Original Article, Physics

The Effect of Low Dose CT Matrix Size Variation on Qualitative and Semi-Quantitative Analysis of Positron Emission Tomography (PET) Images

Abdel Gawad, H [1]. Elsayed Y[1]. Abdelhafez, Y[2] .

[1] Nuclear Medicine Unit, Faculty of Medicine, Cairo University, Egypt[2] Nuclear Medicine Unit, South Egypt Cancer Institute, Assiut University, Egypt

ABSTRACT:

Objective: The purpose of the study was to evaluate the qualitative and semi-quantitative effects of using different low-dose computed tomography (CT) matrix sizes for attenuation correction of PET images. **Methods:** Co-registered 2-[F18]-fluoro-2-deoxy-D-glucose (FDG)-PET and CT images were acquired using a combined PET/CT scanner according to a standardized protocol. PET/CT reconstruction was repeated using default reconstruction protocols with different matrix sizes for low dose CT (512,768 and 1024) in 25 patients. The resulting images were analyzed qualitatively *"image quality"* and semi-quantitatively using *"mean SUV & Signal to Noise Ratio (SNR)"*. **Results:** No significant difference in the resulting attenuated corrected images reconstructed with the different matrix sizes either qualitatively or semi-quantitatively.

Conclusion: The matrix size of the low dose CT used in the attenuation correction of PET images does not affect the image quality or semi-quantitative parameters.

Key Words: PET/CT, Attenuation Correction, Matrix Size, SUV, SNR.

Corresponding Author: Abdel Gawad, H. **Email:** hesham_ag@yahoo.com.

INTRODUCTION:

Positron Emission Tomography (PET) is being increasingly used as an imaging tool for tumor diagnosis, staging and assessing treatment response in patients with various cancers. PET imaging is based on radiotracer compounds labeled with positron emitting radionuclides. This radiopharmaceutical can then be used to track biochemical and physiological processes in vivo. The largest area of clinical use of PET is in oncology and 2-[fluorine-18] fluoro-2-deoxy-D-glucose (18F-FDG), *glucose analog*, is the most widely used radiopharmaceutical because of their increased glucose metabolism in tumor cells. Although qualitative interpretation is the main stay for image interpretation, quantitative indices are used to measure tumor metabolic avidity and evaluate their responses to therapy [(1)]. Standardized uptake value (SUV) is a semi-quantitative measurement of radioactivity concentrations at a fixed time and it increases continuously in tumor cells as a function of time after ^{18}F-FDG intravenous administration. The SUV has been defined as tissue concentration (kBq/ml) divided by the activity injected per body weight (kBq/g) [(1, 2)]. Despite the popularity of SUV, the reliability of SUV is still somewhat a debate. The primary problem with the SUV is that it is subjective to too many sources of variability which are not controlled such as glucose level, length of the uptake period, body weight, body composition, recovery coefficient and partial volume effect (PVE) [(3,4)]. Biases in SUVs only slightly depend on the emission scan duration and on the presence of out-of-the-field-of-view activity, but strongly depend on the attenuation coefficient (μ) map used for attenuation correction[(6)]. Most of the factors affecting the SUV value have been thoroughly studied [(5, 6)]; however, only few data discussed the effect of changing the matrix size of attenuation correction CT. The aim of this work is to evaluate the effects of changing PET reconstruction using different low-dose CT matrix sizes on the quality of PET images and semi-quantitative indices using SUV & SNR.

PATIENTS AND METHODS:

Patients:

This prospective study was performed at a private radiology center and included a total of 25 patients referred for different oncological indications during November 2013. Patients with uncontrolled diabetes or known to have liver disease were excluded from the study.

PET/CT study protocol: A standardized protocol was adopted. The patient was asked to fast for 6 hours prior to the study and have their blood glucose level checked on arrival. Blood glucose levels above 200 mg% were excluded from the study. FDG dose was calculated based on the patient's weight (about 5 MBq/Kg). Waiting time after injection varied from 45 to 90 minutes before the scan.

PET/CT acquisition and reconstruction protocol:

The study was performed on a combined PET/CT scanner "Philips Gemini Time-of-Flight PET/CT machine equipped with LYSO crystals with 64 slice CT scanner; Philips, USA". First, a low-dose CT scan *(5-mm contiguous axial cuts)* was obtained in a 64 integrated multi-slice CT machine, from the skull base to the mid-thigh. The acquisition was obtained in a helical mode, using 120 kV, 60 mAs, and a 512 x 512 matrix size, acquiring a field of view (FOV) of 700 mm in 22.5 seconds. The first CT scan was used for attenuation correction. Immediately after the low-dose CT, an emission PET scan was acquired in a three-dimensional mode over the same anatomical regions starting from the base of the skull to the level of the mid-thigh. The acquisition time was 2 minutes per bed position in 9 bed positions, with a one-slice overlap at the borders of the FOV. Finally, a diagnostic CT was acquired using 120 kV, 300 mAs, and a 512 x 512 matrix size. The acquired FOV was 500 mm using dose automatic modulation in the Z direction. The radiation exposure dose from low-dose CT was in average 3.37 mGray (mGy) while that for diagnostic CT was 11.48 mGy.

Reconstruction protocols:

At the end of the study, additional offline reconstructions for the low dose CT were performed using two matrix sizes "768 x 768 & 1024 x 1024" in addition to the default reconstruction "512 x 512 matrix size". Hence, for each patient, 3 reconstructions were performed.

"Figure 1": reconstruction 1: using matrix size 512 x 512, reconstruction 2: using matrix size 768 x 768, and reconstruction 3: using matrix size 1024 x 1024.

Qualitative and semi-quantitative measurements:

Each of the three produced reconstructions was evaluated visually by three independent readers with experience in reading PET/CT images taking into account contrast, resolution, sharpness and tissue details. The reader was asked if there is a difference between any of the three images or not, and if there is a difference, is it major "affecting their diagnoses" or minor "not affecting their diagnoses". For semi quantitative analyses, three different ROIs, with the same pixel size, were drawn on non-lesion sites over the liver **"Figure 2"**. The ROIs were copied to ensure the exact size and location met among different reconstructed images. For each of the three ROIs, SUV mean & SNR were recorded: SUV was calculated according to the following equation:

$SUV_{BW} = \frac{C(T)}{D/BW}$	*Where: C(T) is the radioactivity concentration in a given ROI (Bq/mL). D is the dose injected (Bq) & BW is the patient's body weight in (g)*

Since one gram of tissue can be approximated as having a volume of 1 ml, SUV_{BW} is a unitless quantity.

SNR was calculated as mean SUV within a ROI divided by the standard deviation (SD) recorded for the same ROI *(mean SUV/SD)*.

Statistical analysis: Inter-reader variability was assessed using weighted kappa test.

The means of SUVs and SNRs within different ROIs were compared using repeated-measures ANOVA test. In all statistics, a *P* value of 0.05 was considered significant. The statistics were performed using SPSS version 18.0 *"SPSS Inc, Chicago, USA"*.

RESULTS:

Qualitative assessment:

There was excellent agreement between the three readers. All of them agreed in 24/25 images that there was no difference in the reconstructed images. Only one reader reported 1 image as being slightly sharper. That image was reconstructed using a matrix size of 1024 x 1024; however, it does not affect his clinical interpretation. Details are presented in ***Table 1.***

Table (1): Three reader's interpretation ratings for the different reconstructed images

Readers	*No change*	*Minor Change*	*Major change*
Reader 1	25	0	0
Reader 2	25	0	0
Reader 3	24	1	0

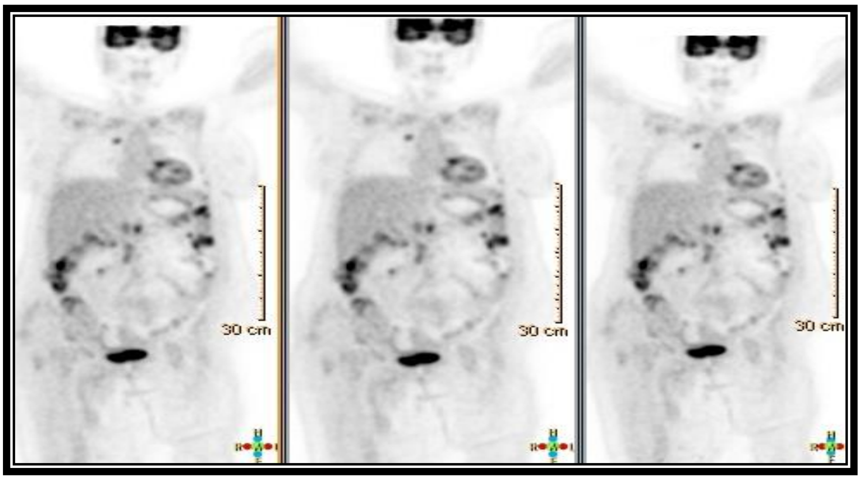

Fig. (1): Reconstructed attenuated corrected PET images using 3 different Methods; *non-contrast low dose CT with matrix size 512 x 512 left, matrix size 768 x 768 middle, and matrix size 1024 x 1024 right.*
There is no significant difference in reader interpretation of all images evaluated.

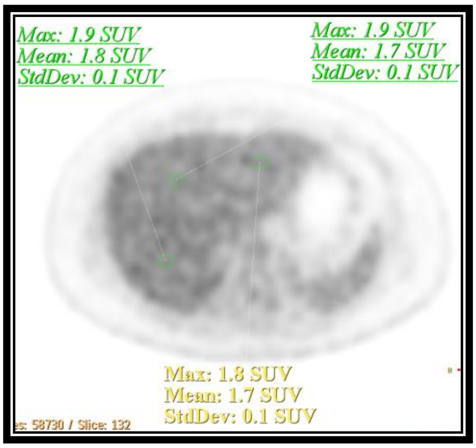

Fig (2): Three different regions of interests (ROIs) of the same pixel size drawn on the liver on non -lesion areas.

Semi-quantitative assessment:

The measured SUV of the three ROIs "R1, R2 & R3" according to different reconstruction matrices "512, 768 & 1024" and their mean values are illustrated in **Tables 2 & 3 and Fig 1.**

There was no statistically-significant difference between the means of SUV generated from ROI 1, ROI 2 or ROI 3 using different reconstructions based on matrix 512, 768 & 1024 in **Table 4 and Fig2.**

Table 2: Measured SUV mean at different ROIs "R1, R2 & R3" using different *reconstruction matrices "512, 768 & 1024"*.

Matrix Size	512			768			1024		
Case No.	R1	R2	R3	R1	R2	R3	R1	R2	R3
1	1.4	1.6	1.3	1.4	1.6	1.3	1.4	1.6	1.3
2	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
3	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
4	2.6	2.6	2.0	2.6	2.5	2.0	2.6	2.6	2.0
5	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
6	1.9	2.0	2.2	1.9	2.0	2.2	1.9	2.0	2.2
7	2.3	2.5	1.7	2.3	2.5	1.7	2.3	2.5	1.7
8	1.6	1.7	1.5	1.6	1.6	1.5	1.6	1.7	1.5
9	2.1	1.9	1.7	2.1	2.0	1.7	2.1	1.9	1.7
10	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
11	1.8	1.7	1.7	1.8	1.7	1.5	1.8	1.7	1.5
12	1.9	1.8	1.5	1.9	1.8	1.5	1.9	1.8	1.5
13	1.6	1.5	1.4	1.6	1.5	1.4	1.6	1.5	1.4
14	1.8	1.8	1.6	1.8	1.8	1.6	1.8	1.9	1.6
15	2.0	2.0	1.8	2.1	2.0	1.8	2.1	2.0	1.8
16	2.2	2.2	1.8	2.2	2.2	1.8	2.2	2.2	1.8
17	1.7	1.6	1.4	1.7	1.6	1.4	1.7	1.6	1.4
18	1.6	1.6	1.4	1.6	1.6	1.4	1.6	1.6	1.4
19	1.5	1.4	1.4	1.5	1.4	1.4	1.5	1.4	1.4
20	1.9	1.7	1.6	1.9	1.7	1.6	1.9	1.7	1.7
21	1.4	1.4	1.2	1.4	1.3	1.3	1.4	1.4	1.3
22	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.5	1.4
23	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.8
24	1.6	1.6	1.4	1.6	1.6	1.4	1.6	1.6	1.4
25	1.9	1.9	1.8	1.8	1.9	1.8	1.8	1.9	1.8
Mean	**1.780**	**1.764**	**1.596**	**1.772**	**1.752**	**1.592**	**1.768**	**1.768**	**1.596**

Table 3: Measured SNRs at different ROIs "R1, R2, &R3" using different *reconstruction matrices "512, 768 & 1024"*.

Case No.	R1	R2	R3	R1	R2	R3	R1	R2	R3
1	14.0	16.0	13.0	14.0	16.0	13.0	14.0	16.0	13.0
2	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
3	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
4	26.0	16.0	20.0	26.0	25.0	20.0	26.0	26.0	20.0
5	18.0	17.0	17.0	14.0	17.0	17.0	17.0	17.0	17.0
6	19.0	20.0	22.0	19.0	20.0	22.0	19.0	20.0	22.0
7	23.0	25.0	17.0	23.0	25.0	17.0	23.0	25.0	17.0
8	16.0	17.0	15.0	16.0	16.0	15.0	16.0	17.0	15.0
9	21.0	19.0	17.0	21.0	20.0	17.0	21.0	19.0	17.0
10	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
11	18.0	17.0	17.0	18.0	17.0	15.0	18.0	17.0	15.0
12	19.0	18.0	15.0	19.0	9.0	15.0	19.0	18.0	15.0
13	16.0	15.0	14.0	16.0	15.0	14.0	16.0	15.0	14.0
14	18.0	18.0	16.0	18.0	18.0	16.0	18.0	19.0	16.0
15	2.0	20.0	18.0	21.0	20.0	18.0	21.0	20.0	18.0
16	22.0	22.0	18.0	22.0	22.0	18.0	22.0	22.0	18.0
17	17.0	16.0	7.0	17.0	16.0	17.0	17.0	16.0	14.0
18	16.0	16.0	14.0	16.0	16.0	14.0	16.0	16.0	14.0
19	15.0	14.0	14.0	15.0	14.0	14.0	15.0	14.0	14.0
20	19.0	17.0	16.0	19.0	17.0	16.0	19.0	17.0	17.0
21	14.0	14.0	12.0	14.0	13.0	13.0	14.0	14.0	13.0
22	15.0	15.0	14.0	14.0	14.0	18.0	14.0	15.0	14.0
23	18.0	18.0	18.0	18.0	18.0	18.0	17.0	18.0	18.0
24	16.0	16.0	14.0	16.0	16.0	14.0	16.0	16.0	14.0
25	19.0	19.0	18.0	18.0	19.0	18.0	18.0	19.0	18.0
Mean	**17.080**	**17.240**	**15.680**	**17.600**	**17.160**	**16.200**	**17.680**	**17.680**	**15.960**

Table 4: ANOVA testing for the mean differences in SUV and SNR between different ROIs

Measurements	*P value*		
	ROI 1	*ROI 2*	*ROI 3*
SUV mean	0.34	0.38	0.32
SNR	0.59	0.44	0.29

DISCUSSION:

Semi quantitative parameters from ^{18}F-FDG PET/CT are being increasingly incorporated in the guidelines of response evaluation for many Oncological diseases including lymphoma and other solid tumors(7-9). However, the reproducibility of SUV values among different centers is still a challenge. Many factors are reported to affect that measurement, starting from the patient's weight and blood sugar status, to the injected activity, timing of acquisition, and finally reconstruction procedures(2). In order to minimize these differences, procedure guidelines and standardized quantification protocols were issued (10, 11).

It was reported that the attenuation correction, reconstruction method and number of iterations can significantly changes SUV values(6, 12).

However, scarce reports evaluated the effect of different matrix sizes on the resulting attenuated corrected PET images. Adams et al. (2) tested three different image matrix sizes for their impact on SUV measurements for 1.0-cm spheres: 128 × 128, 192 × 192, and 256 × 256 voxels. They reported that using a larger matrix for a given FOV increased SUVmax measurements for 1.0- cm spheres. However, that was likely because larger matrix sizes for a constant FOV make each voxel smaller. Smaller voxels may yield higher spatial resolution but also increase the probability of sampling the peak of the lesion.

In this work, three different low-dose CT matrices were used for the attenuation correction of PET images. No significant difference in the resulting corrected PET images was observed either qualitatively or semi-quantitatively.

This study has some points of weakness: first, it studied the impact of low-dose CT matrix on the attenuation-corrected images but did not actually change the PET matrix. size. Second, it includes relatively few patients. Third: it calculated the mean SUV over non-lesion sites using a fixed size ROI.

Ongoing work is currently undertaken to test these results on lesion sites using different SUV metrics.

Nevertheless, this was the first study to document that CT matrix size does not affect the resulting attenuation-corrected PET image. Its prospective design, and standardized acquisition and processing protocol are other points of strength.

CONCLUSION:

The change of the low-dose CT matrix size used in attenuation correction of PET/CT studies does not affect the quality or semi-quantitative measurements of the resulting attenuated-corrected PET images.

REFERENCES:

1. **Bar-Shalom R, Valdivia AY, Blaufox MD.** PET imaging in oncology. Semin Nucl Med.; 30 (3):150-85. 2000.
2. **Adams MC, Turkington TG, Wilson JM, Wong TZ.** A systematic review of the factors affecting accuracy of SUV measurements. AJR Am J Roentgenol.;195 (2): 310-20. 2010.
3. **Keyes JW, Jr. SUV:** standard uptake or silly useless value? J Nucl Med.; 36 (10): 1836.
4. **Sugawara Y, Zasadny KR, Neuhoff AW, Wahl RL.** Reevaluation of the standardized uptake value for FDG: variations with body weight and methods for correction. Radiology.;213(2):521-5. 1999.
5. **Zasadny KR, Wahl RL.** Standardized uptake values of normal tissues at PET with 2-[fluorine-18]-fluoro-2-deoxy-D-glucose: variations with body weight and a method for correction. Radiology.;189(3):847-50. 1993.
6. **Jaskowiak CJ, Bianco JA, Perlman SB, Fine JP.** Influence of reconstruction iterations on 18F-FDG PET/CT standardized uptake values. J Nucl Med.;46 (3): 424- 8. 2005.
7. **Cheson BD, Pfistner B, Juweid ME, et al.** Revised response criteria for malignant lymphoma. J Clin Oncol.; 25 (5): 579-86. 2007.
8. **Wahl RL, Jacene H, Kasamon Y, Lodge MA.** From RECIST to PERCIST: Evolving Considerations for PET response criteria in solid tumors. J Nucl Med.;50 Suppl 1:122S-50S. 2009.
9. **Young H, Baum R, Cremerius U, et al.** Measurement of clinical and subclinical tumour response using [18F]-fluorodeoxy-glucose and positron emission tomography: review and 1999 EORTC recommendations. European Organization for Research and Treatment of Cancer (EORTC) PET Study Group. Eur J Cancer.; 35 (13):1773-82. 1999.
10. **Boellaard R, O'Doherty MJ, Weber WA, et al.** FDG PET and PET/CT: EANM procedure guidelines for tumour PET imaging: version 1.0. Eur J Nucl Med Mol Imaging.; 37 (1):181-200. 2010.
11. **Boellaard R, Oyen WJ, Hoekstra CJ, et al.** The Netherlands protocol for standardisation and quantification of FDG whole body PET studies in multi-centre trials. Eur J Nucl Med Mol Imaging.;35(12):2320-33. 2008.
12. **Westerterp M, Pruim J, Oyen W, et al.** Quantification of FDG PET studies using standardised uptake values in multi-centre trials: effects of image reconstruction, resolution and ROI definition parameters. Eur J Nucl Med Mol Imaging.;34 (3): 392-404. 2007.