

**ORIGINAL****The relationship between standard uptake value (SUV) and Hounsfield Unit (HU) of oral contrast agent for FDG-PET/CT study**Hideki Otsuka<sup>1,2</sup>, Akiko Kubo<sup>2</sup>, Michael Graham<sup>1</sup>, and Hiromu Nishitani<sup>1</sup>*Division of Nuclear Medicine, Department of Radiology, University of Iowa, USA ; and* <sup>2</sup>*Department of Radiology, Institute of Health Biosciences, The University of Tokushima Graduate School, Tokushima, Japan*

**Abstract :** The aim of this study was to examine the relationship between CT density (Hounsfield Unit, HU) and the degree of fluoro-deoxyglucose (FDG) uptake, demonstrated as standard uptake value (SUV). Twenty contiguous patients (9 males, 11 females, age range of 29-79) were performed FDG-PET/CT scan with 750ml of 5% iodine-based oral contrast agent. A region of interest (ROI) was placed manually on oral contrast in the lumen of stomach, small bowel and ascending colon, avoiding contamination of other structures, and the average SUV and average HU were determined. R square and p value were applied to evaluate the correlation. The correlation between SUV and HU in each separate location is not significant. When all regions are combined, p value is significant ( $< 0.05$ ), but R square is not significant. Oral contrast can be one factor that influences measured FDG, and it is possible it acts as an irritant that increases metabolism in the bowel wall, resulting in increased FDG uptake. *J. Med. Invest.* 51 : 226-229, August, 2004

**Keywords :** FDG-PET/CT, oral contrast, gastrointestinal tract, standard uptake value, Hounsfield Unit

**INTRODUCTION**

PET/CT can demonstrate both anatomic and metabolic information in a single session (1). In PET/CT systems, CT data is used for attenuation correction of PET images, and imaging time can be shortened because a transmission scan is not necessary as it is with PET-alone systems. To improve image quality in the CT part of PET/CT studies, oral contrast or intravenous contrast agent can be given to distinguish other structures or to observe contrast enhancement. For CT-based attenuation corrected PET images, the high attenuation associated with contrast can lead to

artificial intense uptake in the corrected FDG images (2-5). Intense uptake in the gastrointestinal tract appears to be seen more frequently in patients with oral contrast compared to those without contrast. Compared to the PET annihilation photons of 511 keV, X-rays at CT energies of 70-140 keV are more attenuated by the structures that contain elements with high atomic numbers, such as iodine or barium. A bilinear scaling method, which distinguishes soft tissue from bone, is used to convert different CT Hounsfield Units (HU) into attenuation-corrected PET images. To evaluate the degree of FDG uptake, standard uptake value (SUV) is used for quantitative analysis. The aim of this study is to evaluate the hypothesis that the increased FDG uptake in gut seen in patients who receive oral contrast is due to inaccurate attenuation correction. If this is true then there should be a strong correlation between FDG uptake (SUV) and contrast density (HU) in these images.

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Address correspondence and reprint requests to Hideki Otsuka, M.D., Ph.D., Department of Radiology, Institute of Health Biosciences, The University of Tokushima Graduate School, Kuramoto-cho, Tokushima 770-8503, Japan and Fax : +81-88-633-7174.

## PATIENTS AND METHODS

This study was approved by the University of Iowa Institutional Review Board.

### *Patient population*

Twenty contiguous patients without any history of bowel disease were examined. The population consisted of 9 males and 11 females with age range of 29-79. The indication for PET/CT was restaging/follow up of lymphoma in 4 patients, breast cancer in 4, uterine cervical cancer in 2, melanoma in 1, leukemia in 1, unknown primary in 2, seminomatous tumor in 1, initial staging for lung cancer in 1, melanoma in 1, evaluation of lung nodules in 3. All studies were performed with a combined PET/CT scanner (Siemens, Biograph). Fluoro-deoxyglucose (FDG) was produced with a 17 meV Scandatronix cyclotron in our PET center.

The patients were asked to fast at least 4h before FDG injection and blood glucose level was confirmed below 150 mg/dl. Oral contrast of 750 ml was prepared with the mixture of 37.5 ml iodine-based oral contrast (Gastroview, 367mg iodine/ml, Diatrizoate Meglumine and Diatrizoate Sodium Solution U.S.P, Mallinckrodt Inc) and 712.5 ml of water. The patient took 500 ml of oral contrast before 370-555 MBq FDG intravenous injection and another 250 ml before positioning on the PET/CT table. After positioning, a topogram was taken for scan range determination. Then a CT image was obtained by 2-slice helical scanner. After the completion of the CT image, the PET scan started 90 minutes after FDG injection from caudal to cranial direction. The scan range was different according to the patient body size and referred disease, typically consisting of 5-8 bed positions. Each bed position took 3 min and the total time on the table was approximately 30 min. Patients breathed freely during the whole study.

## DATA ANALYSIS

CT-based attenuation corrected PET images, CT images, fused images and uncorrected PET images

were displayed on the monitor for image interpretation. Using the fused PET/CT image, a region of interest (ROI, 3-4cm<sup>2</sup> in size) was placed manually on oral contrast in the lumen of stomach, small bowel and ascending colon, avoiding contamination by other structures, and the average SUV and average HU was determined. SUV was calculated as follows : SUV= tissue concentration (kBq/ml)/injected FDG dose (kBq)/body weight (g). If focal uptake was observed, an ROI was placed on the most intense area visually. R square and p value was determined to test the relationship between SUV and HU, using linear correlation. We calculated 3 sites separately to evaluate within region relationships, and put the 3 sites together to evaluate correlation across the entire gastrointestinal tract.

## RESULTS

Images are displayed in Fig.1a-attenuation corrected PET image, b-CT image, c-PET/CT fused image, d-uncorrected PET image. It is difficult to assess the difference of CT density (HU) by visual assessment, although FDG uptake in the ascending colon seems to be more intense compared to that in the stomach on both corrected and uncorrected PET images. The distribution of SUVs and HUs is shown in Fig.2. Both SUV and HU varied over a wide range. The results of the linear correlation analysis are displayed in Table 1. The correlation between SUV and HU in each separate location is not significant. When all regions are combined, p value is significant (< 0.05), indicating a slope not equal to zero, but R square is not significant.

## DISCUSSION

After we began to use FDG-PET/CT with oral contrast, we noticed that intense uptake appeared to be seen more frequently in the bowel when patients were given oral contrast than without. These foci of intense uptake are seen in attenuation corrected images and

Table 1. The results of R square and p value are displayed in Table 1. The correlation between SUV and HU is not significant.

	meanSUVavr (SD)	meanHUavr (SD)	R square	p value
stomach	1.10 (0.41)	296 (38)	0.005	0.77
small bowel	2.03 (0.57)	315 (112)	0.02	0.55
ascending colon	3.03 (0.55)	359 (68)	0.003	0.822
3 combination	2.05 (0.94)	323 (82)	0.097	0.016

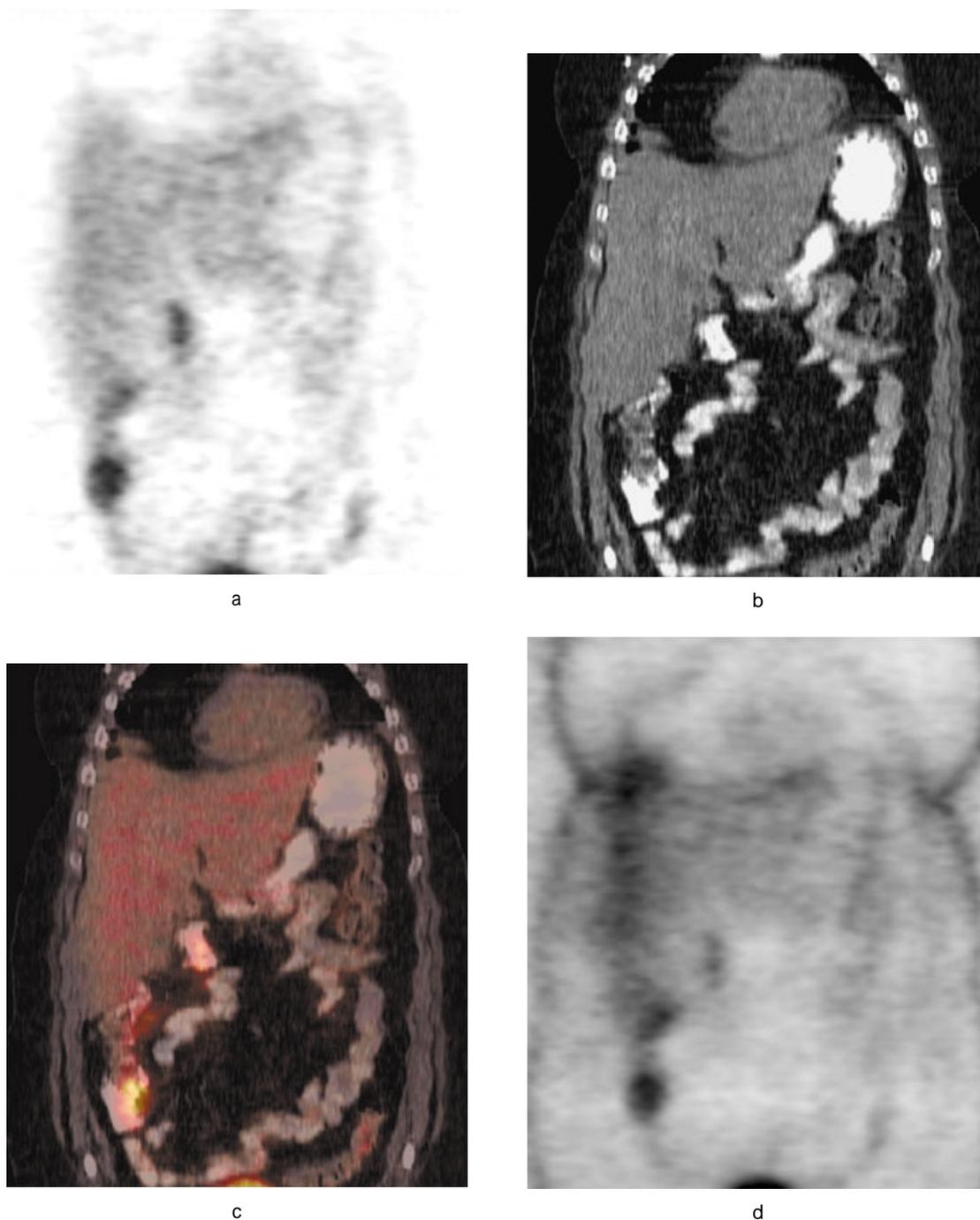


Fig 1. Forty-two year old female underwent FDG-PET/CT for restaging of breast cancer. a-corrected PET image, b-CT image, c-fused image, d-uncorrected PET image. Oral contrast in the stomach and large bowel shows similar density visually. Intense uptake is seen in both corrected and uncorrected PET images.  $SUV_{avr}$ ,  $HU_{avr}$  in the stomach ; 0.87, 285, small bowel ; 1.58, 223, ascending colon ; 3.76, 338.

also in uncorrected PET images. We hypothesized that an error in attenuation correction due to high concentration of oral contrast is not the only factor affecting measured FDG activity. There are several reports about the effect of oral contrast agents on the GI tract. Antoch reported that the degree of attenuation overestimation correlates with contrast concentration (2). According to their data, FDG activity can be overestimated by 5-30% in clinically-used concentration. We used 5%

iodine-based oral contrast that shows approximately 315 HU. Our system uses 300 HU as a threshold to distinguish soft tissue from bone for CT-based attenuation correction. Since our data shows amounts of contrast in the range of 300-400 HU with SUVs varying from 0.5 to 4.5, it is difficult to explain the variation in SUV simply by variation of HU. Our data also showed that the contrast concentration differs along the GI tract. Though we found little correlation between SUV

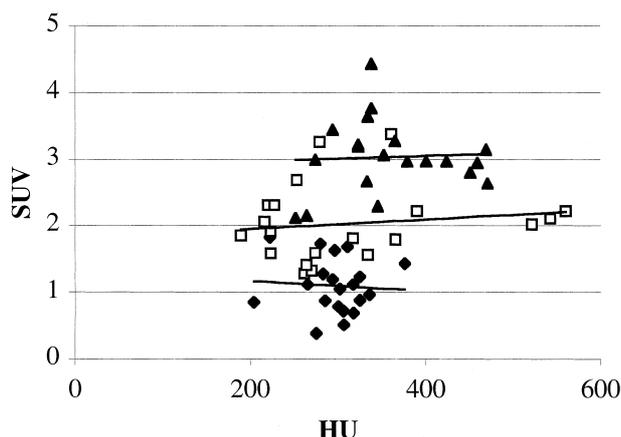


Fig 2. The distribution of SUV and HU.  $\blacktriangle$  : stomach,  $\square$  : small bowel,  $\blacklozenge$  : ascending colon. HU is most widely ranged in small bowel. Trendline equation for the stomach ;  $Y = -0.0007 X + 1.32$ , small bowel ;  $Y = 0.0007 X + 0.81$ , large bowel ;  $Y = 0.0004 X + 0.88$ , 3 combination ;  $Y = 0.0036 X + 0.89$

and HU in separate GI locations, the p value was less than 0.05 for the combination of all 3 regions. This result supports the concept that contrast concentration is one of the factors that influences measured FDG activity.

In normal tissues or structures, SUV does not correlate well with HU. Urine shows very small HU but very high SUV because of FDG excretion from urinary system. Brain parenchyma and heart muscle show soft tissue density on CT and commonly display very intense FDG uptake because of the large demand of glucose as an energy source in these tissues.

One limitation of this study is the movement of oral contrast during the time between the CT scan and the PET scan. We took PET images moving from caudal to cranial to minimize the difference of location of oral contrast between the two images. The time lag is up to 10 minutes in the upper abdomen. Peristalsis naturally occurs through the scan and oral contrast in the lumen moves distally. It is quite difficult to predict the degree of bowel peristalsis, but it is unlikely to be sufficient

to explain our findings.

In conclusion, our study supports the hypothesis that oral contrast concentration can influence measured FDG activity by mechanisms other than attenuation effects. It is possible it acts as an irritant that increases metabolism in the bowel wall, resulting in increased FDG uptake. Further investigation may be needed to address this possibility.

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