Annals of Nuclear Medicine Vol. 18, No. 4, 333–336, 2004

Quantitative assessment of truncal FDG-PET examination with postinjection transmission scan —Comparison with preinjection transmission scan—

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The purpose of this study was to assess the quantitative accuracy of truncal FDG PET with a postinjection transmission scan. ***Methods:*** Ten subjects with lung cancer were recruited for this study. Prior to the emission scan, a transmission scan was performed for 10 min. All subjects received 370 MBq of intravenous administration of FDG prior to a 60-min emission scan. Immediately following the emission scan, a postinjection transmission scan was performed. Emission data from 40 to 60 min postinjection were reconstructed with either pre- or postinjection transmission data and converted to a standardized uptake value (SUV) image. On each SUV image, 5 regions of interest were placed and regions of interest on the SUV image with a postinjection transmission scan (SUVpost) were plotted against those with preinjection transmission (SUVpre), and a regression line was generated. Using the slope and *Y*-intercept of the regression line, percent error of estimation of the SUV was calculated based on the following equation: % error = |SUVpre – SUVpost| × 100/SUVpre. ***Results:*** In the low SUV area (SUV = 1), the averaged percent error was 9.4 ± 12.0% (mean ± SD), whereas in the high SUV area (SUV = 10), the averaged percent error was 2.8 ± 3.1%. The least percent error was 1.8 ± 1.8% (SUV = 3.8) in this study. ***Conclusion:*** In the study on truncal FDG PET with postinjection transmisson scan, the quantitative accuracy was preserved and the method is clinically available.

Key words: FDG-PET, postinjection transmission scan, misregistration

INTRODUCTION

POSITRON EMISSION TOMOGRAPHY (PET) has several advantages over single-photon emission computed tomography (SPECT) with regards to the quantitative accuracy. One reason is the successful attenuation correction by means of the transmission scan with an external source. Using the transmission scan data, the radioactivities in the deep area of the body were estimated, and the attenuation correction contributed to the accuracy of the quantitation. However, if misregistration between the transmission and emission scan occurs, the quantitative accuracy can no longer be guaranteed. When the emission scan is performed just after the transmission scan, misregistration will not occur, but in the PET study with fluorine-18 2-fluoro-2-deoxy-D-glucose (FDG), a static emission scan was performed 40–60 min postinjection. To minimize the possibility of misregistration, the subject must lie on the bed of the PET camera during the examination. However, this position causes low throughput of the PET examination, and is uncomfortable for the patient.

To resolve these issues, the postinjection transmission scan method can be used. In the postinjection transmission data, the radioactivities of the injected tracers are included, and their quantitative accuracy must be

Received December 1, 2003, revision accepted April 11, 2004.

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assessed. Quantitative estimation has been performed in neurological FDG-PET study,[1] but no report of the quantitative estimation of truncal FDG PET studies exists. Therefore, we examined the quantitative accuracy of truncal FDG PET with postinjection transmission scan.

MATERIALS AND METHODS

PET procedure

In this study, 10 patients (7 males and 3 females; age 65–77 yrs) with lung cancer were recruited. Written informed consent was provided by all patients. FDG was produced by the method of Hamacher et al.[2] with an automated FDG synthesis system (NKK, Tokyo, Japan) and a small cyclotron (OSCAR3, Oxford Instruments, UK). PET scanning was performed with a GE Advance system (GE, Milwaukee, WI, USA). The performance characteristics of this scanner have been described in detail by DeGrado et al.[3] This system permits the simultaneous acquisition of 35 transverse slices with interslice spacing of 4.25 mm with septa (two-dimensional mode). The images were reconstructed to a full width at half maximum (FWHM) of 8 mm in both the transaxial and axial directions. The field of view and pixel size of the reconstructed images were 512 mm and 4 mm, respectively. After overnight fasting, each patient lay on the bed, and was then secured to the bed using a Velcro band. A transmission scan with a rotating Ge-68 pin source was performed for 10 min, and this procedure was a preinjection transmission scan. After the preinjection transmission scan, intravenous administration of FDG (approximately 370 MBq) was performed, and the emission scan was started at the same time. The emission scan lasted 60 min, and after the end of the emission scan, a postinjection transmission scan was performed for 10 min.

Image preparation and data analysis

For the quantitative evaluation, 40 to 60 min postinjection emission data were applied in this study. The emission data were reconstructed with either preinjection transmission data or postinjection transmission data. As raw postinjection transmission data contain both emission and transmission data, the contaminating emission data were subtracted according to Carson's report[4] and the remaining postinjection data were used as postinjection transmission data in this study. The reconstruction filter was a Hanning 6.5 mm. The reconstructed images were converted to standardized uptake value (SUV) images with the patient's body weight and injected dose according to the following equation:

SUV = tissue activity (kBq/m*l*)/((injected dose (MBq)/body weight (kg))

Then, the SUVpre image which the preinjection transmission data had used for reconstruction and the SUVpost image which the postinjection transmission data had used, were prepared in each patient. Five regions of interest (ROIs) were placed on the cancerous area, myocardium, left ventricle, soft tissue, and lung parenchyma in each SUV image. The shape and size of the ROIs were circular, and the ROIs were 3 pixels in diameter.

To estimate the quantitative accuracy of the SUVpost, a percent error of estimation of the SUV was applied. It was calculated with the following equation:

$$\%\ \text{error of estimation} = \frac{|\text{SUVpre} - \text{SUVpost}|}{\text{SUVpre}} \times 100 \quad (1)$$

When the SUVpost was plotted against the SUVpre, they were linearly correlated, and the relationship between the SUVpre and SUVpost was expressed as below:

$$\text{SUVpost} = a \times \text{SUVpre} + b, \quad (2)$$

where a is the slope and b is the Y-intercept of the regression line.

By combining (1) and (2), the percent error of estimation was expressed as follows:

$$\%\ \text{error of estimation} = |1 - a - b/\text{SUVpre}| \times 100 \quad (3)$$

In each patient, a and b were obtained from the regression line, and then by changing the SUVpre simulation curve of the % error of estimation was generated.

In this study, it was essential to confirm that misregistration was not recognized between the emission and transmission scan. Therefore, we measured the degree of misregistration between the preinjection transmission and postinjection transmission data. Each transmission datum was reconstructed and coregistered 3-dimensionally manually. In this coregistration procedure, the patients were divided into 2 groups, misregistration (+) and misregistration (–) groups. The criteria for misregistration (–) is as follows: 1) no misregistration in the z-direction, 2) misregistration within 1 pixel in both the x-, and y-direction, 3) misregistration within 2 pixels in either the x-, or y-direction.

RESULTS

Based on the criteria for discrimination, 7 patients were included in the misregistration (–) group. The remaining 3 patients were included in the misregistration (+) group; two with misregistration in the z-direction and one with misregistraion of 2 pixels in x- and 1 pixel in y-direction.

Figure 1 shows a representative case of the relationship between the SUVpre and SUVpost. The regression line was almost one of identity.

Figure 2 shows the simulation curve of the percent error of estimation of the case shown in Figure 1. The larger the SUVpre became, the smaller the % error of estimation became.

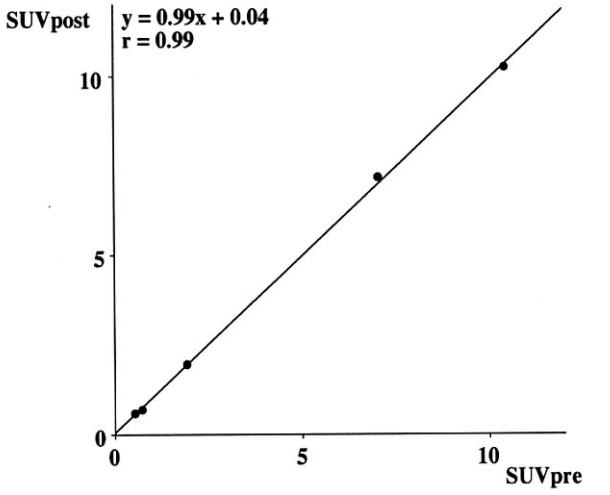

Fig. 1 Representative case of the relationship between SUVpre and SUVpost. Excellent linear correlation was observed.

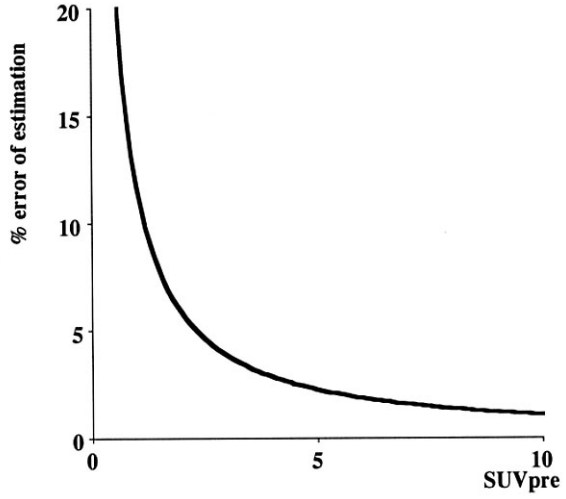

Fig. 2 The simulation curve of the % error of estimation of SUV (the same case shown in Figure 1).

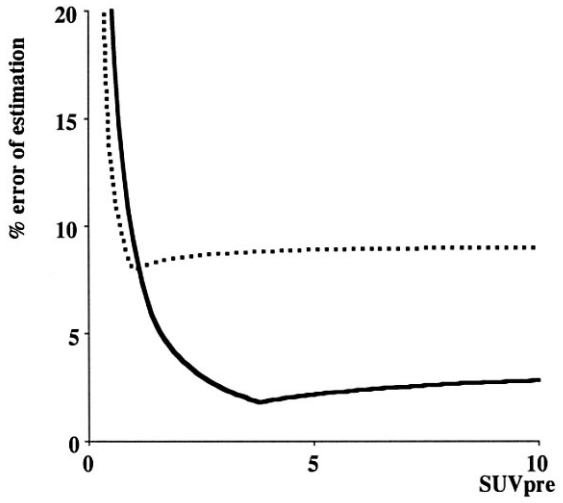

Fig. 3 The averaged simulation curves of the % error of estimation in misregistration (–) (*solid line*) and misregistraion (+) (*dotted line*) group.

Table 1 % error of estimation in each patient

	% error of estimation		
	SUV = 1	SUV = 3.8	SUV = 10
Misregistration (–)	11.8	3.0	1.1
	32.6	0.04	7.2
	3.1	4.5	6.2
	9.1	1.8	3.1
	0.6	0.5	0.5
	5.4	2.4	1.7
	3.2	0.4	0.2
Average	9.4	1.8	2.8
SD	12.0	1.8	3.1
Misregistration (+)	3.7	6.4	7.0
	21.1	12.6	11.0
	0.9	7.4	9.0
Average	7.9	8.8	9.0
SD	10.7	3.4	2.0

The averaged simulation curves in both the misregistration (–) group and misregistration (+) group are shown in Figure 3. In the misregistration (–) group, the averaged percent error was 9.4 ± 12.0% (mean ± SD) in a low SUV area (SUV = 1), 2.8 ± 3.1% in a high SUV area (SUV = 10). The least percent error was 1.8 ± 1.8% (SUV = 3.8). In the misregistration (+) group, the averaged percent error was 7.9 ± 10.7% in a low SUV area, 9.0 ± 2.0% in a high SUV area. The percent error was 8.8 ± 3.4% when the SUV was 3.8.

DISCUSSION

In this study, we found that the quantitative accuracy was preserved when postinjection transmisson data were applied for the reconstruction of emission data in misregistration (–) group. The problem of misregistration between the transmission and emission data is a serious one, especially in a FDG PET study. If only FDG static images are required, patients do not need to stay on the bed after the transmission scan is completed. When the patient leaves the bed, misregistration can occur easily. McCord et al. reported[5] that a 2-cm shift between the attenuation and emission scans produced an up to 30% change in regional activity in a myocardial FDG PET study. Therefore, accurate coregistration between transmission and emission is essential. In this study, the % error of estimation in misregistration (+) group was larger than that in the misregistration (–) group.

Postinjection transmission scan is a useful procedure

for minimizing the misregistration between transmisson and emission. The theory of postinjection transmisson scan has been described in detail by Carson et al. and other investigators.[4,6–8] Postinjection transmission data contain radioactivities from both the external source and injected tracer. Under the assumption that the distribution of the tracer does not change during the postinjection transmission scan, the fraction of the tracer will be successfully subtracted and a continuous emission scan and postinjection transmission scan will minimize the misregistration. In a clinical study, Hooper et al.[1] reported accurate cerebral glucose metabolism with postinjection transmission scan. However, it is easy to fix the position for the brain, and excellent coregistration software like statistical parametric mapping (SPM) may be available. In contrast, appropriate software has not been distributed for truncal PET studies, although Bettinardi et al.[9] developed a procedure for compensation of misalignment. Recently, CT/PET was used for image fusion, and attenuation correction was performed with CT data, but the bed had to be moved and misregistration may have occurred. Moreover, CT/PET is not available in our country. Based on these circumstances, postinjection transmission scan is a very favorable approach.

In this study, a relatively higher percent error of estimation was observed in low SUV areas. However, the difference of 10% in this area was small (i.e., the difference between 1.0 and 0.9 of the SUV). In the diagnosis of pulmonary malignancies, the cut-off level of the SUV is usually set from 2.5 to 3, and in this range, the percent error is less than 3%. Therefore, these percent errors seem to be acceptable in clinical situations.

As stated above, the postinjection transmission data contain radioactivities from the injected tracer. Therefore, the balance between the radioactivity from the tracer and external source has to be accounted for. Oda et al.[10] reported that high tracer and low external source radioactivities will increase the noise and diminish the quantitative accuracy. In our study, the radioactivities from an external source were markedly higher (868 ± 10 kcps) than those from the injected tracer (17 ± 4 kcps). Therefore, the subtraction of the tracer fraction was successfully performed, and SUV with postinjection transmission scan was accurately quantitated. In a situation in which there are low external source activities, further assessment will be needed.

CONCLUSION

In this study, the quantitative accuracy of SUV with postinjection transmission scan was certified in cases of no misregistration between the emission and transmission scan. Postinjection transmission scan was found to be useful for minimizing the misregistration, and can be used in a truncal FDG PET study.

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