Bone	Cylinder	4.74
Brain	Ellipsoid	14.13
Cardiac Muscle	Ellipsoid	0.52
Harder Gland	Ellipsoid	1.76
Heart	Ellipsoid	65.41
Muscle (Right Flank)	Ellipsoid	4.19
Tumor (Left Flank)	Ellipsoid	4.20
Urinary Bladder	Ellipsoid	14.10

The activity concentration in the VOIs was determined by the product of the conversion coefficient, previously determined, to the counts per second per voxel (CPS/voxel) reported by AMIDE. The SUV_mean and SUV_max were determined, respectively, from the mean and maximum activity concentration in each VOI and calculated according Equation 1.

Last step consisted in the SUV_mean and SUV_max analysis to determination the influence of resolution mode in SUV for the interest organs/tissues in LabPET SOLO 4/LIM/CDTN.

3. RESULTS AND DISCUSSION

Figure 1 shows the mouse PET image reconstructed with protocols of standard resolution and high resolution. Qualitatively, it is possible to see light improvement in tissue/structures definition in HR image when compared to SR image.

Figure 1: Reconstructions of the mouse PET image with standard resolution and high resolution modes. Arrow indicates the tumor in left flank.

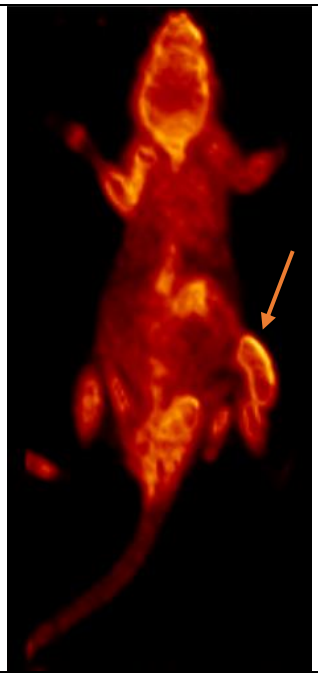
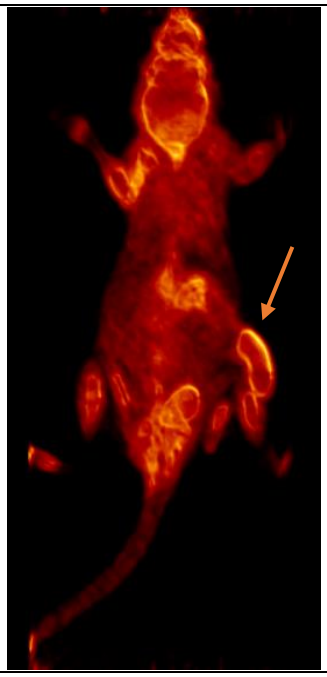
Resolution Mode	
Standard	**High**
	

Figure 2 and 3 shows, respectively, SUV_mean and SUV_max obtained for the analyzed tissues for both image reconstruction protocols (SR and HR).

Figure 2: SUV_mean for different organs/tissues using standard and high-resolution mode in the image reconstruction protocols.

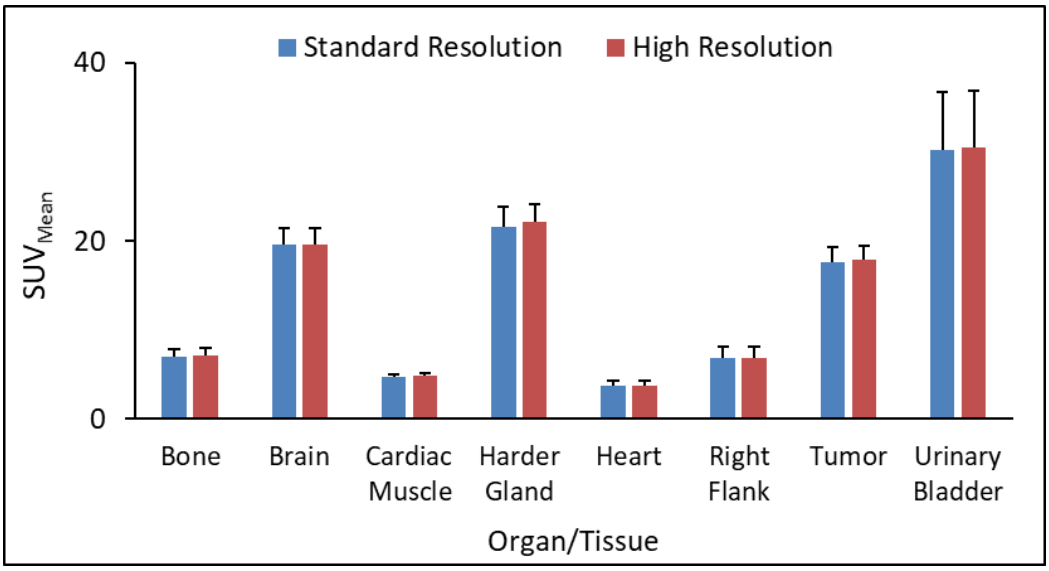
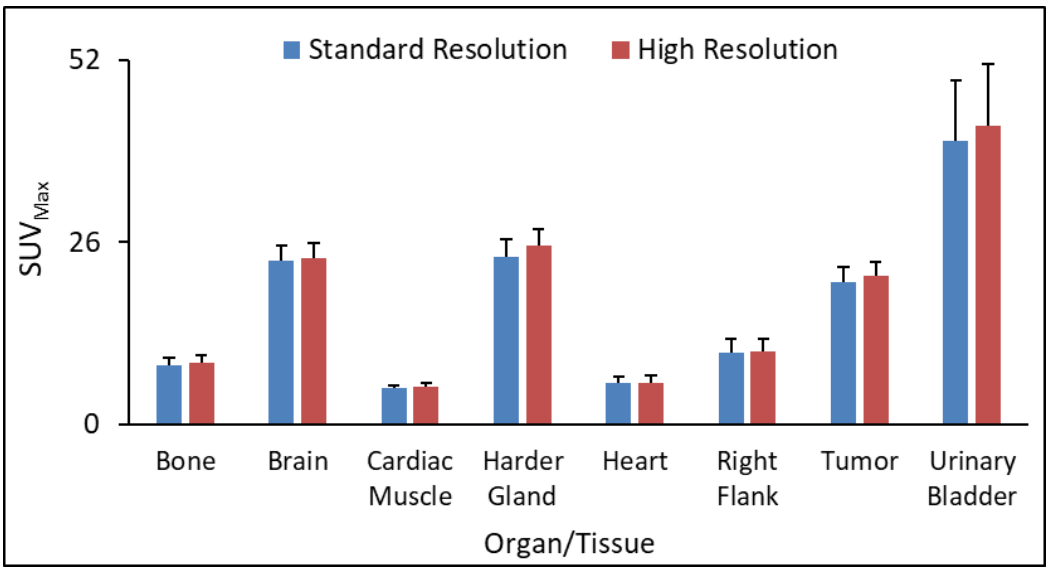


Figure 3: SUV_max for different organs/tissues using standard and high-resolution mode in the image reconstruction protocols.



Figures 2 and 3 reveal a slight increase in SUVs for image reconstructed using high-resolution mode when compared to image reconstructed using standard resolution. Table 5 presents the ratio between high-resolution and standard resolution results for SUV_mean and SUV_max.

Table 5: Ratio between SUV results obtained using high and standard resolution modes.

Organ/Tissue	**Ratio =** $\frac{\textbf{\textit{High Resolution}}}{\textbf{\textit{Standard Resolution}}}$	
	SUV_mean	**SUV_max**
Bone	1,03	1,05
Brain	1,00	1,01
Cardiac Muscle	1,03	1,05
Harder Gland	1,03	1,07
Heart	0,98	1,02
Right Flank	1,00	1,02
Tumor (Left Flank)	1,01	1,04
Urinary Bladder	1,01	1,06

Table 5 indicates a very low increase in SUV_mean when comparing standard and high-resolution modes, ranging from 1% to 3% (exception for heart). In the same way, it was observed a very low increase in SUV_max when high-resolution modes were used, ranging from 1% to 7%. However, as can be observed in Figures 2 and 3, the differences between high resolution mode and standard resolution mode in SUV_mean and SUV_max were not statistically significant. These founds indicates that, for PET images from the LABPET SOLO 4 scanner, there is not an important impact on SUV determination depending on the resolution mode used to PET image reconstruction.

The ratios between SUV_max and SUV_mean for the analyzed organs/tissues are presented in Table 6. Considering the images reconstructed using standard resolution the ratio between SUV_max and SUV_mean ranged from 9% to 55% depending on the organ/tissue, while the same ratio for images reconstructed using high resolution ranged from 11% to 60% depending on the organ/tissue.

Table 6: Ratio SUV_max/SUV_mean.

Organ/Tissue	**Ratio =** $\frac{Maximum\ SUV}{Mean\ SUV}$		
	Standard Resolution	**High Resolution**	**Difference (%)***
Bone	1.20	1.23	2.0
Brain	1.19	1.21	1.2
Cardiac Muscle	1.09	1.11	1.8
Harder Gland	1.11	1.15	3.9
Heart	1.55	1.60	3.2
Right Flank	1.49	1.52	1.7
Tumor (Left Flank)	1.16	1.19	2.7
Urinary Bladder	1.34	1.39	4.4

* Calculated by: $\frac{HR\ Ratio - SR\ Ratio}{SR\ Ratio} \times 100$

Since the high resolution voxel is 25% of the volume of the standard resolution voxel, the counting statistics on the high resolution mode is expected to be worse. This statistical worsening, in theory, would lead to a greater variance of SUV value in high resolution. Such fact should not change the value of SUV_mean, but could increase the SUV_max. Another situation that could explain the increase in SUV_max in high-resolution mode would be the presence of small spots of highly concentrated activity in the organs or tissues evaluated. In this case – because the voxel in high resolution mode is smaller than in standard resolution mode – the partial volume effect would be lower in high resolution, resulting in higher SUV_max in this spots [8]. However, SUV_mean should not be affected considering the whole VOI. These facts could explain the trend of systematic increase in the SUV_max/SUV_mean ratio obtained for high resolution compared with standard resolution, observed in Table 6. However, again based in Figures 2 and 3, SUV_max/SUV_mean ratio obtained with high resolution were not statistically different from standard resolution ones. Table 6 indicates that there were no important differences for SUV_max and SUV_mean ratios related to the use of standard or high-resolution mode.

The results for target/non-target (tumor/right flank) tissue analysis are presented in Table 7. Results indicates that ^{18}F-FDG uptake into tumoral tissue (tumor implanted in animal left flank) was approximately twice as high as uptake in healthy tissue (healthy right flank). Once more, considering the experimental setup used for image acquisitions and the reconstruction parameters used in this work the resolution mode do not affect significantly the SUV values calculated.

Table 7: Target/non-target tissue (tumor/right flank) comparison.

	Ratio = $\frac{SUV\ tumor}{SUV\ right\ flank}$		
	Standard Resolution	**High Resolution**	**Difference* (%)**
Mean	2.58	2.61	1.4
Maximum	2.00	2.05	2.4

* Calculated by: $\frac{HR\ Ratio - SR\ Ratio}{SR\ Ratio} \times 100$

4. CONCLUSIONS

This study allowed evaluate the influence of standard resolution and high resolution modes in quantification of SUV_mean and SUV_max to LabPET SOLO 4 scanner of LIM/CDTN. As observed in previous work with IQ phantom [3], the use of high resolution mode, despite promoting a slight improvement in the definition of structures in the qualitative analysis (visual inspection), did not significantly change the quantification of radiopharmaceutical uptake in the analyzed tissues.

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