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GATE Monte Carlo Simulation for FDG-18 Image Quality Evaluation of the Siemens Biograph mCT 64S – 3R PET-CT scanner at ORCI

Image quality in Fluoro-2-deoxyglucose-18 (FDG-18) positron emission tomography–computed tomography (PET-CT) is a critical determinant of diagnostic accuracy, as lesion detectability and quantitative reliability depend directly on image contrast and noise characteristics. In FDG-18 PET-CT imaging, administered radiotracer activity governs photon statistics, thereby influencing key image quality metrics including contrast-to-noise ratio (CNR), contrast recovery coefficient (CRC), and background variability (BV). Since the relationship between FDG-18 activity and image quality is non-linear and constrained by competing physical and clinical factors. Therefore, studying the influence of FDG-18 activity is essential to achieving high-quality images while maintaining clinical feasibility at the Ocean Road Cancer Institute (ORCI).

This study evaluated the influence of FDG-18 activity on PET-CT image quality using the Geant4 Application for Tomographic Emission (GATE) Monte Carlo simulation framework and a NEMA image quality phantom. FDG-18 activity was varied from 4.0 to 5.0 MBq/kg, and image quality was quantified using CNR, CRC, and BV. Results demonstrated that increasing FDG-18 activity from 4.0 to 5.0 MBq/kg improved CNR by approximately 18–25%, with small lesion CNR increasing from 4.2 to 5.3, exceeding the Rose criterion threshold of 5 required for reliable lesion detectability. CRC improved by 10–15% for lesions ≤17 mm, indicating enhanced recovery of true FDG-18 uptake, particularly in small structures affected by partial volume effects. Concurrently, BV decreased from 12% to 8%, reflecting improved image uniformity and reduced noise.

An optimal FDG-18 activity of approximately 5.0 MBq/kg was identified, where CNR ≥5, CRC was maximized, and BV minimized. Thus, this study establishes a quantitative framework for establishing FDG-18 PET-CT image quality protocols at ORCI, supporting improved diagnostic reliability in Tanzania.

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