DEVELOPMENT OF HYBRID COMPUTATIONAL NEWBORN PHANTOM FOR DOSIMETRY CALCULATION: THE SKELETON

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Computational phantoms have been used for decades in computing organ doses from occupational, medical, and accidental exposures from internal and external radiation sources. The evolution of computational phantoms began with mathematically based stylized phantoms, which allowed for organ repositioning and shape, but were anatomically unrealistic. Then, with the advent of image-based segmentation and more powerful computer processors, voxel-based phantoms utilizing 3D voxel matrices provided realistic anatomy, but at the expense of limited organ transformations. Current technology has led to the development of hybrid computational phantoms which combine the flexibility of organ redefinition in stylized phantoms and anatomical realism in voxel-based phantoms. The purpose of this study is to apply the Non-uniform rational B-spline (NURBS) advanced mathematical modeling tool to the University of Florida's voxel newborn phantom to replace the simple mathematical equations used in stylized phantoms, while preserving anatomical detail. ICRP Publications 70 and 89 report limited reference pediatric whole skeleton data based on uncertain assumptions. However in this study, newborn hybrid skeletal site-specific red bone marrow, yellow bone marrow, trabecular bone, cartilage, and cortical bone masses, volumes, densities, and elemental compositions were mathematically derived from image-based CT homogeneous bone segmentation, microCT data from newborn autopsy skeletal specimens acquired from UF Shands Hospital, along with some published data in ICRP, ICRU, and ORNL publications. Once established, this methodology can be replicated for the entire ICRP age series in an attempt to move away from masses tied to the stylized phantoms, and present additional skeletal data that is not found in ICRP or other literature resources.

The current 2003 Stabin and Siegel pediatric dosimetry models do not account for energy escape, cortical bone cross fire, or cellularity changes during transport. The models also uses infinite two-dimensional chord-length distribution data from limited bone samples of a 1.7 year-old and a 9 year-old acquired at the University of Leeds, along with masses tied to the ORNL stylized phantoms. As skeletal size decreases, the effect of these limitations becomes more apparent. To address these issues, an EGSnrc computational Monte Carlo model was developed at the University of Florida. This Paired-Image Radiation Transport (PIRT) Model (Shah 2004) merges the actual CT three dimensional skeletal macrostructure with the imaged three-dimensional microstructure from skeletal specimens acquired via autopsy. Given the image-based methodology of obtaining skeletal data, the skeletal masses are tied to more realistic skeletal anatomy compared to the stylized masses. Preliminary results have shown between 5% and 35% overestimation at intermediate energies and between 35% and 150% overestimation at high energies in the current newborn model for some absorbed fraction results. Future studies will include a comprehensive assessment of internal electron and external photon skeletal dosimetry models, along with the development of

corresponding age and skeletal site-dependent photon fluence-to-dose conversion factors, both which will take into account the non-homogeneity and finite size of bone tissue for the development of additional pediatric hybrid phantoms for the entire ICRP age series.

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