A Study on Usefulness Evaluation of SUV Measured in Mini-PACS for Each One of PET/CT Equipment

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Abstract To save and analyze the data from a positron emission tomography/computed tomography (PET/CT) scan, it is sometimes important to use a server away from the workstation of the equipment or to install and operate mini-picture archiving and communication system (PACS). Mini-PACS was developed to save the data from a scan and measure the standard uptake value (SUV) in PACS that could be measured only in PET/CT equipment manufactured by many companies. Against this background, this study examined whether the SUV measured in PET/CT equipment was the same value in mini-PACS. This study evaluated Biograph 16 and Biograph 40 manufactured by SIEMENS and Discovery Ste 8 manufactured by GE, all of which are installed in this hospital. The SUV of the aorta of 30 patients, who had undergone an ^{18}F -FDG whole body PET scan in the period from February to October 2012, was measured at the height of the liver and mediastinum. In the mini-PACS program, the SUV was also measured and analyzed in an image with the same phase. According to the study results, the coefficient of the SUV of the liver in PET/CT equipment and mini-PACS was 0.99, 0.98, and 0.64 in Biograph 16, Biograph 40, and Discovery Ste 8, respectively, where the coefficient of the

SUV of aorta was 0.98, 0.98, and 0.66 in Biograph 16, Biograph 40, and Discovery Ste 8, showing a positive correlation in all equipment.

Keywords PET/CT scan · Mini-PACS · SUV

Introduction

Medical imaging technology has been developed for the diagnosis of diseases by providing both anatomical and functional images. Computed tomography (CT) and magnetic resonance (MR), which display the anatomical structure, have been developed with a focus on high resolution. Single photon emission computed tomography (SPECT) and positron emission tomography (PET), which are nuclear medicine imaging equipment that displays functional changes, have been developed with a focus on high sensitivity and high resolution [1]. Pinpointing a lesion is difficult in a PET image but this has been overcome by the improved resolution of the recently developed positron emission tomography/computed tomography (PET/CT) [2]. In PET/CT, the standard uptake value (SUV) has been used to evaluate disease [3, 4]. PET/CT using ^{18}F -FDG (fluorodeoxyglucose) is especially useful to assess staging and malignant tumors of various organs through SUV measurement. However, SUV, which is a semiquantitative numerical value of the measurement about the degree of consumption, may be different from quantitative data. Moreover, SUV can be affected by physical characteristics of each, and since it is influenced by diverse factors of the patients, it can play an important role in the result analysis. The mechanism for how FDG is uptaken by cells is as follows. FDG is moved to the inside of cells with the help of the transport involved in the movement of glucose in the cell membrane before it exists in the form of FDG that is phosphorylated by hexokinase. In most cells with malignant tumors, there is an

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increase in the glucose metabolism and glycolysis, which leads to higher FDG uptake than normal cells [5, 6]. As explained thus far, measurements of the SUV has been a significant yardstick for an evaluation of malignant tumors. Generally, for measurements of the SUV, a workstation installed in equipment for a PET/CT scan in each hospital is used to save the image data and make quantitative analysis. The data from one set of PET/CT equipment, however, is not compatible with other sets of PET/CT equipment. For this reason, hospitals use their own server or install mini-picture archiving and communication system (PACS) for image analysis. The existing PACS has been used only for the simple purpose of reading an image, but the recently installed mini-PACS, which is applied to the efficient operation of server or memory as a communication system used only in specific treatment units, including the department of diagnostic radiation, without being linked with the whole clinic information system, allows image reading and saving scan data as well as measurements of the SUV, which previously could only be measured in the PET/CT equipment of individual companies [7]. Against this background, this study examined whether the SUV measured in PET/CT equipment was the same as that determined by mini-PACS.

Materials and Method

Experiment Materials

PET/CT devices were used in SUV comparison between Workstation and mini-PACS, including Biograph Sensation 16 (SIEMENS, Germany; hereafter, referred to as “Bio 16”), Biograph Truepoint 40 (SIEMENS, Germany; hereafter, referred to as “Bio 40”), and Discovery STE 8 (GE healthcare, USA; hereafter, referred to as “DSTE 8”) while employing mini-PACS (INFINITT, Korea, Xelis Ver. 1.0.4.1) for the experiment. Thirty patients who underwent ^{18}F -FDG whole body PET/CT test from February to October 2012 for the diagnostic or therapeutic purpose were adopted as subjects, and SUV analysis was carried out for them. This study excluded the patients aged 18 or younger from the test because they were low in isotope dosage, compared to adults, thus possibly causing any difference in SUV.

Image Acquisition

Discovery DSTE 8 (GE Healthcare) PET/CT was used to obtain an image. The PET image was obtained approximately 1 h after an intravenous injection of ^{18}F -FDG in 7.4 MBq (0.2 mCi)/kg. Under the conditions of 120 kVp and auto mA after a topocan, a Helical CT (hereafter HCT) image was obtained from the skull base to the mid-thigh for an attenuation correction. Without attenuation correction, PET and CT

images are so mixed that it is restrictive to set up region of interest (ROI) accurately. This is why attenuation correction is performed to remove CT images using the method of addition and subtraction. Immediately after acquiring the HCT image, a Cine CT image in the vicinity of the diaphragm was photographed for the ACT under the following conditions: 2 cm/5.9 s duration, 120 kVp and 10 mA. A PET image was obtained at 3 min/bed.

Analysis Method

For the analysis, the acquired images were sent to the Biograph Sensation 16, Biograph Truepoint 40, and Discovery STE 8 workstations and mini-PACS. The analysis method involved calculating the ratio of the uptake rate of a lesion against the uptake rate of a standard region, such as the blood pool, mediastinum, liver, and cerebellum, which is used to measure the uptake of a tumor [8]. A comparison was made based on measurements of the SUVs of the liver and aorta, which are used for measurement in this hospital. For measurements of the SUV of the liver, the ROI in 15 cm² was set at the region that did not overlap with the lesion on the slice where the liver appeared the largest. To measure the SUV of the aorta, the ROI in 3 cm² was set to the height of the mediastinum. In mini-PACS, the ROIs were drawn in the region on the same phase as those for the liver and aorta to measure the SUVs before comparing the values [9]. Liver, the largest organ, is easy to monitor in images; aorta, the largest site through which blood passes in chest, makes it easy to monitor radioactive medicaments. For these reasons, the two organs were selected.

SPSS ver. 16 was used as the statistical program. A paired *t* test was conducted to confirm the difference in the SUVs measured using each workstation and mini-PACS. In addition, the study used the Pearson coefficient analysis which is the most effective for analyzing the statistical significance of the relationships between two variables. Pearson correlation coefficient was used to analyze the correlation between each of the workstations and mini-PACS. A *p* value <0.05 was considered significant.

Results

Comparison of the SUVs for Patients Who Underwent Scan in Bio 16 and Mini-PACS

The mean SUV of the liver was 1.65 when measured in both of Bio 16 and mini-PACS, whereas the average SUV of the aorta was 1.09 and 1.08 in Bio 16 and mini-PACS, respectively. A paired *t* test showed no significant difference between Bio 16 and mini-PACS (Fig. 1 and Table 1) (*p*>0.05).

Fig. 1 Standardized uptake of PET/CT and mini-PACS

Comparison of the SUVs for Patients Who Took Scan in Bio 40 and Mini-PACS

The mean SUV of liver was 1.82 when measured in both Bio 40 and mini-PACS, whereas the average SUV of aorta was 1.31 and 1.32 in Bio 40 and mini-PACS, respectively. A paired t test showed no significant difference between Bio 40 and mini-PACS (Fig. 1, Table 2) ($p > 0.05$).

Comparison of the SUVs for Patients Who Took Scan in DSTE and Mini-PACS

The mean SUV of the liver was 1.48 and 1.67 when it was measured in the DSTE and mini-PACS respectively, whereas

the average SUV of the aorta was 0.96 and 1.16 in the DSTE and mini-PACS, respectively. A paired t test showed a significant difference between the DSTE and mini-PACS (Fig. 1 and Table 3) ($p < 0.05$).

To calculate the SUV, the SUV is measured basically from the acquisition time in DSTE equipment. On the other hand, in mini-PACS, the SUV was measured using the series time. Therefore, for an equal time setting, the series time in the mini-PACS option was turned off before measuring the SUV. The mean SUV in the adjusted mini-PACS was 1.53 and 1.05 for the liver and aorta, respectively. At the significance level of 0.05, there was no statistical difference in the value of the liver between the DSTE and adjusted mini-PACS, whereas the value of aorta showed a statistical difference (Fig. 1 and Table 4) ($p < 0.05$).

Table 1 Standardized uptake of Bio 16 and mini-PACS

Classifications	Liver			Aorta		
	Mean	SD	p	Mean	SD	p
Bio 16	1.65	0.21	0.075	1.09	0.13	0.060
Mini-PACS	1.65	0.21		1.08	0.14	

Note: The interaction effect was determined using a paired t test model

Table 2 Standardized uptake of Bio 40 and mini-PACS

Classifications	Liver			Aorta		
	Mean	SD	p	Mean	SD	p
Bio 40	1.82	0.30	0.120	1.31	0.21	0.135
Mini-PACS	1.82	0.29		1.32	0.21	

Note: The interaction effect was determined using a paired t test model

Table 3 Standardized uptake of DSTE and mini-PACS

Classifications	Liver			Aorta		
	Mean	SD	<i>p</i>	Mean	SD	<i>p</i>
DSTE	1.48	0.15	0.020*	0.96	0.12	0.045*
Mini-PACS	1.67	0.18		1.16	0.13	

Note: The interaction effect was determined using a paired *t* test model

**p*<0.05

Pearson Correlation Coefficient Between the PET/CT Equipment and Mini-PACS

The graph below shows the dispersion for the liver and aorta. The Pearson correlation coefficient between PET/CT and mini-PACS was calculated. The Pearson correlation coefficient between Bio 16 and mini-PACS was 0.99 and 0.98 for the liver and aorta, respectively (Fig. 2). The Pearson correlation coefficient between Bio 40 and mini-PACS was 0.98 for both the liver and aorta (Fig. 3). The Pearson correlation coefficient between DSTE and mini-PACS was 0.64 and 0.66 for the liver and aorta, respectively (Fig. 4). The Pearson correlation coefficients are expressed as the values from −1.0 to +1.0. The closer a value is to 1.0, the more positive the correlation is; the closer a value is to −1.0, the more negative the correlation is; the closer a value is to 0, the closer the correlation reaches nothing.

Discussion

Recently, ^{18}F -FDG PET has been used as an essential tool for a diagnosis of tumors, determining the disease stage and providing follow-up examinations after treatment. In terms of the diagnostic performance, PET/CT is superior to single PET [10–12] because PET/CT provides the anatomical location and additional diagnostic information (CT) in addition to functional image information (PET). In general, PET/CT used the SUV to evaluate diseases [3, 4]. To measure the SUV, the workstation that is installed in the equipment for a PET/CT

Table 4 Standardized uptake of DSTE and modified mini-PACS

Classifications	Liver			Aorta		
	Mean	SD	<i>p</i>	Mean	SD	<i>p</i>
DSTE	1.48	0.15	0.035*	0.96	0.12	0.040*
Modified	1.53	0.15		1.05	0.14	

Note: The interaction effect was determined using a paired *t* test model

**p*<0.05

Fig. 2 Scatter diagram of Bio 16 and mini-PACS

scan in each hospital is used to save the image data and make quantitative analysis.

The workstation enables an adjustment of the image window, a precise measurement of the size, HU measurements in CT, SUV measurement in PET, combination of PET and CT, and interworking of a precise location, which results in an accurate analysis and determination of PET/CT image. Recently, image analysis was performed using a workstation that is not installed in the equipment itself but mini-PACS. The existing PACS has been used only for the simple purpose of reading an image, whereas the recently installed mini-PACS enables not only image reading and saving scan data but also measurements of the SUV that could previously be measured only in the PET/CT equipment from the individual companies [7]. To analyze an image using mini-PACS, it is important to obtain entire cross-sectional PET images in the standard form of the DICOM and entire cross-sectional CT images.

The SUV can be measured in a precise manner using mini-PACS. Therefore, the purpose of this study was to determine if the SUV measured in PET/CT equipment was the same in

Fig. 3 Scatter diagram of Bio40 and mini-PACS

mini-PACS. According to the results, both Biograph 16 and Biograph 40 installed in this hospital showed a strong positive correlation with mini-PACS. Discovery STE 8 showed a lower correlation than Biograph equipment. In particular, there was no significant difference in the SUVs between mini-PACS and Biograph equipment. The SUVs measured in mini-PACS and Discovery STE 8 were 0.19 ± 0.03 g/mL and 0.20 ± 0.01 g/mL, respectively, for the liver and aorta, which showed higher values in mini-PACS. In mini-PACS, the series time was turned to off to make a comparison with Discovery STE 8. The mean SUV was 0.05 ± 0.00 g/mL and 0.09 ± 0.02 g/mL for the liver and aorta, respectively, which showed a decrease in the difference. Statistically, there was no difference for the liver, whereas there was a difference for the aorta.

The larger difference in GE System compared to that in SIEMENS System is considered to arise from the difference between mini-PACS algorithms. SIEMENS System employs series time method that every bed is calibrated through time correction as a whole together with mini-

Fig. 4 Scatter diagram of DSTE and mini-PACS

PACS, while GE System uses acquisition time method that time correction is carried out for each bed to the starting point of the bed for calibration. Moreover, even larger difference in aorta is assumed to be caused by the low count and the error occurring in a small ROI. Therefore, the limitations of this study are (1) imperfect agreement of ROA between PET/CT and mini-PACS, (2) fluctuation of SUV data depending on the settings of acquisition time and series time, and (3) not having accurate confirmation of

Fig. 5 Series time and acquisition time

SUV items attributable to the influential relationship between PET/CT and mini-PACS. For Series Time, denoting the time for generating series, no change of time is traced among beds after the test completion, but acquisition time have time differences at the end because an individual time is generated for each bed. For instance, if images of seven beds are acquired for 3 min per bed, the first bed has the same time with that in series time while the last bed has a time difference of 18 to 19 min (Fig. 5).

Conclusions

When measuring the SUV, both of Biograph 16 and Biograph 40 installed in this hospital showed a strong positive correlation with mini-PACS, whereas Discovery STE 8 showed a lower correlation than Biograph equipment. In particular, there was no significant difference in the SUVs between mini-PACS and Biograph equipment. When the series time was turned off in mini-PACS for a comparison with Discovery STE 8, the mean SUV for the liver and aorta was 0.05 ± 0.00 g/mL and 0.09 ± 0.02 g/mL, respectively, which showed no difference for the liver but some difference for the aorta. In the future, it will be necessary to overcome such shortcomings for the SUV calculation method in mini-PACS for each set of equipment. If this occurs, it will be possible to provide quantitative analysis data that is consistent for patients who require a follow-up examination by performing quantitative and comparative analysis in a mini-PACS system in cases where the same patient had previously undergone an examination using other equipment.

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