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Hybrid Computational Phantom VOXMAT: Combination of Voxel and Mathematical Representation of the Anatomy

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ABSTRACT

Computational phantoms, based on closed-form mathematical equations, have been the standard for assessing the radiation dose from internal and external radiation sources for over three decades. Recently, voxel-based phantoms, derived from medical image data, have been developed. Although voxel phantoms model the organs in great detail and realism, some computational challenges are noted (e.g., increased computational times and memory requirements). For good resolution, several million voxels are needed to represent the anatomy of the human body. Furthermore, when image data are acquired, the subject is lying down with arms at the sides. For some occupational radiation exposures, it is necessary to evaluate the dose with the arms and legs in positions other than that used in acquiring the image data. It is difficult to reposition the voxels to articulate the arms and legs to simulate these exposure geometries. Since the torso and head contain significant anatomical details, the use of voxels for the description is desirable for these parts. However, the bones and soft tissue in the arms and legs can be adequately represented by mathematical equations. If needed, even veins can be modeled. There are certain advantages of using such a hybrid computational phantom for radiation dose assessment. First, the number of voxels required to describe the human anatomy can be reduced substantially by the hybrid approach—a voxelized description for the head and torso and a mathematical description for the arms and legs. The decrease in the number of voxels translates to a reduction in computational time and memory requirements. Secondly, the arms and legs can be structured to enable articulation and movement. In this manner, when needed, the analysis can be done for a problem-specific exposure geometry. Further, the equations describing the arms and legs can be revised to be individual specific. Some modeling challenges need to be addressed; these include how to avoid discontinuities in the union of the voxel torso and the mathematical structures of the arms and legs. In this paper, the concept of VOXMAT—a hybrid mathematical and voxel phantom—is presented. The potential benefits and challenges are also discussed.