Simultaneous Acquisition of Emission and Transmission Data in PET

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I. 9. Simultaneous Acquisition of Emission and Transmission Data in PET

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Introduction

The imaging error due to the mismatch between an emission data and an attenuation correction data obtained by transmission scan is one of the serious problems in the quantitative PET study. Simultaneous acquisition of emission and transmission (SET) data is employed to solve this problem[1-2], and it enables to reduce a study time. But this method has a problem that degrades signal to noise ratio (SNR) in emission images. This problem is caused by contamination of emission data by random and cross-talk events from a transmission source[2]. In this study, we examined the SNR of emission images in conventional scanning and also SET scanning and evaluated a suitable condition for SET scanning.

Material and Methods

All data were obtained by a SET-2400W PET system (Shimadzu Cop., Kyoto, Japan). SET was carried out by the scan mode of post-injection transmission (PIT) with a sinogram window technique where transmission window is defined with lines of response (LORs) containing a transmission source, and an emission window is defined with LORs except for transmission window. A border window should be provided between the transmission window and the emission window to omit their cross-talk. The fraction ratio of emission window in a whole sinogram is 83.8% at an average.

Experiment 1

We compared the SNR of emission image obtained by SET mode with that of normal emission (NE) image obtained by a usual mode. A 20 cm diameter cylindrical phantom was used in all scans. Dynamic NE scan and SET scan were carried out for 20 min comprising 20 frames, respectively. One frame was 1min duration scan. The emission activity varied from 9.6 to 1.1 KBq/mℓ at each dynamic scan. Two different transmission activities (117 and 85 MBq) were used for SET acquisitions. Adding 1 min scan data each other in dynamic scan data sets, we made up emission data for the scan time of 1, 2, 3, 5, 7, 10, 15 and 20 min. Attenuation correction data was made from the dynamic SET transmission data by the same manner in emission data processing. Emission data were corrected with transmission data and was reconstructed by the filtered back projection method. Coefficients of variation (COV) in PET images which is useful for an indicator of the image SNR were estimated from ROIs of diameter 16 cm on the central regions of 59 image planes.

Experiment 2

We evaluated the influence on SNR of the crosstalk and random events from transmission source at the SET scan mode. We carried out SET scans without transmission source and with emission activity (: SET(T-)) and with transmission source and without emission activity (:SET(E-)) as same as in the experiment 1. By combining the emission data of SET(T-) with the emission data of SET(E-), scan data for 5, 10 and 20 min were obtained with the same process as in the experiment 1. Attenuation correction of these data set were done with the transmission data obtained at the experiment 1, and COV values were obtained by the same manner as in experiment 1.

Results and Discussion

Figure 1 shows COV as a function of the scan duration and COV for SET and NE emission images at the phantom activity of 3.7 KBq/mℓ. COV is proportional to the inverse of the square root in scan duration. COV of SET is higher than COV of NE at the same scan duration. The ratios of COV of SET to that of NE were 1.46 at the 117MBq transmission activity and 1.13 at the 85MBq. Consequently, SET scan duration should be 2.1 times longer than NE in the case of 117 MBq and also it is 1.7 times for 85 MBq. This reduction on SNR is due to a decrease in effective emission scan duration, crosstalk and random events from transmission source. The crosstalk and random events depend on the strength of transmission source. Therefore transmission source strength is required to be kept in proper range. When 10 minutes is adopted as maximum scan duration per position, normal transmission scan duration becomes about 7 min at 117 MBq source[3], and so emission duration become 3 min. ET is useful in this case, since 10 min SET scan is longer than twice of 3 min and the transmission data is more reliable than 7 min scan. But SET SNR would become worse than separate scan when transmission activity stronger than 180MBq, since emission duration become over 5.min. Conversely, when transmission activity weaker than 83 MBq, transmission scan needs over 10 min by itself then scan is absurd.

COV values of SET(T-) and SET(T-)+SET(E-) obtained in experiment 2 are shown in table-1. Contribution fraction of the SNR reduction by the crosstalk and random events were derived from table-1 and are shown in table 2. Fraction of window, crosstalk and random were 11, 25 and 64% respectively at 10 min SET scan. This result means that major source of the reduction of SNR is random events obviously. Since random events are proportional to the square in count rate, it is supposed that the reduction by random becomes a main contribution at a stronger transmission source.

Conclusion

In this study, we showed clearly that random event from transmission source is major source of the reduction of SNR in the SET emission image.

We concluded that the following manners make SET scan be useful.

1) Transmission source activity should be from 83 to 180 MBq at SET-2400W.*
2) When transmission source activity is over 180 MBq, carry out a short transmission scan with SET and add its emission data to normal emission scan data*.

3) Use a short rod source method proposed by M. Dahibom et al.[4] .

(* When scan duration will be 10 min per position.)

References

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Table 1. COV values of emission image were obtained for different scan conditions and different scan duration with 117 MBq transmission source. Values of SET(T-) reflect the influence of emission window on a NE image. Value of SET(T-) + SET(E-) was added the influence of crosstalk of transmission events to SET(T-), and Value of SET was added the influence of random events to SET(T-) + SET(E-).

Scan Duration / mode	COV (%)		
	5 min	10 min	20 min
CE	83	59	43
SET(T-)	87	62	45
SET(T-) + SET(E-)	96	69	50
SET	121	87	62

Table 2. Contribution fraction was derived from the COV values in Table 1. The value is a fraction of each noise sources in total noise caused by SET on emission image.

Scan Duration / mode	Relative Reduction Ratio (%)		
	5 min	10 min	20 min
Emission Wind	10	11	11
Crosstalk Event	24	25	26
Random Event	66	64	63

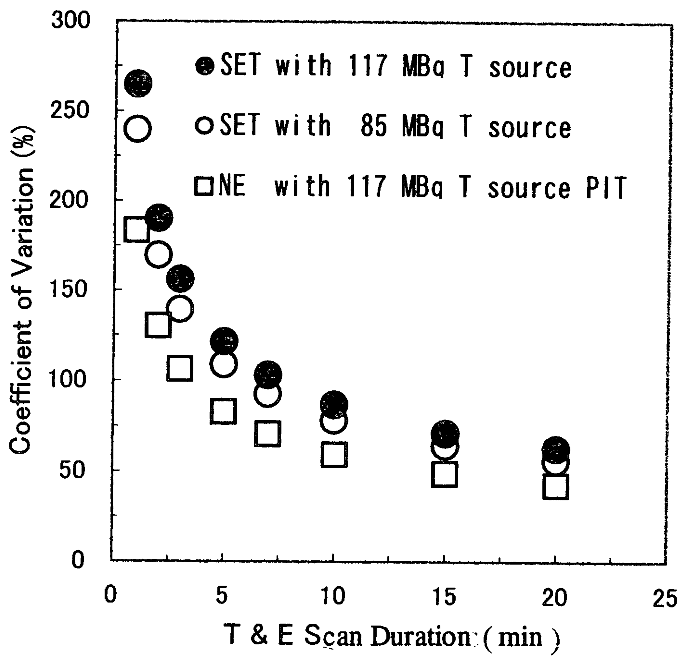

Fig. 1. COV values of emission image (3.7 KBq/mℓ) as a function of scan duration for the normal emission scan (NE) with PIT and for simultaneous emission/transmission scans (SET) with different transmission source activities of 117 and 85 KBq.