Evaluation of standardized uptake values in PET normalized using a predictive equation for lean body mass

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Aims and objectives

Maximum standardized uptake value (SUV$_{max}$) is a commonly used as a semiquantitative parameter in PET/CT studies valuable for diagnosis of various diseases and therapy response. However, It is reported that SUV$_{max}$ is modified by various factors, differs from the true value, then it makes undervalue or overvalue patient conditions. We have experienced that SUV$_{max}$ is occasionally not useful to diagnose and compare with other patients in clinical. It was known that patient's physique make it be difficult to get true SUV$_{max}$, and it is reported to the over weight especially that SUV$_{max}$ becomes an excessive evaluation in the patient. Using lean body mass normalized SUV$_{max}$ (SUL) is weight-independent indice for FDG uptake, and SUV$_{max}$ appears to be more appropriate for quantifying FDG uptake to avoid overestimation of glucose utilization in obese patients$^{1}$). Also SUL is used in the therapy evaluation in PERCIST1.0 advocated as therapy evaluation$^{2}$). Moreover, a lot of methods of obtaining lean body mass (LBM) from the calculation are instituted, and the calculating formula to which Morgan DJ et al. modified the James method is adopted widely now$^{3}$). Whether using the predictive equation SUV$_{max}$ (SUL$_{PE}$) could be clinical suitable or not is uncertain. The purpose of the present study is that SUV$_{max}$ obtained from the actual measurement value of the body fat scale (SUL$_S$) is defined as Golden standard, and evaluate SUL$_{PE}$ by comparing in physiological accumulation and to clarify the differences among body type in SUV$_{max}$.
**Fig. 1:** MIP images of a thin patient and a fatty patient. It is displayed with the same SUV range.

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Methods and materials

Subjects

Object were consecutive 135 patients underwent 18F-FDG-PET/CT examination for routine clinical purpose, who agreed to research, in August 2013 to March 2014. The 18F-FDG-PET/CT study has been performed for malignant discrimination; 11pts., for staging malignant disease; 47pts., for decision of treatment result; 5pts., for follow-up; 65pts., health screening; 3pts. Four patients whose blood glucose is over 150 mg/dl and/or who had multiple liver tumors were excluded. In the all patients, after over 6 hr fasting, each patient was injected with approximately 185MBq of fluorine-18 fluorodeoxyglucose (18F-FDG)(nihon mediphysics, Tokyo, Japan). Body weight, height, and body fat percentage were measured by body fat analyzer (FitScan 100, Tanita, Japan) just before the PET/CT studies. They were divided into three groups; low body mass index group (BMI #18.5), normal BMI group (BMI 18.5-25), and high BMI group(BMI #25)(Table 1). They spent complete bedrest until PET/CT scan starting after the dosage of 18F-FDG.

F-18-FDG-PET/CT Imaging

All fluorodeoxyglucose (FDG) PET/CT scans were performed from the top of the skull through the proximal femurs 60 min after F-18-FDG injection (185 MBq/body intravenously) on a Lu₂SiO₅ (4.0mm*4.0mm*20#). Emission data were collected at 2.5-3.0 min of emission per bed position on a 168 x 168 pixel matrix, using a Ge-68 source for attenuation correction and a gaussian filter of 5 mm in full width at half maximum. PET/CT studies were obtained on Siemens Biograph TruePoint 16 (Siemens Healthcare, Erlangen, Germany). SULPE and SULS were calculated using following equations:

\[ \text{SUL}_{PE} = \frac{C(T)}{(D/LBM1)} \]
\[ \text{SUL}_{S} = \frac{C(T)}{(D/LBM2)} \]

\( C(T) \): the total radioactivity concentration.

\( D \): injected dose (Bq).

The LBM1³) and LBM2 were calculated using the following formula:
LBM1 (Male) \(^3\) = 1.10 \times \text{weight (kg)} # 120 \times \text{weight} \div \text{height (cm)}
LBM1 (Female) \(^3\) = 1.07 \times \text{weight (kg)} # 148 \times \text{weight} \div \text{height (cm)}
LBM2 = \text{weight (kg)} \times \text{body fat percentage}

**Measurements and Data Analysis**

Volume of interests (VOIs) of constant size (radius: 5mm) were drawn sections of aortic arch and liver on axial CT slices (Figure 2). VOIs were drawn in the peripheral right hepatic lobe avoiding large veins or the biliary ducts. FDG uptake was measured and \(\text{SUV}_{\text{max}}\), \(\text{SUL}_{\text{S}}\), and \(\text{SUL}_{\text{PE}}\) were calculated. The differences among \(\text{SUV}_{\text{max}}\), \(\text{SUL}_{\text{S}}\), and \(\text{SUL}_{\text{PE}}\) were compared in all and for 3 groups: low BMI, normal BMI, and high BMI group. \(\text{SUV}_{\text{max}}\), \(\text{SUL}_{\text{S}}\), and \(\text{SUL}_{\text{PE}}\) were compared in all groups. Moreover \(\text{SUL}_{\text{PE}}\) average among 3 groups was compared with \(\text{SUV}_{\text{max}}\) average among 3 groups.

**Statistical methods**

The Wilcoxon t-test was used to compare \(\text{SUL}_{\text{S}}\) to \(\text{SUL}_{\text{PE}}\) in each groups. The non-repeated measures ANOVA test was used analyze for \(\text{SUV}_{\text{max}}, \text{SUV}_{\text{S}}, \text{and SUV}_{\text{PE}}\) each BMI groups. The level of statistical significance was \(p < 0.05\).
### Table 1: Patient groups.

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Fig. 2: Measurement areas. VOIs (radius; 5mm) were set in the aortic arch and right lobe in liver.

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Results

Result
In the aortic and liver ROIs, $\text{SUV}_{\text{max}}$ (mean±SE) were 2.04±0.29 and 2.50±0.28 in the low BMI group, 2.41±0.41 and 2.98±0.47 in the normal BMI group, and 2.71±0.28 and 3.42±0.41 in high BMI group, respectively. $\text{SUL}_\text{PE}$ were 1.72±0.27 and 2.10±0.27 in the low BMI group, 1.90±0.35 and 2.36±0.44 in the normal BMI group, and 1.86±0.27 and 2.33±0.35 in the high BMI group, respectively. $\text{SUV}_S$ were 1.70±0.27 and 2.07±0.28 in the low BMI group, 1.82±0.30 and 2.25±0.36 in the normal BMI group, and 1.76±0.26 and 2.23±0.35 in the high BMI group.

Table 2 shows the differences in aorta and liver $\text{SUV}_{\text{max}}$, $\text{SUL}_S$, and $\text{SUL}_\text{PE}$ in each BMI group. The value of $\text{SUL}_\text{PE}$ was significantly higher than that of $\text{SUL}_S$ in total (aorta; $p$ #0.001, liver; $p$ #0.001). Although there is no significant difference between $\text{SUL}_S$ and $\text{SUL}_\text{PE}$ in the low BMI group (aorta; $p$ =0.19, liver; $p$ =0.17), in the normal and high BMI groups we found a significant difference between $\text{SULs}$ and $\text{SUL}_\text{PE}$. The similar trend of $\text{SUL}_S$ and $\text{SUL}_\text{PE}$ in liver was seen.

Meanwhile, Figure 3 and 4 shows each $\text{SUV}_{\text{max}}$, $\text{SUL}_S$, and $\text{SUL}_\text{PE}$ in aorta and liver of each BMI groups. Evaluation each group, no systematic dependence of SUVs on patient BMI was found in aorta and liver. On the other hand, in aortic $\text{SUV}_\text{PE}$, a significant difference was founded, but relatively small between the low BMI and normal BMI groups. As well as in hepatic $\text{SUV}_\text{PE}$, low BMI group was a significantly lower than normal and high BMI group, but relatively small.

However, there is distinct difference in aortic and hepatic $\text{SUV}_{\text{max}}$ value among 3 groups. There was 27.5% difference in the aortic $\text{SUV}_{\text{max}}$ between the low BMI group and high BMI group. As well as it was reached 31.2% in the hepatic $\text{SUV}_{\text{max}}$. By contrast, the difference of $\text{SUL}_\text{PE}$ is only about 10% of mean value in the aortic and hepatic VOIs.
Table 2: SUVmax, SULS and SULPE in aorta and liver.

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Fig. 3: Result SUV and SUL in Aorta #P#0.05

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Fig. 4: Result SUVmax, SULS and SULPE in liver. *P*<0.05

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Conclusion

$SUV_{\text{max}}$ was found to be dependent on patient weight with a systematic variation of about 30% across the three categories: underweight, normal, and overweight.

$SUL_{\text{PE}}$ should be considered as a clinical useful proxy measure of FDG uptake.
Personal information

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