A Positron Emission Computed Tomograph : "POSITOLOGICA"[†]

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Received May 7, 1980

Key Words: emission computed tomography, positron imaging, bismuth germanate

A new positron emission computed tomograph, "POSITOLOGICA", has been developed. The device was designed aiming at human brain study using cyclotron-produced positron emitters such as ^{11}C , ^{13}N , ^{15}O and ^{18}F . It has a field of view of 24 cm in diameter with a variable slice thickness of 1-2 cm. A new rotational scanning is adopted for data sampling to achieve a high spatial resolution with a good counting statistics¹⁾. This paper presents the design criteria, initial performances and preliminary results of clinical tests.

1. Detector assembly and scanning for sampling

The device has a rotary detector assembly which consists of 64 scintillation detector units arranged on a circular ring (44 cm ϕ) with special non-uniform spacings. Each detector unit consists of a 12 $\times$ 20 $\times$ 26 mm BGO (bismuth

germanate) crystal coupled to a 29 mm ϕ photomultiplier tube. The detector arrangement was determined by a computer iteration method²⁾ so that the sampling density in projections is as uniform as possible over a region of interest when projection data are binned in every 2mm width. As a result, a fairly uniform sampling density was obtained even with the narrow bin width: the number of coincidence pairs per projection bin is 11.9 on average, with a minimum of 11, in a region of 23 cm. Another advantage resulting from the rotation scanning is that the reconstructed images are fairly insensitive to artifacts caused by instability or misadjustment of detector gain, since each data point of a projection consists of the contributions of at least 11 detector pairs. The detector assembly is rotated at about 60 rpm.

2. Electronics

Simple leading-edge type timing discriminators are designed and adopted for the BGO detectors. Best time resolution has been obtained with detection of the first arrival photoelectron. A preliminary experiment has shown that the time resolution for a BGO-BGO pair is about 5.2 ns in FWHM and 11.3 ns in FWTM. The coincidence time window of the device is

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set at 20 ns.

The timing signals from the 64 detectors are divided into 8 groups, and group coincidences (20 pairs in total) are recorded. Address signals of detector pairs for coincidence events are converted into a 12-bit binary format. For dynamic subtraction of accidental coincidences, both prompt and delayed coincidences are detected, and the counts in the latter are subtracted from those in the former during or after the data accumulation. The address signals and event flags are transmitted from the rotary gantry to a computer interface through a parallel 16-bit rotary photo-coupler. The photo-coupler consists of a rotary circular array of 16 light-emitting diodes optically coupled to a stationary circular array of 32 photo-sensitive diodes and electronics for angular shift correction. A mini-computer, Interdata 8/32, is used for data acquisition and image reconstruction.

3. Corrections of projection data and image reconstruction

A rotary positron source assembly containing several small ^{68}Ge - ^{68}Ga sources is equipped for body attenuation correction and detector calibration. The source assembly is remotely controlled to rotate around a patient at a speed geared down to 7/64 detector gantry rotations,

so that a multiple of 64 revolutions of the gantry provides an apparent uniform ring source.

The coincidence address data are finally arranged into 128 parallel projections, each consisting of 128 data points. After correcting the projections for accidental coincidences, sampling densities, detector sensitivities and body attenuation, a section image is reconstructed by a convolution algorithm using the Shepp and Logan filter function³⁾.

4. Results

A preliminary test shows that the sensitivity is about $0.46 \text{ cps} \cdot \text{Bq}^{-1} \cdot \text{mL}^{-1}$ ($17 \text{ kcps} \cdot \mu\text{Ci}^{-1} \cdot \text{mL}^{-1}$) for a 20 cm diameter water phantom with a 2 cm slice. The spatial resolution is about 6 mm FWHM at the center of the field of view and less than 8.5 mm FWHM in a circle 16 cm in diameter. Figure 1 shows images of a normal subject. The ^{11}CO image shows blood volume distribution, while the $^{13}\text{NH}_3$ image indicates blood perfusion in the brain. From these results, it is concluded that this device demonstrates excellent imaging performance for positron emitting isotope distribution in the human brain.

This work was supported in part by a Grant-in-Aid for Cancer Research from the Ministry of Health and Welfare.

Fig. 1 Preliminary images obtained with a normal subject (OM+4cm plane).

- (A) ^{11}CO administered by inhalation
- (B) $^{13}\text{NH}_3$ administered by intravenous injection

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