

GSF Male and Female Adult Voxel Models Representing ICRP Reference Man

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Motivation

- **Medical image data provides**
 - Improved anatomical realism
 - Studies indicate dosimetric impact (photons)
 - Few tens percent external
 - Order magnitude on internal sources
- **ICRP desires to adopt computational phantoms**
 - Limitations of voxel models
 - Individual organ topology
 - Individual organ masses
- **ICRP Reference computational phantoms**
 - Needs to represent population average
 - Reference Man Publications 23 and 89

Methodology-1

- **Strategy**

- **Select CT image data set of persons close to Reference Man (height and weight)**
- **Segmentation of the data set**
- **Adjust body height to reference value (scaling voxels)**
- **Adjust skeletal mass to reference value (in plane voxel dimensions)**
- **Adjust individual organs to reference values by addition/subtraction of voxels**

Methodology-2: Skeleton

- Proportion of bone marrow and bone mineral based on CT values in skeleton voxels
- Regional distribution of active marrow as in Publication 89
- Fraction of marrow that is active (red) is based on cellularity data in Pub 89
- Yellow marrow located in all other regions
- Structure of trabecular bone not modeled
- Response functions used to estimate active marrow and endosteal dose from fluence

Methodology-3

- **Software package *VolumeChange* for modification of soft-tissue organs**
 - **Programming language IDL**
 - **Represent organ by its surface voxels (i.e., voxels that have at least one neighbor that does not belong to the same organ)**
 - **Modify organs by shifting surface voxels**

Methodology-4

- **Advantage of software system**
 - Various platforms (Windows/Unix/Linux)
 - Direct manipulation of segmented data set
 - Possible to decide if voxel belonging to neighboring soft-tissue organ maybe overwritten (bone never overwritten)
 - Easy to modify to address new needs
- **Limitation**
 - Not a segmentation tool
 - *AnalyzeAVW* 3.0 used in segmentation

Modification to Golem-1

- **Segmentation of additional organs**
 - **Blood (large vessels in trunk)**
 - **Breast (adipose and gland tissue)**
 - **Cartilage**
 - **Pituitary gland**
 - **Salivary gland**
 - **Tongue**
 - **Tonsils**
 - **Ureters**

Modification to Golem-2

- **Contents added to previous solid organs**
 - Gall bladder
 - Heart
 - Small Intestine
- **Subdivision of colon**
 - Ascending colon
 - Transverse colon, right and left
 - Descending colon
 - Recto sigmoid colon
- **Consistent with pending alimentary tract publication (ICRP Publication 99)**

Methodology- Adult Male

Comparison of Golem and Reference Male

	Golem	Reference	
Height (cm)	176	176	ok
Mass (kg)	69.6	73.0	Adjust

Golem voxel size (0.208 x 0.208 x 0.8 cm)

Modification to Golem-3

- **Reference Model in supine position**
 - No attempt made to adjust organ positions
- **Lungs are compressed: adjusted to reference mass by density (0.427 g cm^{-3})**
- **Skeletal mass 10.45 vs. 10.5 kg reference value**
- **Voxel dimensions**
 - Height 8 mm (not modified)
 - Pixel dimensions (2.08 mm \rightarrow 2.085 mm)

Modification to Golem-4

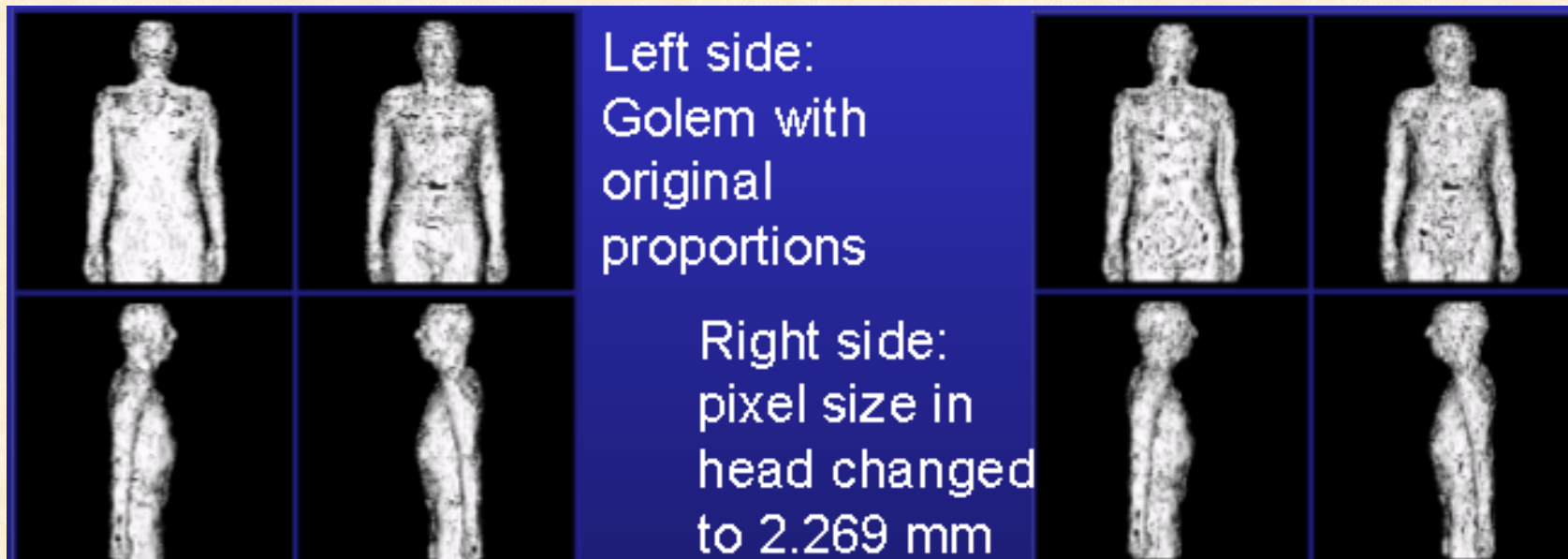
- **Adjustment to organs**
- **First difficulty: brain**
 - **Mass: Golem 1224 g Reference Man 1450 g**
 - **Brain surrounded by skull – can not add voxels**
- **Further organs in head**
 - **Salivary gland 64.7 g vs. 85 g**
 - **Teeth 39.1 g vs. 50 g**
 - **Tongue 36.3 g vs. 70 g**
- **Necessary to adjust pixel size in head**

Modification to Golem-5

- Pixel size in head changed to 2.269 mm
- Volume re-sampled to accommodate voxel of original size (2.085 mm)
- Larger number of head voxels, constant voxel size for whole body
- Mass of skeleton: 10.58 kg vs. 10.5 kg reference value

Modifications to Golem-6

Did adjustment to skull distorted body proportions?

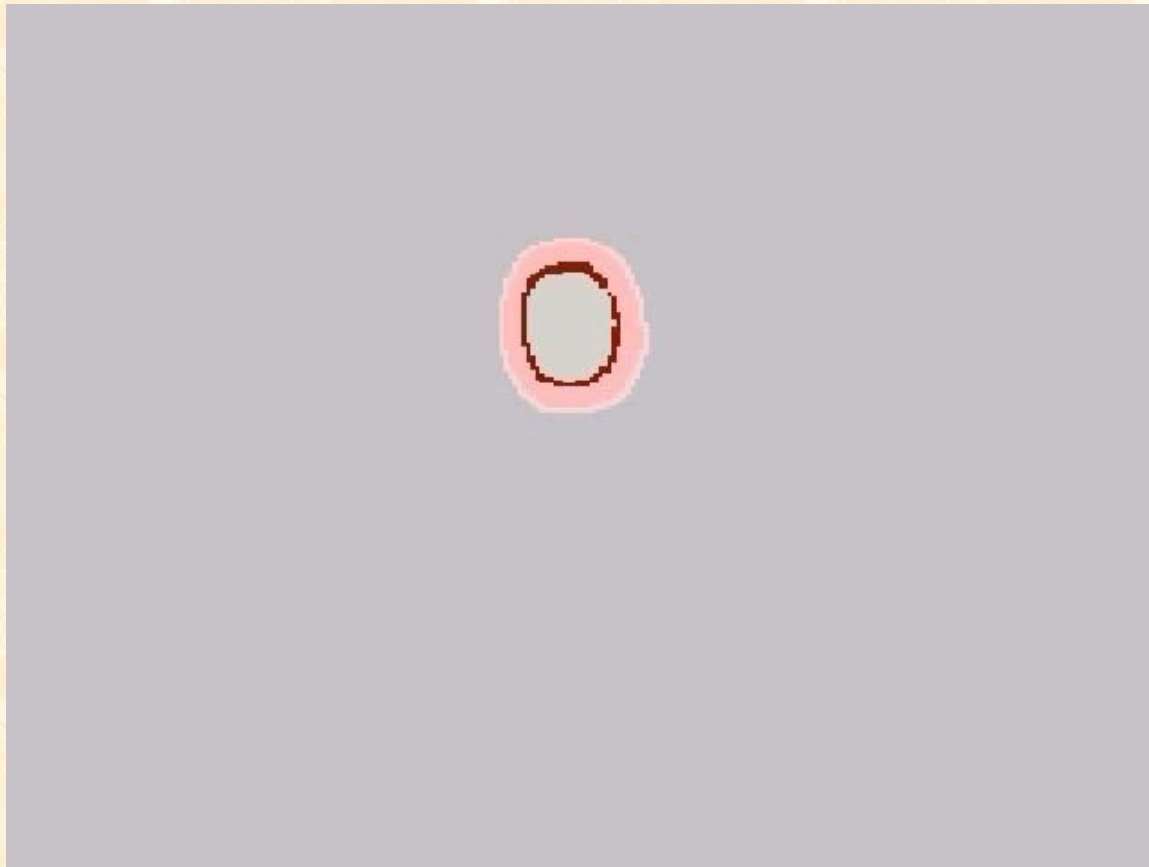


Judged acceptable.

Reference Male Phantom

- **220 cross-section images**
 - 256 x 256 pixels (2.085 mm)
 - 8 mm in vertical
- **Phantom**
 - 2,021,500 tissue voxels
 - Voxel volume 0.0348 cm³ or ~ 35 mg
 - Each voxel assigned 1 byte ID
 - 85 tissues/contents identified
 - 14.1 Mbyte data file

Reference Male Phantom



Methodology – Adult Female

Reference Adult Female based on GFS' Laura

Comparison of Laura and Reference Female

	Laura	Reference	
Height (cm)	168.5	163	Need to
Mass (kg)	62	60	Adjust

Laura voxel size (0.1875 x 0.1875 x 0.5 cm)

Follow same adjustments as for male

Reference Female Phantom

- **346 cross-section images**
 - 256 x 256 pixels (1.765 mm)
 - 4.84 mm in vertical
- **Phantom**
 - 3,911,611 tissue voxels
 - Voxel volume 0.0156 cm³ or ~ 16 mg
 - Each voxel assigned 1 byte ID
 - 89 tissues/contents identified
 - 22.1 Mbyte data file

Reference Female Phantom



Limitations of Methodology

- **Some tissues not reference values**
 - Extrathoracic airways
 - Skin
 - Gall bladder wall
 - Major blood vessels
 - Bronchi
 - Adipose tissue
- **Limited by resolution**

Development in Final Stages

- **Add identification of left-right organ pairs**
- **Further work on skeleton**
- **ICRP Committee 1 tissues at risk**
 - **Tissues of remainder**
- **Input from ongoing reviewers**
- **Prepare ICRP Publication**
 - **Computational phantoms on CD**

Reference Adult Male and Female



Male

Female