Further Evaluations of ECAT II

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Positron computed tomograph (PCT) is one of main tools for the cyclotron nuclear medicine. Its fundamental characteristics are already reported[1]. Because of limited performance of the PCT; e.g. resolution & sensitivity. Obtained data may not be free from serious artefacts. Therefore thorough performance cheque will benefit to evaluate clinical ECAT data. This paper is a more detailed report of ECAT performance. Thechniques for routine scanning are also proposed.

Scanner

A positron tomograph, ECAT II, EG & G Ortec U.S.A., used. It has 66 NaI detectors hexagonally arranged. The scanner is provided three types of collimator; high, medium, low resolution. Options of data sampling are also for high, medium, low resolution and rapid scan mode. Each mode except rapid scan has two different data sampling area for head or body. Several reconstruction filters are available; high, medium, low resolution, or user defined. Correction for tissue attenuation of annihilation photons are performed either by actual measuring of the attenuation using an external positron ring source or by calculation simulating an object as a ellips.

Methods and Results

(1) Linearity

A cylinder phantom of 20 cm bore filled with 11-C solution is scanned. The relation of isotope concentration in decay and total coincidence (CPM) are shown in Fig. 1. The response is sufficiently linear up to 2.5 μCi/ml. Two cm bar phantoms containing different concentration of isotope are set in a cylinder. This is a simulation to check detectability of a small lesion surrounded by low radioactive background. Good linear response is seen in higher concentration up to 9 μCi/ml, but the count is less reliable in the concentration lower than the surrounding (Fig. 2).

(2) Data size and S/N

Amount of collected data effects on the S/N of images. A cylindrical phantom of 20 cm bore is scanned for various time and count homogenuity is related to total counts. Standard deviation (SD) of image becomes larger when total counts per plane is less than 750,000 but is constant above the level (Fig. 3).

(3) Effect of transmission data smoothing

Cylinder phantom of 20 cm bore is filled with 68-Ga solution and scanned. Figure 4 shows the emission images with smoothing of the transmission data. The phantom contains a teflon ring inside, which is visible most clearly in the image corrected for attenuation by ellips simulation method but hardly recognizable in the image with measured attenuation without any smoothing. Smoothing of transmission data apparently improves quality of emission data. The effect of transmission smoothing is expressed as decrease of standard deviation in Fig. 5.

(4) Effects of collimation, data sampling and filter function

Sensitivity and resolution for each scanning mode is shown in Table 1 and Fig. 6. Though there is not much difference both in resolution and sensitivity as expressed count/cm^2 between high and medium resolution mode, image quality is better in the latter mode as count/pixel is a half in the former. Count plot of the same scan data with changing convolution filter is shown in Fig. 7. FWHM changes slightly according to the filter used, but the difference of count recovery between the data is remarkable.

(5) Partial volume

The effects of thickness of a lesion on count is tested by scanning rectangular sources. Full recovery of peak count is seen if the thickness is more than 2 cm. The count of 1 cm thick source goes down to 55 % of others. The count rate of cubic sources are also examined (Fig. 9). Full recovery of the count is unlikely in the source smaller than 4 cm cube. The count of 1 cm cube is only 14 % of 8 cm cube.

Discussion

Physical characteristics of positron tomography are ability to get transaxial images with high S/N using electronic coincidence collimation and accurate correction for tissue photon attenuation. These features are essential for quantitative evaluation of isotope concentration in the body. Performance of ECAT is good enough in the sence of image homogenuity, both of count and resolution[1]. But present study has picked up some problems that needed to be in mind when applying ECAT for clinical examinations.

(1) Count linearity

ECAT responds linearly to the count up to 2.5 μCi/ml for 20 cm bore phantom. Consider injection of 10 mCi of 18-FDG into a person and 1/5 of activity accumulates in the brain. As brain volume is about 1,600 ml, activity of 0.9 μCi/ml may exist in the brain at the time of the scan, usually 45 min after injection. Then linear response up to 2.5 μCi/ml may be sufficient for the scan. But if one intend rapid follow up of clearance of activity and introduce higher dosage to a subject, saturation of count in detectors may become a problem.

The count in cold lesions is contaminated with surrounding higher activity (Fig. 2). Then much care is needed to evaluate less radioactive area.

(2) Image quality

Amount of gathed data is far less in positron CT than in X-ray CT. Then in order to get reliable images with less count fluctation, as much as data should be gathered. As PCT uses transmission data for attenuation correction, the quality of transmission data affects emission images. Smoothing of transmission data may be useful to improve the detectability in emission images.

(3) Partial volume effect

The effects is one of most serious problems in positron tomography. Experiment of band phantom shows thickness of 2 cm is necessary for 100 % count recovery. ECAT may be used mainly on the brain and main concern may be activity of cerebral cortex. Then the thinkness of cortex must be considered to assess cerebral PCT count.

(4) Scanning technique

High resolution technique using high resolution collimator and data sampling looses sensitivity. As the gain in resolution is not much, the technique does not seem so useful for routine examination. Therefore medium resolution technique may be better. As for reconstruction filter function, high resolution filter may be superior to others not loosing count in hot foci.

Becuase count recovery is much influenced by scanning thechnique and convolution filter, great care is needed to use the same scanning technique in order to compare data between patients.

Reference

1) Ito M., Matsuzawa T., Yoshioka S., et al. CYRIC Annual Report (1981) 237.

Table 1. Effect of reconstruction filter on ECAT count.
Medium resolution collimator used.

Data sampling	Filter	Relative count*/cm^2
high resolution body	high resolution	.69
	medium resol.	.51
high resolution head	high resol.	1.34
	medium resol.	.99
medium resol. body	high resol.	.66
	medium resol.	.50
medium resol. head	high resol.	1.28
	medium resol.	1.00

* Measured at center of the field of view using 15 cm phantom.

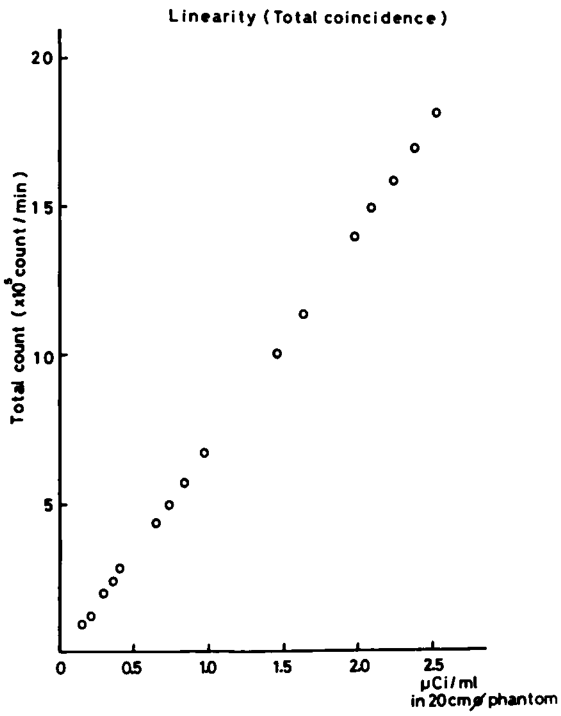

Fig. 1. Count linearity. Isotope distributes throughout a phantom of 20 cm bore.

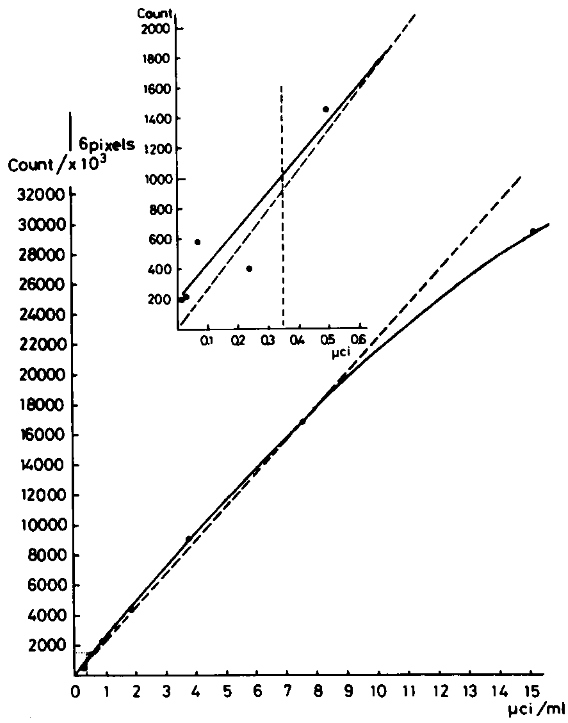

Fig. 2. Count linearity for 2 cm bar source in back-ground of low activity, 0.35 μCi/ml.

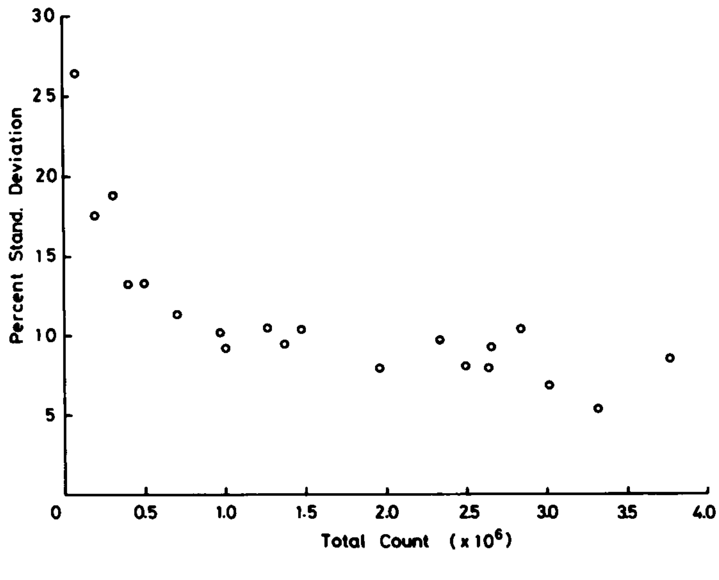

Fig. 3. Effect of total count per scan on image homogenuity.

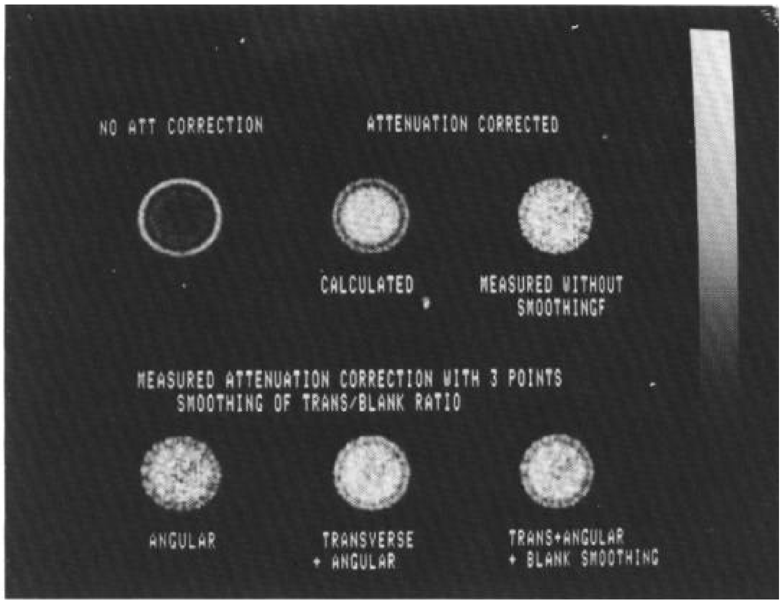

Fig. 4. Effect of smoothing of a transmission scan on an emission image. Top left: without attenuation (ATT) correction, top middle: calculated ATT correction, top right: measured ATT correction with no smoothing, bottom left: 3 pixel smoothing among angular data array of transmission data, bottom middle: 3 x 3 pixel smoothing among angular & linear data array, bottom right: same as bottom middle with 3 point smoothing for blank air scan.

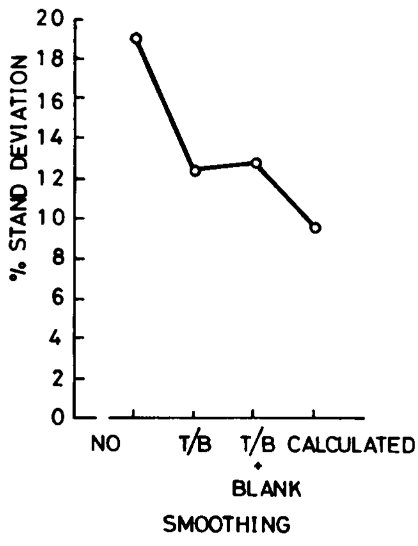

Fig. 5. Smoothing of a transmission scan and count variation.

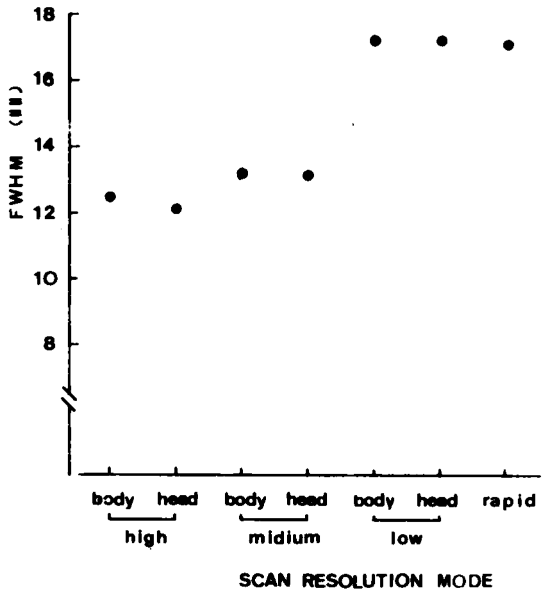

Fig. 6. Data collecting mode and resolution (FWHM).

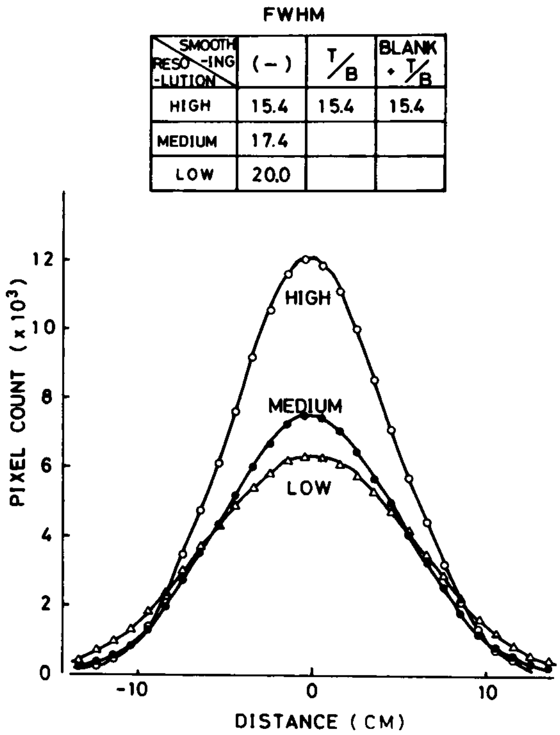

Fig. 7. Effects of reconstruction filter on the count recovery.

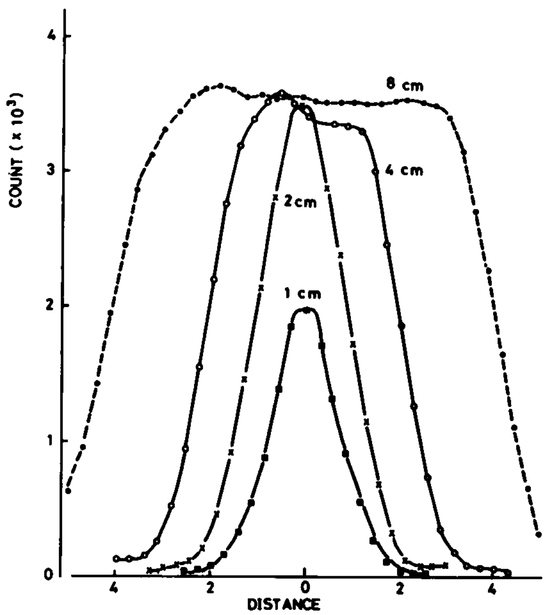

Fig. 8. Partial volume effect. Band phantoms used.

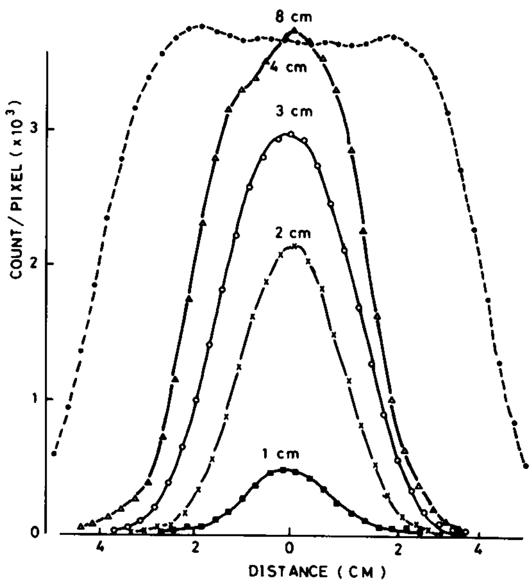

Fig. 9. Partial volume effect. Cubic phantoms used.