30 Years Ago: First PET Scanner in Canada

Submitted by Chris Thompson
Montreal Neurological Institute,
Montreal, QC

In April 1975 Ernst Meyer, (the late) Lucas Yamamoto, and I drove to the Brookhaven National Laboratory on Long Island and returned with the first instrument for positron emission tomography (PET) in Canada. Thirty years ago, "PET" was a domestic animal, not a medical imaging technique. To many or you reading this today, PET, and better still PET/CT, is something that your department "has" or "wants" to improve the work-up and radio-therapy treatment planning of cancer patients. This is a relatively recent phenomenon, and even though PET has been around for over 30 years, it had very little impact on the lives of most Medical Physicists until 10 years ago with the advent of whole-body PET scanning with the glucose analog commonly known as FDG.

Soon after the Montreal Neurological Institute (MNI) acquired the first CT scanner in 1973, interest in other tomographic imaging modalities was initiated. Lucas Yamamoto had worked at the Brookhaven National Lab. (BNL) of the US Department of Energy for several years before coming to the MNI. He often talked about a device, that he had worked on while at BNL known as the "head shrinker", that was now unused. He was convinced that if it was in Montreal it would work, even though it had never performed satisfactorily in Brookhaven. He, and the director of the MNI, Dr William Feindel, had perfected two techniques for investigating regional cerebral blood flow (rCBF)in the exposed brain, both in animal experiments and during human surgery for arterial-venous malformations and certain highly vascular brain tumours. They saw this instrument as being able to measure rCBF non invasively. One of these techniques involved applying small silicon diode radiation detectors and administrating Xe-133 and measuring the "washout" of this inert gas in the exposed brain. The other involved injecting fluoresceine dye into the blood and taking rapid sequences of photographs to study the passage of the dye through the blood vessels and the exposed cortex. The positron emitting isotope Kr-77, could perform the same function as the Xe-133 and the generator produced Ga-68 EDTA could measure the blood transit time and breakdown of the blood-brain barrier. Since all of the studies involved using a computer, and I had been involved in getting them to work, I was expected to get the "head shrinker" to work as well!

There had been a few trips to Brookhaven to look at the instrument, and to negotiate the "loan" of it to the MNI. During these trips, I became familiar with the detectors, amplifiers and circuits which detected coincident gamma rays from positron annihilation, as well as the program which was supposed to reconstruct the images. I was quite familiar with the way the "EMI-scanner" reconstructed images, but had no idea how the algorithm used by the Brookhaven group worked [1]. I did know that it took a long time on the Lab's main-frame computer and I was expected to get it working on a PDP-12 with 16K of memory. (That's right 16,384 12-bit words!). One day we were in the small on-site hospital negotiating the transfer. During a break, I looked at a display of occupational therapy where patients had made patterns by stringing coloured yarn over arrays of nails. Many patterns were possible and some were very pretty. It occurred to me that these nails were like the ring detectors in the scanner, and the yarn between two nails represented the lines of response of the each pair of detectors. If they were organized in the correct way, they would look like the projections in a CT scanner. Instead of the attenuation along each line we would have the number of counts acquired during the time of a study. So perhaps the same algorithm used in CT scanners would work here.

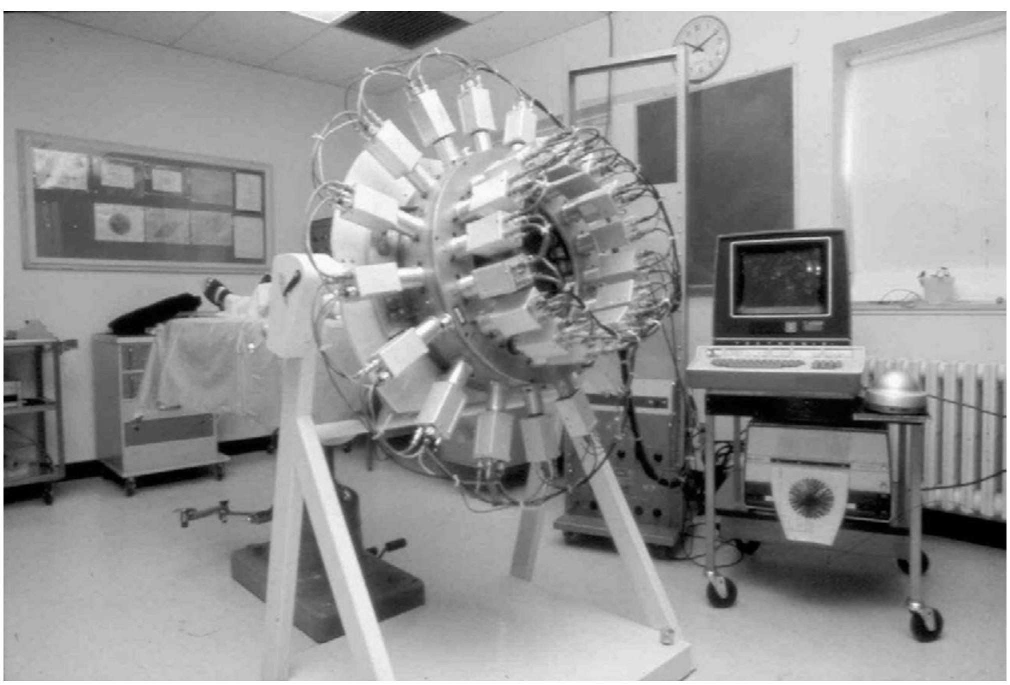

Figure 1: Original Positome configuration.

At Brookhaven, the original concept had the patient sitting in a chair and the detectors were arranged in a hemisphere and looked rather like a strange hair dryer. By the time I was involved with it, the detectors were arranged in a single ring. There were 32 1" diameter NaI crystals and PMTs, the even ones inserted radially and the odd ones axially. We decided that the patients would be scanned supine like in a CT scanner, and had a stand built for them. I did not think that patients would like being told that the device was called the "head shrinker" and decided that "Positome" would be a better name.

(Continued on page 49)

30 Years of PET in Canada…. (Continued from page 48)

The Positome was installed on the second floor of the MNI, as shown in Figure 1, and a cable was run up to the 7th floor where the computer was. The programs for acquisition of the scans, reconstruction, and display were initiated on a Tektronix graphics terminal. This had a storage screen (like a big storage oscilloscope screen) with both a character generator, and 1024 by 768 addressable points. The images were reconstructed using the Shepp and Logan algorithm, see figure 2, which was published in 1974 [2]. This simple technique was able to reconstruct 32 x 32 images in less than 30 seconds on a computer with a clock speed of 0.5 MHz. The Brookhaven algorithm (which involved inversion of the Radon transform) was run as a batch job on a main-frame computer and the images were not available until the next day.

This Positome was used for three years. One or two days a week we could get Kr-77 from the cyclotron in the Foster laboratory of the McGill Physics Department. The gas was trapped in a U-tube immersed in liquid nitrogen, then sealed. Ernst Meyer, who did all the data analysis for our studies then carried this tube in a lead pot about one block up University St from the Foster lab. to the MNI. (The half- life of Kr-77 is just over an hour, so he did not have to run!) On other days we used Ga-68 EDTA from a Ge-68/Ga-68 generator. The software allowed dynamic studies which were displayed on the terminal screen by intensifying a pseudo-random array of 7x7 sub-pixels which formed each of the 32x32 image pixels to simulate shades of grey in a similar fashion to a dot matrix printer. They were painted on the storage screen where they were stable for a few minutes or until erased. The display software allowed for multiple images to be displayed, regions of interest to be selected, and the display log-linear time-activity plots from which the washout or transit time was estimated from the down-slope of a fitted line.

One of the images included here is what Dr. Feindel believes to be the first image of a glioblastoma made with PET. This was made with Ga-68 EDTA after an initial dynamic study. The 68 minute half-life allowed "static" images through several slices through the brain.

The first paper we wrote about PET [3] was presented in August 1975 at a conference in Stanford Ca. At that time we had still not performed any patient studies. A more complete report on its performance and use in clinical studies appeared the following year[4].

In 1978 we made Positome II which was the first PET scanner to use bismuth germanate detectors. This new, high density, scintillator became the mainstay in PET for over 25 years.

1) Shepp L A, and Logan B F: The Fourier Reconstruction of a Head Section. IEEE Trans. Nucl. Sci. NS-11:21-38 (1974)

2) Marr RB, On the Reconstruction of a Function on a Circular Domain from a Sampling of its Line Integrals. J. Math. Anal. and App. 357-374 (1974)

3) Thompson C J, Yamamoto Y L and Meyer E: "Positron emission tomography: reconstruction of images from a multiple coincidence detector ring". Proc. Amer. Optical Soc Meeting on Image Processing for 2D and 3D Reconstruction from Projections. pp. TuA4-1 to TuA4-4, (Aug. 1975)

4) Thompson C J, Yamamoto Y L and Meyer E: "A positron imaging system for the measurement of regional cerebral blood flow." Proc. Soc. Photo Optic Instrument Engineers: 96: Optical Instrumentation in Medicine V, 263-268 (1976)

Figure 2: Shepp-Logan reconstruction code.

```
DO 20 J=1,N
THETAJ=(J-1)*PIN
COSTHTAJ=COS(THETAJ)
SINTHTAJ=SIN(THETAJ)
COSDELOA=COSTHTAJ*DELTA/A
READ(12) (PROJ(K),K=1,M)
*******************************
DO 30 KR=1,M
CONV(KR)=0
DO 40 K=1,M
KABS=IABS(KR-K)+1
CONV(KR)=CONV(KR)+PROJ(K)*PHI(KABS)
40 CONTINUE
30 CONTINUE
***********************
DO 51 IY=1,NY
Y1=-YPOS+2*YPOS*IY/NY
R=(-XPOS*COSTHTAJ+SINTHTAJ*Y1+1)/A
 -COSDELOA
DO 50 I=1,NX
R=R+COSDELOA
L=R
IF(L.LE.O.OR.L.GE.M) GO TO 50
Z(I,IY)=Z(I,IY)+(L+1-R)*CONV(L)+(R-L)
*CONV(L+1)
50 CONTINUE
51 CONTINUE
20 CONTINUE
```

Figure 3: Glioblastoma Ga-68 EDTA from 1975.