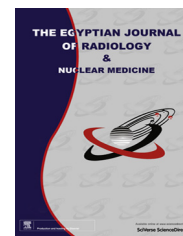




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ORIGINAL ARTICLE

Reconstruction of head-to-knee voxel model for Syrian adult male of average height and weight



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Abstract *Purpose:* This study embodies the reconstruction of head to knee voxel model, named “SyrMan”, of an adult living Syrian male of average height and weight. This model contains main organs of one adult man representing the average of a group of adult males (25–50) years. SyrMan model was reconstructed to be used for Monte Carlo simulations to calculate dosimetric quantities for radiation protection and medical purposes.

Method: The model was reconstructed from segmented CT images of a living volunteer who was 33 year-old, 172 cm in height, and 75 kg in weight. Masses of segmented organs were calculated and compared with previously published models.

Results: Specific Absorbed Fractions (SAFs) were calculated and tabulated for each considered source organ. Comparison of SAF values was carried out with Zubal model where some significant differences were found due to differences in organ masses and in anatomy between both models.

Conclusion: Comparisons with SAFs data of Zubal model accentuated the fact that the organ masses and the specific anatomy have a significant effect on SAFs. SyrMan model can be considered as the first model built in the Middle East region, and it is an important step toward the Syrian Reference Man.

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1. Introduction

Early models representing the human body for radiation dosimetry were known in North America and Europe in the 1960s of the last century (1,2). Afterward, models for other

racial ethnicities, such as Japanese, Chinese, and Korean models had been reconstructed (3–7). These models were reconstructed to be used in ionizing and/or non-ionizing radiation fields (7).

First models for human body were mostly homogeneous simple geometric forms such as spheres, cylinders or slabs and it based on surfaces that described by quadric equations and commonly referred to as “stylized” phantoms (1,2) (Fig. 1).

The first heterogeneous anthropomorphic model was created for the Medical Internal Radiation Dose (MIRD) by

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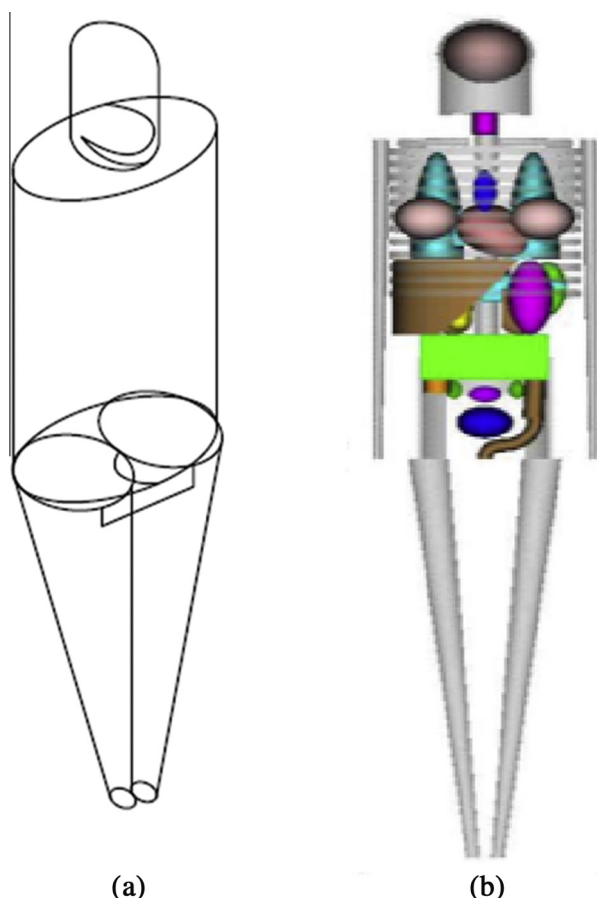


Fig. 1 Stylized phantoms: (a) external vision of the adult male. (b) Skeleton and internal organs (7).

Snyder et al. (1969–1978) using constructive solid geometry (CSG) modeling techniques (1,2,4,8). This model, known as MIRD Phantom, was based on the concept of the “Reference Man” for radiation protection purposes (ICRP 1975). Reference Man was originally defined as being a 20–30 year-old Caucasian, weighing 70 kg and 170 cm in height (9).

After that, several models were developed, but they were not be able to describe accurately the realistic anatomy of the human body. It is clear, however, that the human anatomy is too complex to be realistically modeled with a limited set of simple equations (7).

With the emerging of computed tomography (CT) and magnetic resonance (MR) imaging techniques, researchers could visualize the internal structures of the body in three dimensions and store images in digital formats. This leads to the idea of creating voxel or tomographic phantoms depending on the real anatomy of the human body (4,7,8).

A tomographic image data set is composed of many slices (images); each image consists of two-dimensional (2D) pixel map representing a real anatomy.

Unlike stylized phantoms which are based on quadric surface equations, a voxel phantom contains a huge number of cubes gathered to denote various real anatomical structures (Fig. 2).

The reconstruction of a voxel phantom includes four common steps as follows: (1) obtain a set of tomographic images

that cover the complete volume or most part of the body; (2) classify organs or tissues of interest from the original image slice; (3) identify the density and chemical composition of organs or tissues; and (4) index the segmented image slices into a 3D volume that can be used for 3D visualization and for Monte Carlo calculations.

First effort to reconstruct a voxel model was introduced by Gibbs et al., it was built from CT scans of a female cadaver and projected to calculate the effective dose from dental radiography (10,11); soon after, Williams et al. began to build a family of voxel models of various ages (12).

Zankl et al. started developing a family of 12 various voxel phantoms using CT images for healthy volunteers at GSF National Research Center for Environment and Health in Germany (12–15). Fig. 2a displays one of GSF family models named Golem voxel model.

Kramer et al., from Brazil, developed an adult male model named MAX06 and an adult female model named FAX06; both models were adjusted according to ICRP 89 reference body heights and organ masses (16,17).

Stabin and Yorlitz published SAF values based on Zubal et al. head-torso model named “Voxel Man” which was reconstructed of CT images with dimensions similar to the MIRD 5 stylized phantom with Improvements to with MRI scan data (18,19).

VIP-Man phantom was the first model that based on a cross-sectional color photographic images of a cadaver (Fig. 2b). A data set was collected depending on color photographic anatomical slice images of the 39 year-old male acquired by the Visible Human Project (VHP) of the American National Library of Medicine (20,21).

Jones created NORMAN phantom which was based on whole body MRI scan data of a healthy volunteer. The exact dimensions of the voxels were scaled so that height and mass of the segmented model agreed with the values of Reference Man (8).

Most of the tomographic phantoms described above were based on Caucasian medical images. Subsequently, several works were accomplished using primary data from different racial ethnicities (3–7).

The first Asian adult male phantom Otoko was developed by Saito et al. from whole body CT data of a patient whose external dimensions are in agreement with the Japanese Reference Man (5,6). Also several Korean phantoms have been developed by researchers Lee and Kim (3,4).

The voxel computational phantoms were combined with various Monte Carlo codes that simulated the radiation transport in human material (7,8,11,12,18–20).

Due to the lack of detailed voxel model for the Middle East region, this study represents the reconstruction of head to knee voxel model, named “SyrMan”, of an adult living Syrian male of average height and weight (Fig. 2c). SyrMan was then exploited in internal dosimetry calculations using Monte Carlo simulations.

2. Methods

2.1. CT data

The primary data were obtained in DICOM format from computed tomographic examination of a single volunteer.

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