INTEGRATION OF GATE MONTE CARLO-BASED RADIONUCLIDE DOSIMETRY AS A PRACTICAL ON-LINE CLINICAL TOOL

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Introduction: We present a general-purpose python program to perform patient-specific radionuclide dosimetry with GATE based on image-based measures of tracer distribution and CT structural volumes. This provides a single user interface to handle image conversion, generation of GATE macro files, and export of dose volumes in PACS-compliant DICOM format.

Materials and Methods: Cumulated activity maps are derived from serial quantitative SPECT images using a previously described methodology [1]. GATE source array described using cumulated activity data and Geant Radioactive Decay process. Patient CT data were converted physical volume using Schneider density and material tables [2]. Monte Carlo dose volume were compared with those derived by traditional voxel dose kernel methods in a series of ten clinical Lu-177 PSMA cases. Further validation is provided by replicating OLINDA sphere geometry and comparing energy deposition with standard sphere masses.

Results: With respect to soft-tissue features, both methods show agreement within 10%. In sphere simulations, energy deposition is within 5% for common diagnostic and therapeutic isotopes. We allow clinical simulations to run for approximately 10 hours achieving visually acceptable noise with a single-threaded instance on a desktop PC. Output dose images are integrated into the hospital PACS system with a unique instance UID and series description. While resampled to 3mm cubic geometry, care is taken to retaining fusion to the original CT volume and images can be viewed and contoured by clinical staff on normal viewing workstations as shown in Figure 1.

Conclusion: Though computationally intensive, Monte Carlo radiation transport presents a number of advantages by accounting for tissue heterogeneity—particularly in osseous metastases—and appropriately tracking particles that have ranges over several centimetres. As voxel-based radionuclide dosimetry techniques become standardised over previous whole-organ methods, we propose that GATE provides a robust backend to simulate radiation transport.

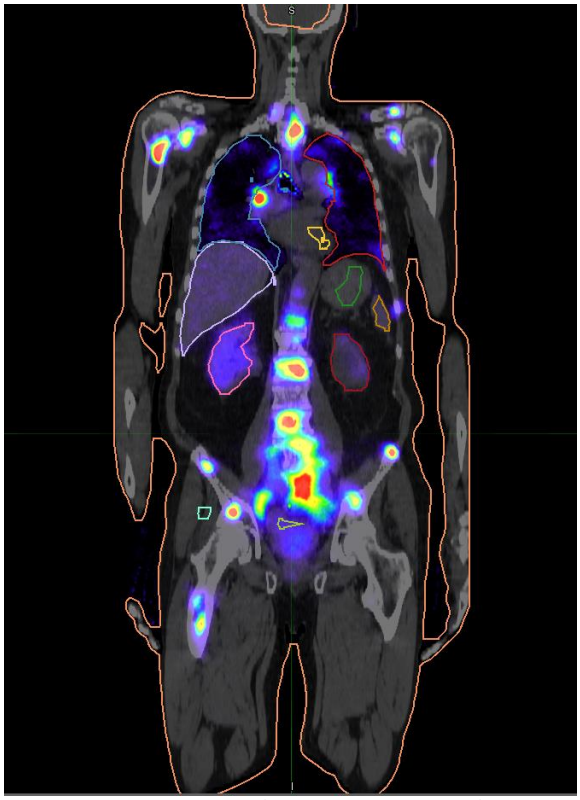

Figure 1. Coronal view of 3D dose image derived from multiple post-treatment SPECT/CTs. Voxel intensity in units of Gray; shown overlaid with corresponding CT image

References:

1. Jackson, Price A., et al. "An automated voxelized dosimetry tool for radionuclide therapy based on serial quantitative SPECT/CT imaging." Medical physics 40.11 (2013).
2. Schneider, Wilfried, Thomas Bortfeld, and Wolfgang Schlegel. "Correlation between CT numbers and tissue parameters needed for Monte Carlo simulations of clinical dose distributions." Physics in medicine and biology 45.2 (2000): 459.