Comparison of SUVs Normalized by Lean Body Mass Determined by CT with Those Normalized by Lean Body Mass Estimated by Predictive Equations in Normal Tissues

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Abstract

Purpose Standardized uptake values (SUVs) normalized by lean body mass (LBM) determined by CT were compared with those normalized by LBM estimated using predictive equations (PEs) in normal liver, spleen, and aorta using ^{18}F -FDG PET/CT.

Methods Fluorine-18 fluorodeoxyglucose (F-FDG) positron emission tomography/computed tomography (PET/CT) was conducted on 453 patients. LBM determined by CT was defined in 3 ways ($\text{LBM}_{\text{CT1-3}}$). Five PEs were used for comparison ($\text{LBM}_{\text{PE1-5}}$). Tissue SUV normalized by LBM (SUL) was calculated using LBM from each method ($\text{SUL}_{\text{CT1-3}}$, $\text{SUL}_{\text{PE1-5}}$). Agreement between methods was assessed by Bland-Altman analysis. Percentage difference and percentage error were also calculated.

Results For all liver SUL_{CTs} vs. liver SUL_{PEs} except liver SUL_{PE3} , the range of biases, SDs of percentage difference and percentage errors were -0.17 - 0.24 SUL, 6.15 - 10.17 %, and 25.07 - 38.91 %, respectively. For liver SUL_{CTs} vs. liver SUL_{PE3} , the corresponding figures were 0.47 - 0.69 SUL, 10.90 - 11.25 %, and 50.85 - 51.55 %, respectively, showing the largest percentage errors and positive biases. Irrespective of magnitudes of the biases, large percentage errors of

25.07 - 51.55 % were observed between liver $\text{SUL}_{\text{CT1-3}}$ and liver $\text{SUL}_{\text{PE1-5}}$. The results of spleen and aorta SUL_{CTs} and SUL_{PEs} comparison were almost identical to those for liver. **Conclusion** The present study demonstrated substantial errors in individual SUL_{PEs} compared with SUL_{CTs} as a reference value. Normalization of SUV by LBM determined by CT rather than PEs may be a useful approach to reduce errors in individual SUL_{PEs} .

Keywords Standardized uptake value · Normalization · Lean body mass · PET/CT

Introduction

Standardized uptake value (SUV) is a commonly used semi-quantitative parameter in PET/CT studies valuable for diagnosis of various diseases and monitoring tumor response to therapy [1]. Many investigators have extensively studied biological and physical factors affecting numerators of the SUV equation such as region of interest (ROI) size, definition of ROI, image resolution and reconstruction algorithm, and uptake period [2]. Several studies have concerned denominator factors (i.e., normalization factors) such as body weight (BW), body surface area, lean body mass (LBM), and blood glucose level [3–9], in which LBM was estimated by various predictive equations (PEs). SUV normalized by BW (SUV_{BW}) is known to be highly dependent on BW [3, 9]. SUV normalized by LBM (SUL) is typically more consistent across patients than SUV_{BW} , as patients with high body mass indices have a relatively large amount of body fat or adipose tissue (AT) in which ^{18}F -FDG does not significantly accumulate in the fasting state [3, 5]. Thus, the use of SUL has been recommended for PET response criteria in solid tumors [10]. However, the estimation of LBM relies on

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indirect measurements using various PEs, which are based on anthropometric parameters such as age, sex, body weight, and height. We chose five PEs which are commonly used in the PET community, and nutrition and obesity fields. These PEs were originally developed to estimate body fat mass based on reference methods including hydrodensitometry (underwater weighing), total body water measurements by isotope dilution technique, total body potassium counting, and total bone mineral measurement.

LBM (i.e., adipose tissue-free body mass) can be directly determined by CT in ^{18}F -FDG PET/CT studies [11]. The CT method for quantifying AT volume or mass has been validated in animals [12], human cadavers [13, 14], and living humans [15, 16]. It is now considered the most accurate method available for direct measurement of AT volume in vivo [17, 18]. This CT measurement method has been widely used in obesity and nutrition research fields, but not yet in ^{18}F -FDG PET/CT studies. The purpose of the present study was to compare SUVs normalized by LBM determined by CT with those normalized by LBM estimated using PEs in normal liver, spleen, and aorta in ^{18}F -FDG PET/CT studies.

Materials and Methods

^{18}F -FDG PET/CT Imaging

In total, 453 patients underwent ^{18}F -FDG PET/CT examination (Biograph 16, Siemens, Knoxville, TN, USA) for routine clinical purposes. Patient characteristics are shown in Table 1. Approval by an institutional review board was not required for this routine clinical study. After 6-hour fasting, each patient was injected with approximately 7.4 MBq kg^{-1} of ^{18}F -FDG after ensuring that blood glucose did not exceed 180 mg dL^{-1} ($99.4 \pm 17.4 \text{ mg dL}^{-1}$). Patients were positioned feet first and supine with their arms laid beside the body, and imaging began 60 min after injection of ^{18}F -FDG ($58.8 \pm 3.9 \text{ min}$). Most PET acquisition was performed from skull base to mid-thigh, and the following

acquisition parameters were used: image matrix size of 168×168 ; reconstruction algorithm of ordered subset expectation maximization with four iterations and eight subsets, and post-smoothing with a Gaussian filter of 5 mm full width at half maximum (FWHM); and acquisition time of 2.5 min per bed position with 28 % overlap. The PET/CT system used in the present study allows 3D mode acquisition, 5.0 mm FWHM, and 16.2 cm trans-axial field of view.

CT acquisition parameters were as follows: tube voltage of 120 kVp, tube current of 60 mAs (care dose), tube rotation speed of 0.5 s, table feed of 36 mm s^{-1} , beam collimation of 1.5 mm, image matrix size of 512×512 , and 5 mm slice thickness of reconstructed images with 3 mm spacing. Scans were acquired from the head to the feet. Neither intravenous nor oral contrast agent was administered. Blank CT scanning of the scanner table including head rest and abdominal binder was conducted three times to determine the number of voxels erroneously assigned to AT depending on patient height ($500\text{--}700 \text{ cm}^3$), and this volume was subtracted from patients' total AT volume. Patient BW was corrected for hospital gown weight (approximately 610 g).

Measurements and Data Analysis

In the present study, AT was defined as voxels identified and measured by CT having a CT number between -140 and -30 Hounsfield units. A built-in software package was used to calculate total AT volume. An AT density of 0.95 kg L^{-1} and an AT fat content (fraction) of 80 % were applied to convert the AT volume to AT or fat mass [19].

LBM_s determined by CT were defined in the following 3 ways (Fig. 1):

$$\begin{aligned} \text{LBM}_{\text{CT1}}(\text{kg}) &= \text{BW} - \text{fat in AT} \\ &= \text{BW} - \text{AT volume}(\text{L}) \times 0.95(\text{kgL}^{-1}) \times 0.8 \end{aligned}$$

(Fig. 1a)

$$\begin{aligned} \text{LBM}_{\text{CT2}}(\text{kg}) &= \text{BW} - \text{AT mass} \\ &= \text{BW} - \text{AT volume}(\text{L}) \times 0.95(\text{kg L}^{-1}) \quad (\text{Fig. 1b}) \end{aligned}$$

$$\begin{aligned} \text{LBM}_{\text{CT3}}(\text{kg}) &= \text{LBM}_{\text{CT2}} - \text{interstitial AT} = \text{LBM}_{\text{CT2}} \\ &\quad - \text{AT mass} \times 0.083 \text{ for male (8.9\% of AT for} \\ &\quad \text{female)}. \quad (\text{Fig. 1c}) \end{aligned}$$

The following 5 different PEs were used for comparison PEs [20–23]:

$$\begin{aligned} \text{LBM}_{\text{PE1}} &= 1.1 \times \text{BW} - 128 \times (\text{BW}/\text{height})^2(\text{male}) \\ &= 1.07 \times \text{BW} - 148 \times (\text{BW}/\text{height})^2(\text{female}) \end{aligned}$$

$$\begin{aligned} \text{LBM}_{\text{PE2}} &= \text{BW} - \{ \text{BW} \times [1.2 \times (\text{BW}/\text{height})^2] \\ &\quad + (0.23 \times \text{age}) - (10.8 \times \text{sex}) - 5.4 \} \times 0.01 \} \end{aligned}$$

Table 1 Characteristics of Patients Studied in SUL Comparison (n=453)

Characteristics	Value (Range)
Men : Women	233 : 220
Age (yr)	59.3 ± 13.4 (22~88)
Weight (kg)	59.3 ± 10.74 (34~93)
Height (cm)	160.3 ± 8.5 (137~185)
BMI (kg m^{-2})	23.05 ± 3.43 (14.37 ± 37.03)

BMI=body mass index; SUL=standardized uptake value normalized by lean body mass; Values are expressed as mean $\pm$ SD.

Fig. 1 Three LBM_{CT} models for male were constructed based on collective data combined with reference values of the Reference Male and Reference Female. (a) LBM_{CT1} model underestimated body fat. (b) The amount of AT measurable with CT and total body fat estimated with LBM model CT2 was similar. (c) LBM model CT3 was corrected for IAT, which was not measured by CT. Areas of LBM CTs are actually larger than those illustrated. AT=adipose tissue; CT=computed tomography; IAT=interstitial AT; IMAT=intermuscular AT; LBM=lean body mass; Le=essential lipid; Ln=non-essential lipid; RAT=retroperitoneal AT; SAT=subcutaneous AT; VAT=visceral AT; YBM=yellow bone marrow

$$\text{LBM}_{\text{PE3}} = 48.0 + 1.06 \times (\text{height} - 152) \text{ (male)}$$

$$= 45.5 + 0.91 \times (\text{height} - 152) \text{ (female)}$$

$$\begin{aligned} \text{LBM}_{\text{PE4}} = & \text{BW} - \{ \text{BW} \times [64.5 - 848 \times (\text{height}^2/\text{BW}) \\ & + (0.079 \times \text{age}) - (16.4 \times \text{sex}) + (0.05 \times \text{sex} \times \text{age}) \\ & + 39 \times \text{sex} \times (\text{height}^2/\text{BW})] \times 0.01 \}. \end{aligned}$$

$$\begin{aligned} \text{LBM}_{\text{PE5}} = & \text{BW} - \{ \text{BW} \times [76 - 1097.8 \times (\text{height}^2/\text{BW}) \\ & - (20.6 \times \text{sex}) + (0.053 \times \text{age}) + 95.0 \times (\text{height}^2/\text{BW}) \\ & - (0.044 \times \text{age}) + (154 \times \text{sex}) \times (\text{height}^2/\text{BW}) \\ & + (0.034 \times \text{sex} \times \text{age})] \times 0.01 \}. \end{aligned}$$

where sex=1 for male and 0 for female, BW is in kg, and height is in m in PE2, 4 and 5, and in cm in PE1 and 3.

ROIs were drawn in the liver at the level of liver segment 6 (3 cm circular ROI), in the spleen at the level of the splenic hilum (2 cm circular ROI), and in the aorta at the level of the pancreas (1.5 cm circular ROI), and each SUV_{BW} was measured. Using LBM_{CTs} and LBM_{PEs} obtained as described above, each SUL was calculated by multiplying SUV_{BW} by the LBM divided by BW.

Bland-Altman analysis was performed to test the agreement between SUL_{CTs} and SUL_{PEs} [24]. The differences between SUL_{CT1} and SUL_{PE1} in each organ were calculated in each patient ($\bar{d} \pm \text{SD}$), with bias defined as the mean difference ($\bar{d}$). The limit of agreement was defined as $\bar{d} - 2\text{SD}$ to $\bar{d} + 2\text{SD}$. To compare the magnitudes of the limit of agreement, the percentage error was calculated and defined as $100 \times 4\text{SD}$ of differences divided by the average of global mean of SUL_{CT1} and SUL_{PE1} [25]. The percentage (relative) differences were calculated to compare the magnitudes of difference, which were defined as $100 \times$ the difference between SUL_{CT1} and SUL_{PE1} divided by the mean of the two methods in each patient.

Analyses of SUL_{CT1} vs. $\text{SUL}_{\text{PE2-5}}$ were conducted similarly. For SUL_{CT2} vs. $\text{SUL}_{\text{PE1-5}}$ and SUL_{CT3} vs. $\text{SUL}_{\text{PE1-5}}$, the same analyses were also repeated.

Table 2 Comparison of Liver SUL_{CTs} and Liver SUL_{PEs} (n=453)

Liver SUVbw=2.65±0.41	SUL _{PE1}	SUL _{PE2}	SUL _{PE3}	SUL _{PE4}	SUL _{PE5}
SUL _{PEs}	2.00±0.29	1.82±0.29	2.45±0.41	1.94±0.30	1.92±0.30
SUL _{CT1} (1.99±0.30)					
Difference ($\bar{d} \pm SD$, SUL)	0.013±0.125	-0.169±0.125	0.465±0.284	-0.050±0.124	-0.065±0.137
Limit of agreement (SUL)	-0.237~0.263	-0.420~0.081	-0.103~1.032	-0.297~0.197	-0.339~0.208
Percentage error (%)	25.07	26.34	51.15	25.18	28.00
Percentage difference (%)	0.80±6.15	-9.04±6.65	20.61±11.25	-2.64±6.20	-3.42±6.88
SUL _{CT2} (1.83±0.30)					
Difference ($\bar{d} \pm SD$, SUL)	0.172±0.161	-0.010±0.155	0.623±0.272	0.108±0.145	0.094±0.148
Limit of agreement (SUL)	-0.150~0.495	-0.320~0.299	0.079~1.168	-0.181~0.398	-0.203~0.390
Percentage error (%)	33.69	33.94	50.85	30.72	31.58
Percentage difference (%)	9.32±8.63	-0.51±8.56	29.00±10.90	5.89±7.66	5.11±7.81
SUL _{CT3} (1.76±0.31)					
Difference ($\bar{d} \pm SD$, SUL)	0.241±0.183	0.058±0.174	0.692±0.271	0.177±0.161	0.162±0.161
Limit of agreement (SUL)	-0.124~0.606	-0.290~0.406	0.149~1.235	-0.145~0.500	-0.160~0.484
Percentage error (%)	38.85	38.91	51.55	34.90	34.96
Percentage difference (%)	13.29±10.17	3.48±9.92	32.89±11.18	9.88±8.90	9.10±8.84

CT=computed tomography; Limit of agreement = $\bar{d} - 2SD - \bar{d} + 2SD$; Percentage difference=difference / mean of two methods; Percentage error=4SD / average of global mean of two methods; PE=predictive equation; SUL=standardized uptake value normalized by lean body mass; SUVbw=standardized uptake value normalized by body weight; Values are expressed as mean±SD.

Statistical Analysis

Statistical analysis was performed using SPSS version 18.0. $P < 0.05$ was considered statistically significant. The normal distribution of differences was tested using the Kolmogorov-Smirnov test. Most of the differences between SUL_{CTs} and SUL_{PEs} were approximately normally distributed, but differences showed somewhat skewed distribution. However, the overall interpretation of the results was not considered to be seriously disturbed.

Results

For all liver SUL_{CTs} vs. liver SUL_{PEs} except liver SUL_{PE3}, the range of biases, SDs of percentage difference and percentage errors were -0.17-0.24 SUL, 6.15-10.17 %, and 25.07-38.91 %, respectively, indicating large percentage errors and differing magnitudes of biases in liver SUL_{PEs} (Table 2; Fig. 2). For liver SUL_{CTs} vs. liver SUL_{PE3}, the corresponding figures were 0.47-0.69 SUL, 10.90-11.25 %, and 50.85-51.55 %, respectively, showing the largest percentage errors and positive biases compared with other liver SUL_{PEs} (Table 2; Fig. 2). Thus, liver SUL_{PE3} was unsuitable for any of the SUL_{CT} models. Irrespective of the magnitudes of the biases, however, large percentage errors of 25.07-

51.55 % were observed between all liver SUL_{CTs} vs. all liver SUL_{PEs} (Fig. 2).

The results of comparison between SUL_{CTs} and SUL_{PEs} in the spleen and aorta were almost identical to those for liver SUL as follows: For all spleen SUL_{CTs} vs. spleen SUL_{PEs}, the range of biases, SDs of percentage difference and percentage errors were -0.13-0.54 SUL, 6.15-11.25 % and 25.42-55.93 %, respectively (Table 3). Corresponding figures for the aorta were -0.13-0.53 SUL, 6.15-11.25 % and 24.51-52.11 %, respectively, showing large percentage errors in individual SUL_{PEs} (Table 4).

Discussion

The purpose of the present study was to determine LBM by CT with a subsequent normalization of SUV and compare it with SUV normalized by LBM estimated by five different PEs. To test agreement between the two methods, Bland-Altman analysis was performed, which is known to be one of the most appropriate analytical methods for comparing clinical measurement methods [24]. The difference between the two methods and the limit of agreement in each patient were calculated. In addition, the percentage differences and percentage errors were calculated.

Fig. 2 Irrespective of biases (bars, mean differences), large limit of agreement (error bars, mean difference - 2SD to mean difference + 2SD) were observed between liver SUL_{CT1} vs. liver SUL_{PE1-5} (a), liver SUL_{CT2} vs. liver SUL_{PE1-5} (b) and liver SUL_{CT3} vs. liver SUL_{PE1-5} (c). CT=computed tomography; PE=predictive equation; SUL=standardized uptake value normalized by lean body mass

95 % of differences between SUL_{CTs} vs. SUL_{PEs} will lie between each mean difference ($\bar{d}$) $\pm 2SD$ (more precisely, $\bar{d} \pm 1.96 SD$). For example, liver SUL_{PE1} was similar for patients A and B, i.e., 2.093 and 2.112, respectively. However, liver SUL_{CT2} values for patients A and B were 1.684 and 2.254, respectively. The difference in liver SUL_{CT2} between the two patients was 0.57. The difference between liver SUL_{CT2} and SUL_{PE1} for the whole group was 0.172 ± 0.161 ($\bar{d} \pm SD$; Table 2). Thus, the difference in liver SUL_{CT2} between the two patients approached 4 SD (2 SD in both directions from the mean difference, i.e., percentage error of 33.69 %), as illustrated by Bland-Altman plot (Table 2; Fig. 3). The differences between liver SUL_{CT2} and SUL_{PE1} for patients A and B each lay, as expected, within 2 SD. In a contrasting case, liver SUL_{PE1} values for patients C and D were 1.790 and 2.382, respectively. The difference in liver SUL_{PE1} between the two patients was 0.592. Thus, the difference in liver SUL_{PE1} between the two patients also approached 4 SD. However, liver SUL_{CT2} values for patients C and D were almost identical: 1.893 and 1.894, respectively.

Among SUL_{PEs} , SUL_{PE3} was considerably overestimated, with a large percentage error compared with other SUL_{PEs} , because SUL_{PE3} was normalized by ideal body weight (i.e., estimated by PE3). This observation suggests that SUV normalized by ideal body weight should be interpreted with caution.

More importantly, it should be noted that irrespective of the magnitudes of biases, large percentage errors ranging from 25.07 % to 51.55 % were observed between all SUL_{CTs} and all SUL_{PEs} .

SUL_{CT1} was based on LBM_{CT1} , which clearly underestimated body fat with a subsequent overestimation of LBM, because fat mass in AT measurable with CT is smaller than total AT fat mass including non-measurable AT (Fig. 1a). SUL_{CT3} was based on LBM_{CT3} , which was corrected for interstitial adipose tissue mass, but interstitial adipose tissue cannot be measured with CT, and large individual variability and uncertainty are associated with interstitial adipose tissue estimation (Fig. 1c). Hence, the SUL_{CT2} model was considered most reasonable among SUL_{CT} models (Fig. 1b).

To our knowledge, the present study is the first report on the application of LBM determined by CT to normalize SUV in ^{18}F -FDG PET/CT studies. Large errors in individual SUL_{PEs} are often encountered when applying PEs to individual patients, even though the magnitudes of mean difference (biases) are small over a whole population. Therefore, normalization of SUV by LBM determined by CT instead of PEs may be a useful approach for reducing errors found in individual SUL_{PEs} .

Table 3 Comparison of Spleen SUL_{CTs} and Spleen SUL_{PEs} (n=453)

Spleen SUVbw=2.04±0.32	SUL _{PE1}	SUL _{PE2}	SUL _{PE3}	SUL _{PE4}	SUL _{PE5}
SUL _{PEs}	1.54±0.23	1.40±0.23	1.90±0.35	1.50±0.24	1.48±0.25
SUL _{CT1} (1.53±0.23)					
Difference ($\bar{d} \pm SD$, SUL)	0.013±0.098	-0.130±0.096	0.364±0.233	-0.037±0.096	-0.048±0.107
Limit of agreement (SUL)	-0.183~0.208	-0.322~0.063	-0.101~0.829	-0.230~0.156	-0.261~0.166
Percentage error (%)	25.42	26.24	54.30	25.48	28.33
Percentage difference (%)	0.80±6.15	-9.04±6.65	20.61±11.25	-2.64±6.20	-3.42±6.88
SUL _{CT2} (1.41±0.23)					
Difference ($\bar{d} \pm SD$, SUL)	0.135±0.128	-0.008±0.121	0.486±0.227	0.086±0.115	0.075±0.119
Limit of agreement (SUL)	-0.122~0.392	-0.249~0.234	0.033~0.940	-0.145~0.316	-0.162~0.312
Percentage error (%)	34.78	34.33	54.89	31.70	32.80
Percentage difference (%)	9.32±8.63	-0.51±8.56	29.00±10.90	5.89±7.66	5.11±7.81
SUL _{CT3} (1.36±0.23)					
Difference ($\bar{d} \pm SD$, SUL)	0.188±0.146	0.045±0.136	0.539±0.227	0.139±0.129	0.128±0.130
Limit of agreement (SUL)	-0.103~0.479	-0.227~0.318	0.085~0.994	-0.119~0.396	-0.131~0.387
Percentage error (%)	40.15	39.45	55.93	36.08	36.47
Percentage difference (%)	13.29±10.17	3.48±9.92	32.88±11.18	9.88±8.90	9.10±8.84

CT=computed tomography; Limit of agreement = $\bar{d} - 2SD - \bar{d} + 2SD$; Percentage difference=difference / mean of two methods; Percentage error=4SD / average of global mean of two methods; PE=predictive equation; SUL=standardized uptake value normalized by lean body mass; SUVbw=standardized uptake value normalized by body weight; Values are expressed as mean±SD.

Conclusion

The present study demonstrated that substantial errors exist in individual SUL_{PEs}, when compared with SUL_{CTs} as a

reference value. Normalization of SUV by LBM determined by CT rather than PEs may be a useful approach to reduce errors in individual SUL_{PEs} in quantitative ¹⁸F-FDG PET/CT examination.

Table 4 Comparison of Aorta SUL_{CTs} and Aorta SUL_{PEs} (n=453)

Aorta SUVbw=2.00±0.33	SUL _{PE1}	SUL _{PE2}	SUL _{PE3}	SUL _{PE4}	SUL _{PE5}
SUL _{PEs}	1.53±0.24	1.39±0.23	1.88±0.34	1.48±0.25	1.47±0.25
SUL _{CT1} (1.52±0.25)					
Difference ($\bar{d} \pm SD$, SUL)	0.010±0.093	-0.131±0.097	0.357±0.218	-0.039±0.093	-0.050±0.103
Limit of agreement (SUL)	-0.177~0.197	-0.324~0.062	-0.080~0.793	-0.226~0.147	-0.256~0.156
Percentage error (%)	24.51	26.56	51.45	24.86	27.51
Percentage difference (%)	0.80±6.15	-9.04±6.65	20.61±11.25	-2.64±6.20	-3.42±6.88
SUL _{CT2} (1.40±0.25)					
Difference ($\bar{d} \pm SD$, SUL)	0.131±0.122	-0.010±0.118	0.478±0.210	0.082±0.109	0.071±0.111
Limit of agreement (SUL)	-0.112~0.374	-0.245~0.226	0.057~0.898	-0.135~0.299	-0.152~0.294
Percentage error (%)	33.26	33.78	51.35	30.18	31.06
Percentage difference (%)	9.32±8.63	-0.51±8.56	29.00±10.90	5.89±7.66	5.11±7.81
SUL _{CT3} (1.35±0.26)					
Difference ($\bar{d} \pm SD$, SUL)	0.183±0.138	0.043±0.132	0.530±0.210	0.134±0.121	0.123±0.121
Limit of agreement (SUL)	-0.093~0.460	-0.221~0.306	0.110~0.950	-0.108~0.376	-0.119~0.365
Percentage error (%)	38.42	38.57	52.11	34.24	34.41
Percentage difference (%)	13.29±10.17	3.48±9.92	32.88±11.18	9.88±8.90	9.10±8.84

CT=computed tomography; Limit of agreement = $\bar{d} - 2SD - \bar{d} + 2SD$; Percentage difference=difference / mean of two methods; Percentage error=4SD / average of global mean of two methods; PE=predictive equation; SUL=standardized uptake value normalized by lean body mass; SUVbw=standardized uptake value normalized by body weight; Values are expressed as mean±SD.

Fig. 3 Bland-Altman plot indicates the differences between the two methods against the mean of the two methods. The difference between the two methods for each patient lay within the 2 SD of the difference in 95 % of cases. However, the difference in LBM between 2 patients would approach 4 SD of the difference when the two patient values were 2 SD from the mean difference in opposite directions. CT=computed tomography; PE=predictive equation; SD=standard deviation; SUL=standardized uptake value normalized by lean body mass

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Conflict of Interest The authors declare that they have no conflict of interest.

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