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Adjustment of a Korean Voxel Phantom and Its Effect on Monte Carlo Dose Calculations

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1. Introduction

Many different voxel models have been developed for use in the calculation of the radiation doses to organs and tissues in the human body. Most of these voxel models are constructed from the CT and MR images of individuals. The organs and tissues are, however, not always discernable on CT and MR images, making it difficult to segment some organs and tissues. Furthermore, these models do not represent the average radiation workers in Korea because the height, weight, and organ masses are different from those of the average Korean workers.

This paper compares two Korean voxel models (VKH-Man, HDRK-Man), which have been constructed from the same data set of serially-sectioned color images, in terms of calculated organs doses. The HDRK-Man has been developed by adjusting the VKH-Man to the data of the 'Reference Korean' [1]. In this study, organs doses were calculated with these developed models and the calculated values were compared each other to see the effect of the adjustment.

2. Method and Results

2.1 VKH-Man and HDRK-Man

The Ajou University School of Medicine performed a national research project 'Visible Korean Human (VKH)' and acquired very valuable images, i.e., the serially-sectioned color images from a cadaver of a Korean adult male of 164 cm in height and 55 kg in weight [2]. Very recently, in an effort to develop a Korean voxel model, a total of 28 organs and tissue have been segmented very accurately at Hanyang University. The voxel model, which is name VKH-Man, has the voxel resolution of 1.875 x 1.875 x 2 mm^3.

The VKH-Man has been constructed from a cadaver and, obviously, can represent only the cadaver. Note the height, weight, and organ masses of the cadaver were different from those of the Reference Korean. Therefore, VKH-Man was adjusted to the data of the 'Reference Korean' following the procedure recently introduced by Zankl et al [3].

The adjustment of the height and skeletal mass was achieved by scaling the voxel size of the model. The height of the VKH-Man (164 cm) was adjusted to the height of the Reference Korean (171) cm by simply increasing the voxel size from 2 mm to 2.0854 mm in the z direction. Due to the absence of the total skeletal mass in the Reference Korean data, it has been calculated based on the method suggested by Clays et al [4]. The skeletal mass of the Reference Korean (171 cm, male) was calculated 9.6 kg. The skeletal mass of the model was then adjusted to the value (9.6 kg) by changing the size of the voxels in the x-y plane direction. The size of the pixel was increased from 1.875 mm x 1.875 mm to 1.981 mm x 1.981 mm to increase the mass of the bone in the model.

The size of the organs and tissues were also adjusted to the data of the Reference Korean by using the Inner Grow and Outer Grow functions of the Photoshop™ software. The data of 'Reference Asian' [5] were used for some organs for which the 'Reference Korean' data are not available. Finally, the mass of the organs and tissues of the model were adjusted to the reference Korean data within 7%, for the most organs and tissues.

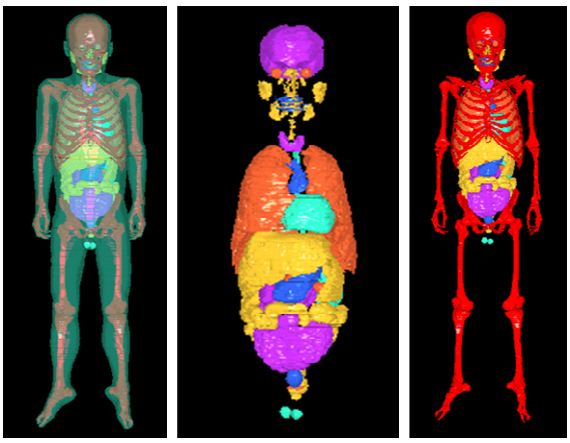

Figure 1. HDRK-Man, a voxel model to represent the average Korean radiation workers in Korea.

Figure 1 shows the developed voxel model HDRK-Man. The voxel model is 171 cm in height and 67.8 kg in weight. The size of the voxels (voxel resolution) is 1.981 x 1.981 x 2.0854 mm^3. The size of the voxel array is 247 x 141 x 850 (29,602,950) in the x, y, and z directions, which corresponds to 489.307 mm, 279.321 mm and 1,772.59 mm, respectively. Considering that the voxel model represents the organs and tissues very accurately and was adjusted to the data of the Reference Korean, the voxel model was named 'HDRK-Man' (High Definition Reference Korean-Man). The current version of the voxel model, which does not include some important organs, will be completed in one or two years.

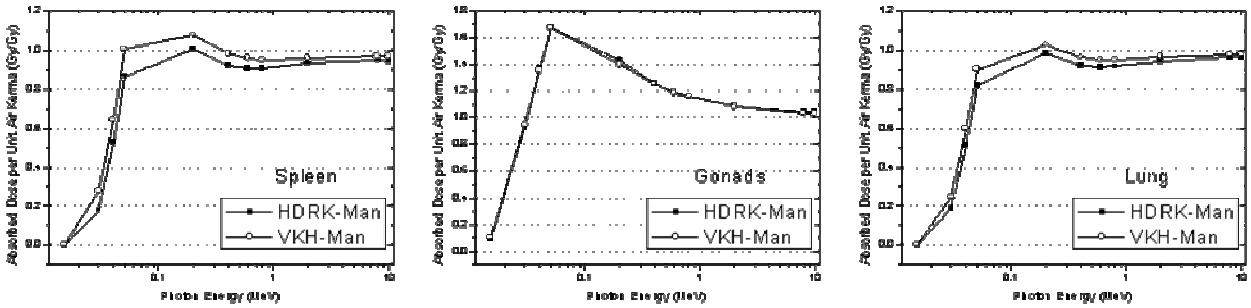

Figure 2. Comparison of organ equivalent doses from HDRK-Man and VKH-Man for the spleen, gonads and lung. The irradiation geometry is antero-posterior (AP).

2.2 Monte Carlo dose calculation

This study calculated the radiation doses to various organs and tissues using the developed voxel models (HDRK-Man, VKH-Man) and compared the calculated values each other. The Monte Carlo code, MCNPX2.5, was used for the dose calculations. The considered irradiation geometries are broad parallel photon beams within the energy range of 0.015 to 10 MeV. Only anterior-posterior (AP) direction was considered in this study.

Figure 2 compares the organ and tissue doses calculated from these two models. The result shows that there is no difference in the gonad doses, which is due to the fact that the size of the gonads were not adjusted at all – the mass of the gonads are identical in these two models. The result suggests that the adjustment of the voxel phantom, in general, does not affect much the dose calculation for the external exposure cases. The difference was generally less than 10%, except for very low energies, even for the spleen, for which the size was reduced by as large as 84% (6 times of difference in size). There was only slight difference of organ dose for the lungs, which was reduced by 36%. The difference of the other organs is not given here, but much less than the above values.

3. Conclusion

This paper compares two Korean voxel models (VKH-Man, HDRK-Man), which have been constructed from the same data set of serially-sectioned color images, in terms of calculated organs doses. The results of this study strongly suggest that the adjustment of the voxel phantom hardly affects the dose calculations for the external exposure geometries.

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