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Validation of the GAMOS Monte-Carlo Toolkit for Nuclear Medicine Dosimetry

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Purpose: Monte-Carlo simulations (MCS) are frequently used in tasks of Nuclear Medicine dosimetry, e.g. for calculating dose-kernels for voxel based dosimetry of Y-90 and Lu-177 therapies. A large variety of MCS are available. The GAMOS MCS framework is based on GEANT4 routines and aims at simplified usability. Consequently, the different physics modules known from GEANT4 are also available in GAMOS. So far, the accuracy of GAMOS has only been shown for external beam radiation and brachytherapy settings. The aims of this study were 1) to evaluate the accuracy of GAMOS for application in voxel based dosimetry of Nuclear Medicine therapies using Lu-177 and Y-90 and 2) to compare the dose values obtained from standard electromagnetic (EM) and Penelope physics modules. **Methods:** Using GAMOS, the voxel-wise deposited energy dose from radiation sources was simulated. Sources were mono-energetic electrons (range 10-2100 keV) and mono-energetic photons (set of energies for most common Lu-177 and Y-90 gamma transitions). Additionally, the decays of radionuclides Lu-177 and Y-90 were directly simulated. Absorbing tissue types included soft tissue and compact bone. The obtained data were compared to reference values from literature, obtained by other MC-codes. Additionally, the dose values obtained from EM and Penelope physics modules were compared. **Results:** Differences between GAMOS and reference data were: 1a) Photons: <5% for central voxel and energies below 1 MeV. For high photon energies and non-central voxels, larger differences of up to 20% were found. 1b) Electrons: <1% for central voxel and energies up to 2.1 MeV. For non-central voxels, larger differences of up to 5% were found. 1c) Lu-177: ~3.2% for central voxel for soft and bone tissue. For non-central voxels slightly higher, with on average 4.0% and 3.7% for soft and bone tissue, respectively. 1d) Y-90: ~0.4% for central voxel for soft and bone tissues. For non-central voxels higher, with on average 3.5% and 2.2% differences for soft and bone tissue, respectively. 2) Physics modules: Only minor differences (<1%) were found for central voxels and Lu-177 and Y-90. Larger differences (up to 10%) occurred for Y-90 for distances which correspond to the bremsstrahlung region. **Conclusion:** Energy dose values obtained from GAMOS show good agreement with those available from literature. For this, GAMOS is suitable for application in Nuclear Medicine therapies with Lu-177 and Y-90. Between standard EM and Penelope physics modules, only minor differences were found.

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Partial volume correction changes intra-tumoral heterogeneity in 18F-FDG PET

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Aim: PET images suffers from the partial volume effect (PVE), a consequence of the limited spatial resolution and the tissue fraction effect. Several partial volume correction (PVC) methods have been developed to enable appropriate quantification for PET images. In the present study, we investigated impact on intra-tumoral heterogeneity by PVC methods as applied to 18F-FDG PET. **Material and Methods:** Thirty-seven lesions from twenty patients were included in the current study. 3D tumor segmentation was performed on CT images, and following tumor delineation, three methods of PVC including Richardson-Lucy (RL), Reblurred Van Cittert (RVC) and Single Target Correction (STC) were used to compensate for PVE. Intra-tumoral heterogeneity was assessed by 31 textural features including gray level co-occurrence matrices (GLCM), gray level run length matrices (GLRLM), gray-level zone length matrix (GLZLM) and neighboring gray-level dependence matrix (NGLDM). Subsequently, we determined the Relative Change (RC %) with respect to uncorrected PET image. **Result:** 46, 75 and 39% of textural features had RC more than 10% for RL, STC and RVC respectively. Homogeneity (RC: 11-43%), Contrast (RC: 12-53%) and Correlation from GLCM (RC: 12-43%), LGRE (RC: 56-84%), LRLGE (RC: 46-86%) from GLRLM, Busyness (RC: 85-211%) from NGLDM, LGZE (RC: 52-82%), SZLGE (RC: 48-79%), LZHGE (RC: 13-173%) from GLZLM exhibited the greatest RC between textural features. **Conclusion:** Our results demonstrated that PVC methods substantially altered intra-tumoral heterogeneity. This change must be considered in quantitative analysis of PET images particularly in radiomics and radio-genomics applications.

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Relationship between intra-tumoral heterogeneity indices and metabolic parameters in 18F-FDG PET

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