CONSTRUCTION OF A LIBRARY OF 25 FULL-BODY MALE NUMERICAL MODELS: RATIONALE AND RESULTS

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Abstract

In order to cover at best the possible extent of heights and weights of male adults the construction of 25 whole body 3D models has been undertaken. Such a library is thought to be useful to specify the uncertainties and relevance of dosimetry calculations carried out with models representing individuals of average body heights and weights.

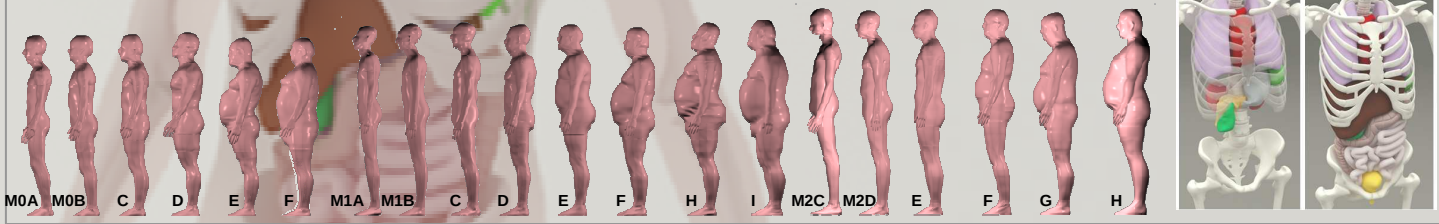
Representative 3D models of Caucasian body types are selected in a commercial database according to their height and weight. 3D models of the skeleton and internal organs are designed using another commercial dataset. A review of the literature enables one to fix volume or mass target values for the skeleton, soft organs, skin and fat content of the selected individuals. The composition of the remainder tissue is fixed so that the weight of the voxel models equals the weight of the selected individuals.

After mesh and NURBS modelling, volume adjustment of the selected body shapes and additional voxel based work, 25 voxel models with 109 identified organs or tissue are obtained. Radiation transport calculations are carried out with some of the developed models to illustrate potential uses.

SELECTION OF REPRESENTATIVE INDIVIDUALS

Twenty five representative male body shapes are selected in the European CAESAR database [1]. For this purpose height and weight classes are defined and individuals as close as possible from the class centres are selected. Sampling is done using 12 cm x 12 kg classes.

The individuals are named using short names. M1C with 177 cm and 73.1 kg is very close from the ICRP reference male. The 3D models of body shapes shown here are obtained after mesh repair of the original 3D models and volume adjustment.



DEFINITION OF TARGET FEATURES

Mass of internal organs and skeleton. The literature shows [2,3] that it is possible to scale the ICRP reference masses as a function of height only : $M_{organ}=k(\text{Height})*M_{reference}$.

Skin mass. The skin weights about as much as two brains, it is thus important to fix it properly for all individuals. An algorithm built the skin in a coherent manner for all models and the skin density is fixed so that its weight is as close as possible from 4.5% of the body weight. This results in 0.95g/cm³, far from the 1.10 g/cm³ of ICRP, but in agreement with well known BSA relations and a skin thickness of 0.188 g/cm².

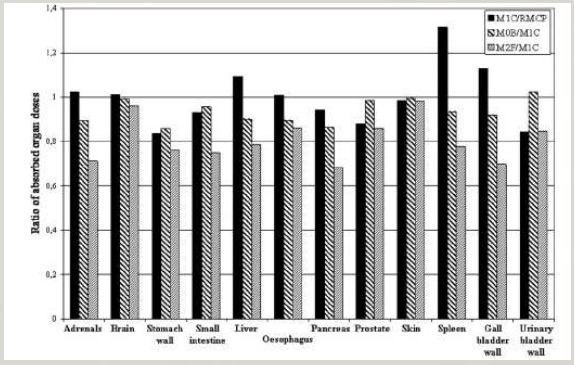
Fat percent. In the final models muscles, fat and excluded organs are gathered in a single remainder tissue. To fix a realistic composition for this tissue the fat percent of individuals is fixed. Due to the huge number of approaches given in the literature, 10 relations have been averaged to fix the fat percent.

Body volumes and density. When the weight increases it is expected that the body density decreases. The Siri relation [4] relates the fat percent and the body density. To match this relation the body shapes are slightly 2D scaled (height is preserved).

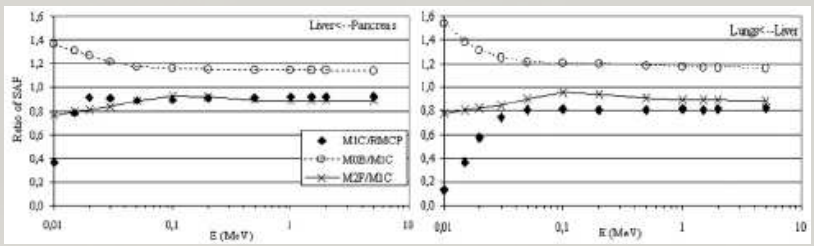
MODELING WORKFLOW AND RESULTS

- The mesh models of the selected individuals are repaired, using NURBS modelling, and 14/25 are scaled to match the required volume.
- The 3D models of organs and skeleton provided by the 3DSpecial company [5] are modified to match the volumes of the ICRP reference computational phantoms.
- These organs are set up in the body shapes using anatomical charts, examples of available voxel models and CT scans and taking into account the advice of a physician. For individuals who are not in the 176 cm height classes scaling factors are applied to organs.
- The 3D models with the internal organs and skeleton are voxelised with the binvox program [6] and intersections of organs are corrected.
- The composition of the remainder tissue is defined so that the weight of the voxel model equals the weight of the selected individual. It is checked that the muscle weight agrees with literature data.
- The voxel size of final models is between 5.6 and 8.7 mm³ and the models contain between 57 and 140 10^6 voxels, including the air in the bounding box. The mass of organs typically agrees with target values within ± 3%. Some organs present more significant departures, in order to preserve a realistic matching of the body shapes (*e.g.* the cranium).

EXAMPLES OF DOSIMETRY CALCULATIONS



Comparison of organ doses for the ICRP Reference Male Voxel Phantom, the M1C, M0B and M2F models in case of AP irradiation with a 0.5 MeV photon beam



Comparison of Specific Absorbed Fractions for the RMCP, the M1C, M0B and M2F models for selected organs

Details about this work can be found in: Broggio *et al* Phys. Med. Biol. 55 7659–7692 (2011)

[1] http://store.sae.org/caesar/
[2] Clairand et al. 2000, Phys. Med. Biol. 45 2771-85
[3] Ferretti et al. 1998, Bone 22 683-90
[4] Lean et al. 1996, Am. J. Clin. Nutr. 63 4-14
[5] http://www.3dspecial.com/
[6] http://www.cs.princeton.edu/~min/binvox/