Deformable Adult Human Phantoms for Radiation Protection Dosimetry: Methods for Adjusting Body and Organ Sizes to Match Population-Based Percentile Data

by

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ABSTRACT

To determine radiation doses in the human body from exposures to various radiation sources, computational phantoms representing workers and patients are used with sophisticated Monte Carlo simulations. Nearly all existing phantoms, however, were purposely designed to match internal and external anatomical features of the Reference Man approximating the 50^{th}-percentile of the adult male and female population as defined by the International Commission on Radiological Protection (ICRP). To reduce uncertainty in dose calculations caused by anatomical variations, a new generation of deformable phantoms of varying organ and body sizes has been recently proposed by the research community. This dissertation demonstrates methods to develop such deformable phantoms representing a range of adult individuals from the 5th percentile to 95th-percentile in terms of the body height, body weight, and internal organ volume/mass. Used to directly design such deformable phantoms, anatomical data in tables and graphs cover two different sets of information: (1) the whole-body height and weight percentile data from the National Health and Nutrition Examination Survey (NHANES); (2) individual internal organ size and volume/mass percentile data derived from those recommended in the ICRP Publications 23 and 89. As a starting point, a pair of 50^{th}-percentile phantoms of the adult male and female, RPI-Adult Male and RPI-Adult Female, were first developed using entirely polygonal mesh surfaces. Embedded software tools were then developed to extend these two basic phantoms, on demand, to percentile-specific and posture-specific phantoms by altering organ boundaries according to the tabulated anthropometric data. Algorithms were developed to automatically match the organ volumes and masses with desired values. Finally, these mesh-based deformable phantoms were converted into voxel-based phantoms for Monte Carlo radiation transport simulations. The dissertation then demonstrates the usage of these percentile-specific phantoms for organ dose calculations for exposure to 0.5-MeV and 1-MeV external photon beams. Finally, this dissertation discusses future research directions that can further improve radiation dose assessment using this new type of deformable and size-adjustable computational phantoms.