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INTRODUCTION

The Oak Ridge National Laboratory (ORNL) computational phantoms have been the standard for assessing the radiation dose due to internal and external exposure over the past three decades [1]. In these phantoms, the body surface and each organ are approximated by mathematical equations; hence, some of the organs are not necessarily realistic in their shape. Over the past two decades, these phantoms have been revised and updated: some of the missing internal organs have been added and the locations of the existing organs have been revised (e.g., thyroid). In the original phantom, only three elemental compositions were used to describe all body tissues. Recently, the compositions of the organs have been updated based on ICRP-89 standards [2].

During the past decade, phantoms based on CT scans were developed for use in dose assessment. Although their shapes are realistic, some computational challenges are noted; including increased computational times and increased memory requirements. For good spatial resolution, more than several million voxels are used to represent the human body [3].

Moreover, when CT scans are obtained, the subject is in a supine position with arms at the side. In some occupational exposure cases, it is necessary to evaluate the dose with the arms and legs in different positions. It will be very difficult and inefficient to reposition the voxels defining the arms and legs to simulate these exposure geometries.

In this paper, a new approach for computational phantom development is presented. This approach utilizes the combination of a mathematical phantom and a voxelized phantom for the representation of the anatomy.

DESCRIPTION OF VOXMAT: COMBINATION OF MATHEMATICAL AND VOXEL PHANTOM

Since the torso and head contain significant anatomical details, the voxel description of these structures is desirable. However, the arms and legs contain less detailed anatomical structures; hence, these can be described by mathematical equations. The arms and legs are composed of bone and soft tissue, which can be approximated by equations once they are divided into several parts. Furthermore, if needed, even veins can be modeled using mathematical equations. In Fig. 1, a voxel phantom, on the left, and mathematical phantom, on the right, are shown. As it can be seen from the figure, internal organs have significant detail; however, arm and leg shapes are relatively simple and can be modeled using equations. The equations that describe arms and legs can be revised to resemble the shapes for arms and legs more realistically.

There are certain clear advantages of using a hybrid computational phantom in dose assessment. These include:

- The number of voxels required to describe the human anatomy is reduced substantially, resulting in decreased computational times and memory requirements.

- Arms and legs can be described in a manner that enables positioning of these structures in the computations as described in Refs. 4 and 5. This enables bending of the arms at the shoulder and elbow, and the legs at the hip and knee. In this manner, the proper exposure geometry can be considered in the dose assessment.

- The equations describing the arms and legs can be easily revised to reflect individual specific stature. The guidance from CT scans would be useful in revising the equations.

There are several challenges that need to be addressed. Some of them include:

- Deciding how to define the union of the voxel torso with the mathematical equations of the arms and legs.

- Defining a realistic representation of the segments of the arms and legs rather than the simple cones, as shown in Fig. 1.

SUMMARY AND FUTURE WORK

For the assessment of organ doses, a computational phantom, defined by the combination of voxel and mathematical structures, has been introduced. Although the concept appears to be feasible and promising, future work will determine the advantages of the approach and benefits gained through this new computational phantom.

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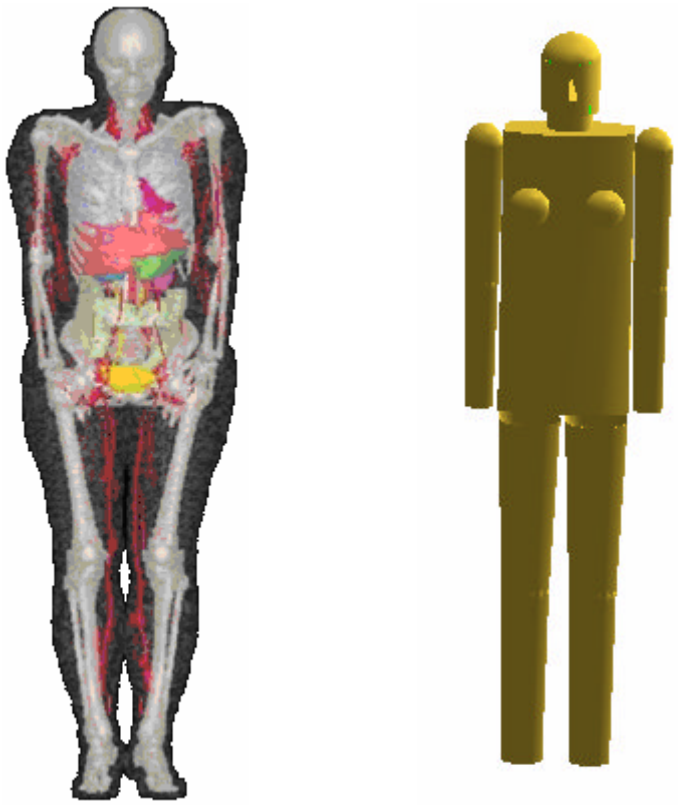

Fig. 1. A voxel phantom (left) [3] and mathematical phantom (right). Although the internal organs of the torso contain significant details of interest in the voxel phantom, the same is not the case for arms and legs.