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Investigating the Optimum Lower Energy Threshold of a New Research PET/CT Scanner

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Abstract– **An investigation of the optimum 3D Lower Energy threshold (LET) setting of the Discovery-RX, a new LYSO based GE research PET/CT scanner is conducted. Methods: Sensitivity and noise equivalent count rate (NECR) performance of the scanner in 3D mode were evaluated at multiple LET settings: 400, 425, 450, 460, 470 and 480 KeV. The performance evaluations were conducted according to the NEMA NU2-2001 standard. In addition, the NECR was also evaluated for the same LET settings using the Data Spectrum whole body phantom in order to more accurately simulate a true clinical setting. For the sensitivity measurements, the line source was filled with 9.25 MBq of F-18. For the NECR measurements, the NEMA and the Data Spectrum phantoms were fitted with a line source having an initial activity of 1400 MBq of F-18. Results: As expected, the sensitivity decreases with increasing LET. The sensitivity at 400 and 450 keV was 13.2% higher and 18.9% lower than the sensitivity at the scanners default LET of 425keV. Also as expected, the scatter fraction (SF) decreased with increasing LET for both NECR phantoms. The NECR curve corresponding to the 450 keV had the highest values over the clinical range of activity concentration usually used. Conclusion: Initial performance evaluation suggests that a LET of 450 keV is the best setting for the phantoms tested. Further clinical tests are needed to validate this observation.**

I. Introduction

The Discovery-RX, a new GE research PET/CT scanner, is an LYSO based tomograph that is currently under development by GE health care. The scanner is very similar to the GE DISCOVERY ST except for the detector material and detector block design. The new PET detector array consists of 4 LYSO block rings each of which is composed of 70 detector blocks. Each detector block is arranged in an array of 6*9 detectors giving a total of 24 rings each of which has 630 detector elements. The size of each detector element is 6.2*4.2*30 mm in the axial, transaxial and radial direction respectively. The total number of detector in the system is 15120.

LYSO is a scintillation detector that has properties that are very suitable for coincidence gamma ray detection (Table 1).

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Table 1

μ @ 511	Photo fraction	Light out	Energy resolution	Decay constant
0.8/cm	~35%	78%	15%	40nsec

The relatively narrow energy resolution of this detector is of particular interest in 3D imaging since it allows increasing the lower energy threshold setting thus reducing scatter events and improving image quality. The manufacturers default setting of the LET for this scanner is 425 KeV. Kohlmyer at al (1) and Turkington et al. (2) have previously investigated the optimal LET setting on the BGO based GE ADVANCE and GE DISCOVERY ST scanner respectively. Their results showed that an LET of 425 keV had the best results for these systems. In this paper, we investigate the optimal setting of the lower energy threshold for the new GE LYSO research scanner with respect to its sensitivity and noise equivalent count rate (NECR) as evaluated by the NEMA 2001 standard (3).

II. Methods

Sensitivity and NECR were measured at multiple LET settings of 400, 425, 450, 460, 470 and 480 KeV using the NEMA standard and corresponding phantoms (figure 1). In addition, the NECR was also evaluated using the Data Spectrum whole body phantom in order to simulate a more accurate clinical setting. The Data spectrum phantom is a fillable whole body phantom with a 36 cm x 21 cm oval cross-section and a 80 cm length (figure 2). For the sensitivity measurements, the line source was filled with 9.25Mbq of F-18. For the NECR measurements, both phantoms were fitted with a 70 cm line source with an average initial activity of 1400MBq. A scan at each LET of the phantom setup without any activity present was also acquired in order to correct for the inherent radioactivity of 176-lutetium according to Watson et al. (4).

Figure 1: Setup for the NEMA 2001 sensitivity and count rate performance phantoms.

Figure 2: Setup for the Data Spectrum phantom for NECR measurement.

Data processing of the NECR measurement was performed by collapsing the 3D raw data using single slice rebinning into 2D sinograms. A mask was applied to the sinograms to retain only lines of response that are near the phantom. The mask was generated from CT images of the phantom after their conversion into sinogram format. Further analysis followed the NEMA standard except for the scatter fraction which was determined from singles based randoms corrected data.

III. RESULTS

Figure 3 shows a plot of the sensitivity values measured at R=0 versus LET. As expected, the results show that the sensitivity decreases as the LET increases.

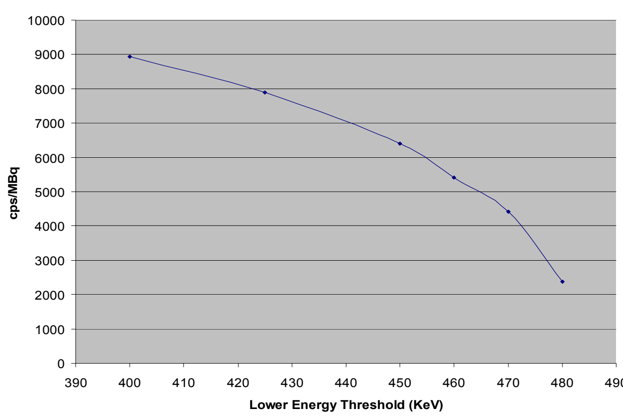

Figure3: NEMA 20001 sensitivity at R=0 versus LET

Table 2 shows the percent change in sensitivity versus LET setting. The comparison is based on the default LET setting of 425 KeV.

Table 2

LET (KeV)	% change in sensitivity relative to 425 KeV
400	13.2 %
425	0 %
450	-18.9 %
460	-31.4 %
470	-44.1 %
480	-69.9 %

Figure 4 shows a plot of the NECR with singles randoms subtraction of the data spectrum phantom versus LET. A plot of the NECR in 2D mode at 425 KeV is also shown for comparison. As expected, the results show that the peak NECR increases as the LET increases.

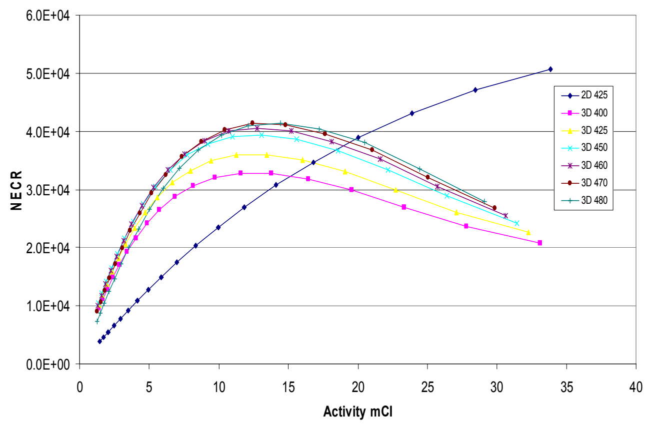

Figure 4: NECR of the Data spectrum phantom versus LET

Table 3 shows the percent change in peak NECR versus LET setting. The comparison is also based on the default setting of the 425 KeV.

Table 3

LET (KEV)	% change in peak NECR relative to 425 KeV
400	-8.6 5%
425	0 %
450	9.56 %
460	12.85 %
470	14.85 %
480	15.03 %

Figure 5 shows a plot of the scatter fraction in the data spectrum phantom versus LET. As expected also the scatter fraction decreases as the LET increases since more scattered gamma rays having lower energy will be rejected.

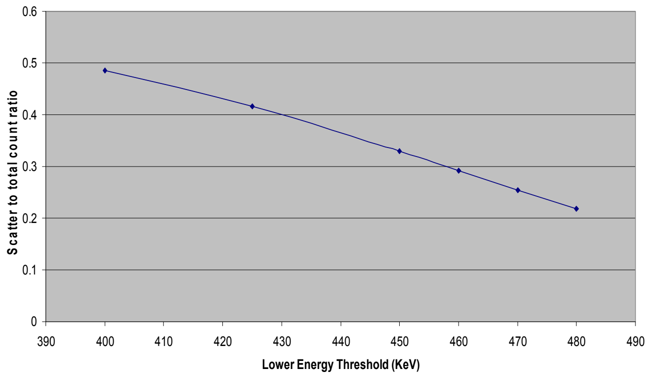

Figure5: Plot of scatter fraction versus LET

IV. Discussion and Conclusion

As expected, sensitivity and scatter fraction decreases as LET increases. Figure 3 also shows a trend whereby the rate of decrease in sensitivity increases at an LET above 450 KeV. This trend however is not evident in the scatter fraction plot of figure 5. Although a further increase in LET decreases the scatter fraction, such an increase also decreases the sensitivity of the scanner with an increasing rate.(figure 2).

The NECR is calculated using the form:

$$NECR = T^2 /(T + S + kR) \qquad (1)$$

Where T is the trues rate, S is the scatter count rate, R is the randoms count rate, and k is a constant whose value is dependent on whether randoms are calculated using delayed events subtraction or singles estimation. As expected, the peak of the NECR curves in figure 4 increase as the LET increases. However, the graph also shows that at any activity concentration, the NECR values at the rising edge of the curves initially increase with LET but eventually starts to decrease with increasing LET setting. For example, the graph shows that the NECR at an activity of 5 mCi initially increases at a LET of 400 KeV, reaches a maximum at a LET of 450 KeV and then starts to decrease at higher LETs. At 450 KeV the peak NECR is 9.56% higher than that at the default setting of 425 KeV, A further increase in LET increases the peak NECR eventually reaching a value at 580 KeV of 15.03% higher than the default setting. Table 3 clearly shows that although the peak NECR increases with higher LETs, the rate of this increase diminishes with increasing LET.

The combination of these plots suggests that an LET of 450 KeV is the best compromise between sensitivity and NECR, particularly over the activity concentration range normally found in clinical settings. Further testing with patient data is needed to validate this observation.

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References

[1] S.G. Kohlmyer, R.M. Miyoka, T.K. Lewellen, "Evaluation of low energy threshold setting for PVI PET systems". IEEE Trans. Nucl. Sci. vol45, no 6 pt.3 pp. 2141-2145, Dec. 1999.

[2] T.G. Turkington, J.W. Wilson, J.G. Colsher. "Adjusting the low energy threshold for large bodies in PET", conference record of the 2004 IEEE Nuclear Science Symposium and Medical Imaging Conference 2004. p.159.

[3] M.E. Daube-Witherspoon, J.S. Karp, M.E. Casey, J. Fernando, H. Hines, G. Muehllehner, V. Simcic, C. Sterans, P. Vernon, L. Adams, S. Kohlmyer, V. Sossi, "PET performance measurements using the NU2 -2001 standard," J. Nucl Med, Vol 43, num 10, pp 1398-1409, 2002.

[4] C.C. Watson, M.E. Casey, L. Erikson. "NEMA NU-2 performance test for scanners with intrinsic radioactivity." J. Nucl Med, vol 45: pp. 822-825, 2004.