Specific Absorbed Fractions and Radionuclide S Values for Human Spleen Microstructure for Radiopharmaceutical Dosimetry

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Introduction

As the largest secondary lymphoid organ, the spleen contains a major portion of the body's lymphocytes and plays a critical role in adaptive immune responses. Hemotoxicity resulting from radiopharmaceutical therapy is in part contributed to by radiation exposure to the spleen. Although the Mesh-Type Reference Computational Phantoms (MRCPs) provided by the International Commission on Radiological Protection (ICRP) define the spleen, it is homogenized and does not describe the present microscale tissues.

Materials and Methods

All structures and material compositions were initially created in the context of the adult female MRCP. Mesh surface data for seven unique microscale models were converted to volume via POLY2TET tetrahedralization. Following a literature review on potential radionuclide localization within the splenic microstructure, preliminary sources and targets for radiation transport were set. Blood, sinusoids, residual red pulp, and marginal zone white pulp are each set as sources for internal dosimetry, with all white pulp regions set as targets to calculate specific absorbed fractions (SAFs). Organ self dose was also considered in addition to cross dose. Monte Carlo radiation transport was performed using the Photon and Heavy Ion Transport System (PHITS). A reflective boundary was used to contain and guarantee total particle absorption in the model. Simulations were performed until an error of less than 5% was achieved for a comprehensive range of monoenergetic photons, electrons, and alpha particles. The absorbed fractions were combined with mesh data to calculate SAFs to then inform the calculation of S values for the radionuclides defined in ICRP 107.

Results

A library of absorbed fractions (AFs) was obtained for 25 monoenergetic photons from 0.015 MeV to 10 MeV, 25 electrons from 0.015 MeV to 10 MeV, and 24 alpha particles from 0.5 MeV to 12 MeV. AFs resultant from the PHITS simulations were combined with the volume, material composition, densities, and mass of each microstructure region to calculate SAFs for all seven microstructure models. Data from ICRP 107 informed S value calculations to create a library of data for 333 radionuclides relevant to nuclear medicine.

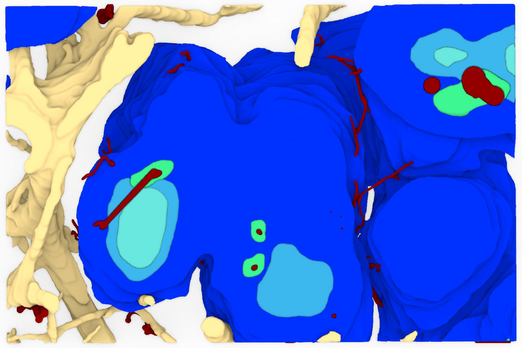


Figure 1: Overhead view of complete ROI7 model, pictured without sinusoids for visibility

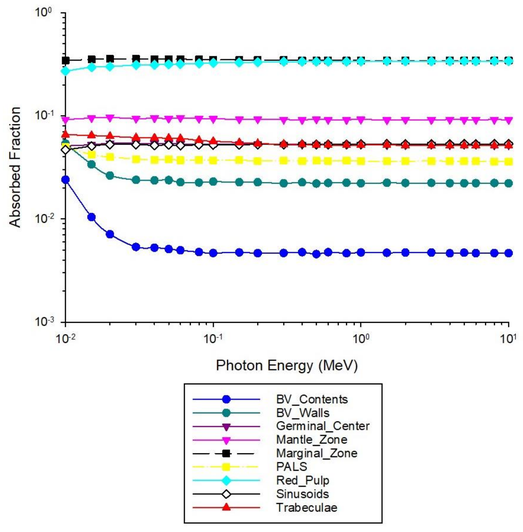
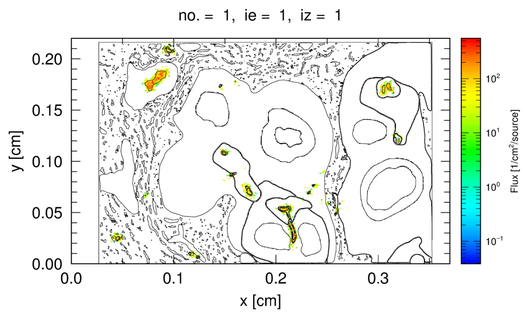


Figure 3: AFs (above) and SAFs (right) for ROI7 using the blood as a source



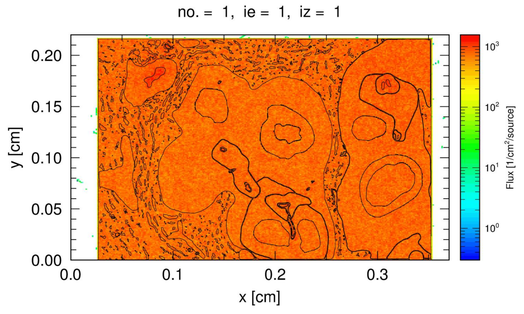
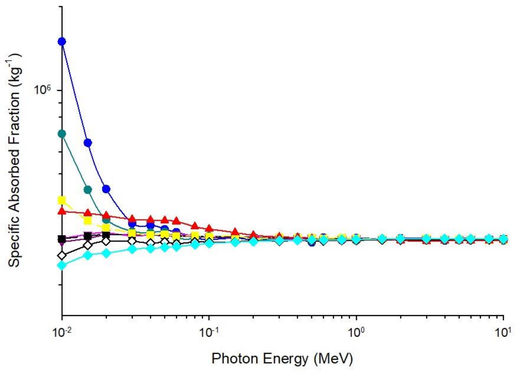


Figure 2: Corresponding PHITS fluence maps for 5 MeV alpha particles (top) and 5 MeV electrons (bottom)



Conclusion

These are the first histology-based 3D microscale models of human splenic tissue being used to perform computational dosimetry. In obtaining SAFs and radionuclide S values, this work provides a robust foundation for splenic microscale dosimetry to better predict radiopharmaceutical hemotoxicity. Furthermore, the use of seven spleen models representing different ROIs enables assessment of dose uncertainties arising from intra-organ variability.

Future Work

Further work will include the use of a modified C++ blood vessel generation algorithm to create a unified arterial-venous macroscale model for the ICRP MRCPs. This will then capture the specified blood volume defined by the ICRP. Complete dosimetry analysis is still in progress due to the implementation and modification of algorithmic vessel parameters and differences in splenic structure material compositions.

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