Effects of Lu-176 Background Radiation on Singles Transmission for LSO-based PET Cameras

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We explore how beta decay background from naturally occurring Lu-176 affects single photon transmission imaging for Lutetium Orthosilicate (LSO) scintillator-based PET cameras by estimating the transmission noise equivalent count rate (NECR) including this background. The transmission, scatter, and background event rates depend linearly with the front surface area of the detector module, so the background fraction is independent of module size. For simplicity, we quote rates for a "standard" PET camera with each detector module utilizing 2 in x 2 in x 30 mm LSO scintillator. We assume single photon transmission measurements using an uncollimated 4 mCi (ECAT EXACT HR^{++}) or 20 mCi Cs-137 point source that is 70 cm from the "far" detector.

We measure a natural background activity of 241 cps/cc, of which 82 cps/cc is within the Cs-137 photopeak window. This implies a 6 kcps Lu-176 background rate for the standard detector module; a rate large compared to a typical chest or abdominal transmission rate of 0.7 and 3 kcps/module for a 4 and 20 mCi source respectively, but not significant compared to a blank rate of 50 and 249 kcps/module for a 4 and 20 mCi source respectively. Even after background subtraction, statistical error from the Lu-176 radiation lowers the NECR. The NECR for singles transmission equals $Tr^2L/(Tr+S+LSO)$ where Tr, S and LSO are the transmission, scatter and Lu-176 rates respectively and L is the system livetime. Others have shown the transmission scatter fraction to be 21% for a water-filled 20 cm diameter cylindrical phantom for 3D PET without septa and 6% for 2D PET. Using these scatter fractions, we predict that the Lu-176 background reduces transmission NECR by 88% and 59% using a 4 and 20 mCi source respectively for a standard 3D PET camera without septa (90% and 63% for 2D). The NECR for blank scans decreases by only 11% and 2% using a 4 and 20 mCi source respectively for both 2D and 3D PET.

Thus, the Lu-176 background has little effect on the blank scan but has a large effect on the singles transmission scan. Even with a 20 mCi source, the transmission scan time must increase 60% to maintain the same level of signal-to-noise ratio obtained with a background-free scintillator.