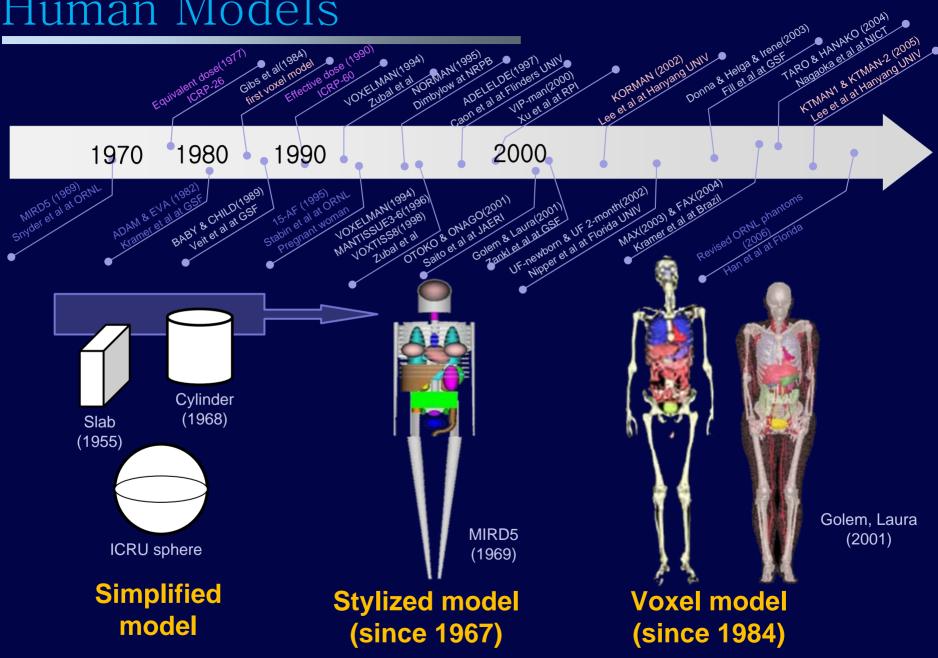
HDRK-Man: A Whole Body Voxel Model Based on High-resolution Color Slice Images of a Korean Adult Male Cadaver

> <u>C. H. Kim</u>¹, S. H. Cho¹, J. H. Jeong¹, C. Lee², M. S. Chng³ ¹Hanyang University, Korea ²University of Florida, Gainesville ³Ajou University School of Medicine

> > CMPWG-II, Gainesville, Florida September 30 – October 4, 2007

Human Models



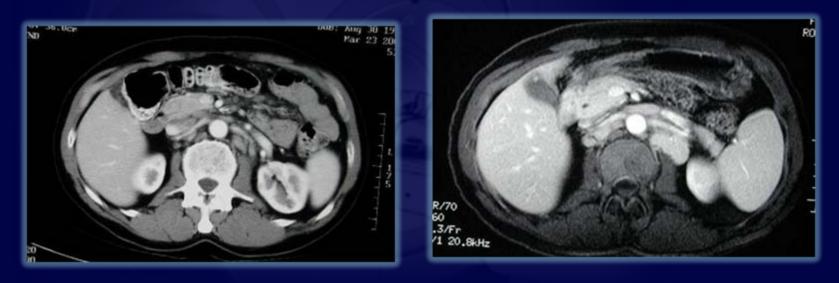
Voxel Models

Model	Images	Subject	Race	Age and gender	Voxel size (mm ³)	Comment
BABY	СТ	Cadaver	Caucasian	8-week-old female	2.90	
CHILD	СТ	Leukemia patient	Caucasian	7-year-old female	19.00	
Zubal Phantom	СТ	Diffuse melanoma	Caucasian	Adult male	46.70	Head and torso
NORMAN	MRI	N/A	Caucasian	Adult male	8.10	
ADELAIDE	СТ	Patient	Caucasian	14-year-old female	64.00	Torso
VIP-man	Photo	Cadaver	Caucasian	38-year-old male (VHP)	0.10	
Golem	СТ	Leukemia patient	Caucasian	38-year-old male	34.60	
Otoko	СТ	N/A	Japanese	Adult male	9.60	
UF newborn	СТ	Cadaver	Caucasian	6-day-old female	0.30	
UF 2 month	СТ	Cadaver	Caucasian	6-month-old male	0.30	
Visible-human	СТ	Cadaver	Caucasian	38-year-old male (VHP)	4.30	Head to knees
Frank	СТ	Patient	Caucasian	48-year-old male	2.80	Head and torso
Donna	СТ	Patient	Caucasian	40-year-old female	35.16	
Helga	СТ	Patient	Caucasian	26-year-old female	9.60	Head to mid thigh
Irene	СТ	Patient	Caucasian	32-year-old female	17.58	
KORMAN	MRI	Volunteer	Korean	30-year-old male	40.00	
MAX	-	N/A	Caucasian	Adult male	46.70	Modified Zubal Phantom
FAX	СТ	Volunteer	Caucasian	37-year-old female	46.70	62Y female legs
TARO	MRI	Volunteer	Japanese	22-year-old male	8.00	
HANAKO	MRI	Volunteer	Japanese	22-year-old female	8.00	
Pregnant woman	СТ	Patient	Caucasian	30-week-pregnant female	6.20	Lower torso
NAOMI	MRI	Volunteer	Caucasian	23-year-old female	7.82	
UF 9-month	СТ	Patient	Caucasian	9-month-old male	0.55	Head and torso
UF 4-year	СТ	Patient	Caucasian	4-year-old female	1.01	Head and torso
UF 8-year	СТ	Patient	Caucasian	8-year-old female	2.02	Head and torso
UF 11-year	СТ	Patient	Caucasian	11-year-old male	1.33	Head and torso
UF 14-year	СТ	Patient	Caucasian	14-year-old male	2.34	Head and torso
KTMAN-1	MRI	Volunteer	Korean	25-year-old male	20.00	
KTMAN-2	СТ	Volunteer	Korean	35-year-old male	20.00	

Limitation of CT/MR

Difficult to delineate some organs

- + If the organs have similar properties or in continuous movement
- Examples ovaries, pancreas, oesophagus, adrenals, thymus, small intestine, heart, etc.



CT Image

MR Image



VIP-Man

Overview

- ✤ Xu et al (2000)
- Based on color photographic transverse slice images of 38-year-old male
- The most complete body description
 - ➤Voxel resolution:
 - 0.33 mm x 0.33 mm x 1 mm
- Limitations
 - Very large (186 cm, 103 kg)
 - Cannot be used to represent the Korean workers (171 cm, 68 kg)

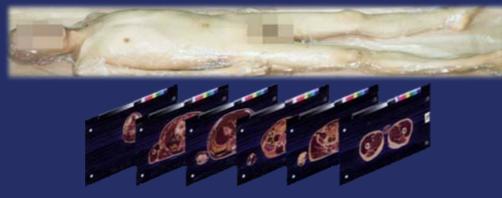




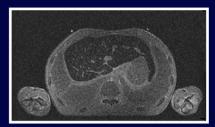
Objective/Serially Sectioned Images



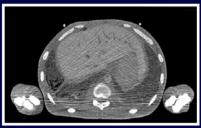
Visible Korean Project (VKH)



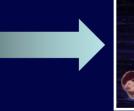
33-years-old, Korean male, 164 cm, 55 kg

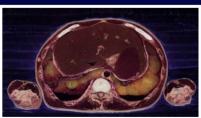


MR (1mm x 1mm x1mm)



CT (1mm x 1mm x 1mm)

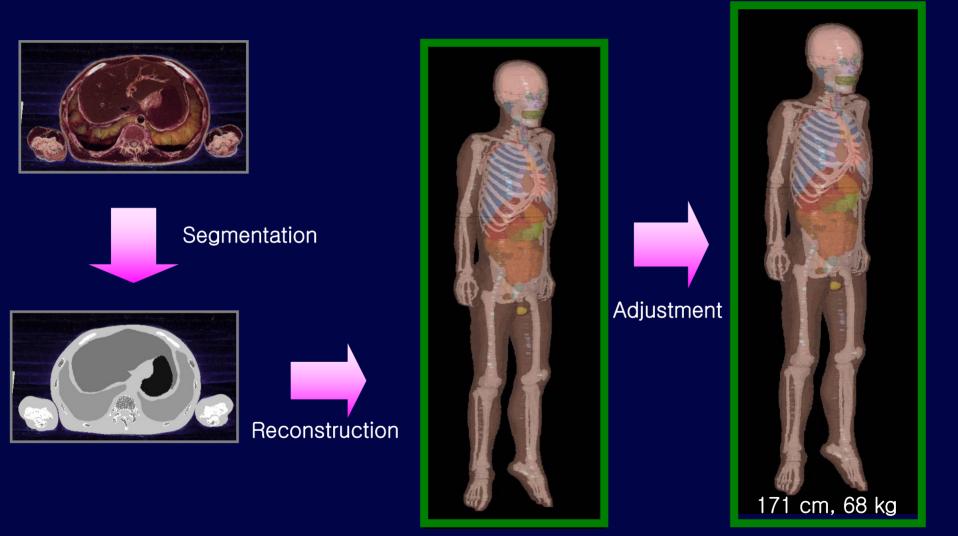




Photographic Image (0.2mm x 0.2mm x0.2mm)



Steps to Construct Model



RIDOL Radiation Interactions and Dosimetry Laboratory

Segmentation

Vertical Resolution

 Slice images selected every 2 mm interval – 850 images out of 8,590 images

Automatic Segmentation

- Organs and tissues clearly distinguish by color (e.g., eye balls, lenses, RBM, muscle)
- Photoshop 7.0 Action, IDL 5.6

Manual Segmentation

- Organs and tissues that could not be segmented automatically (e.g., prostate, pancreas, adrenals, oesophagus, …)
- Screen digitizer (CINTIQ 15X) + Magnetic Lasso tool (Photoshop 7.0)









Photoshop 7.0 IDL 5.6

RIDOL Radiation Interactions and Dosimetry Laboratory



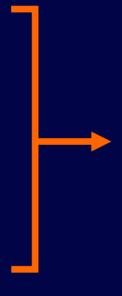








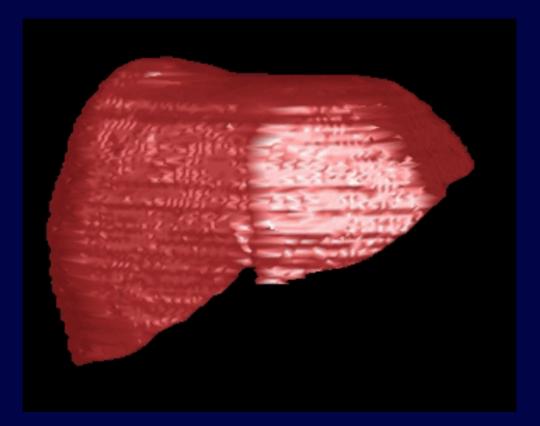




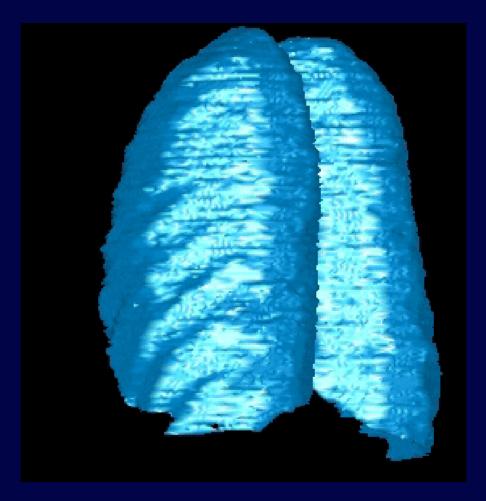




Liver

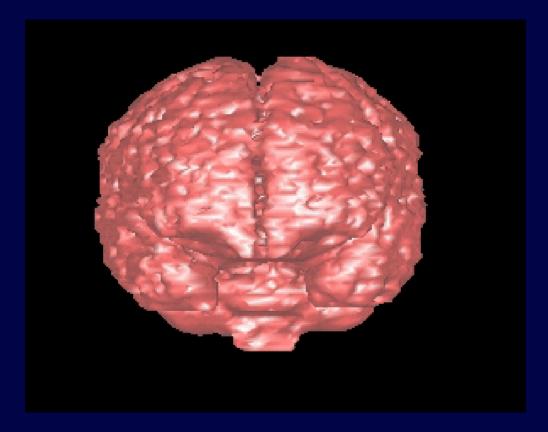






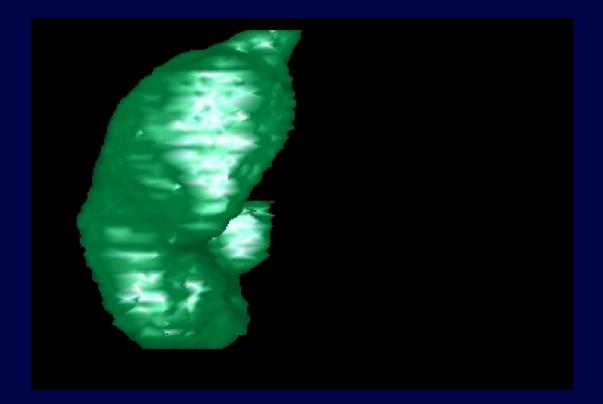


Brain



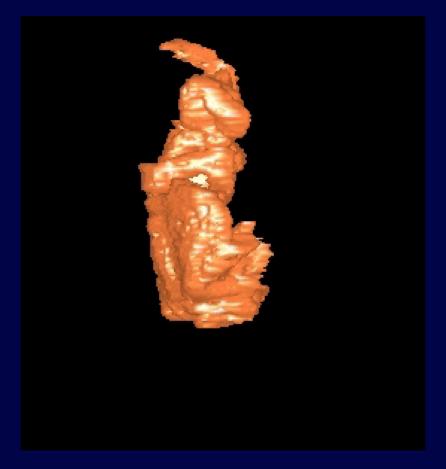


Stomach



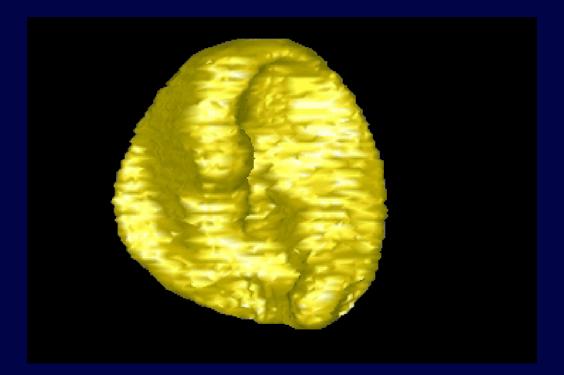


Intestines



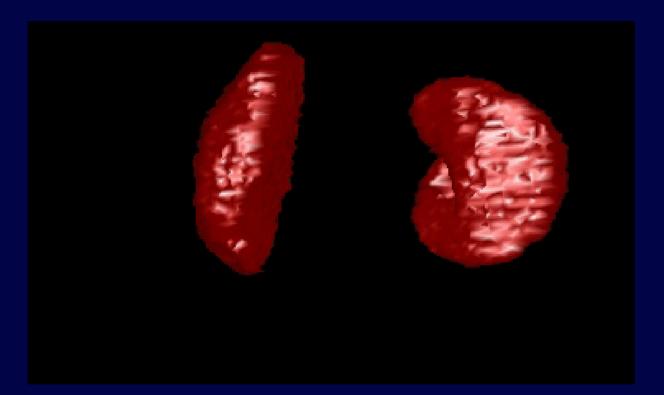


Spleen



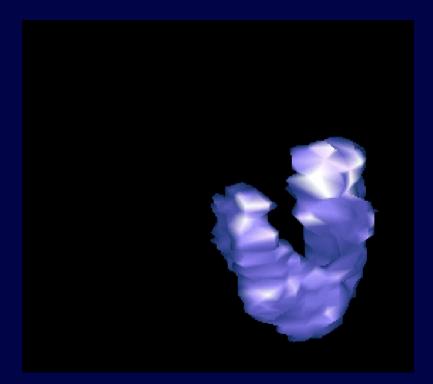


Kidneys



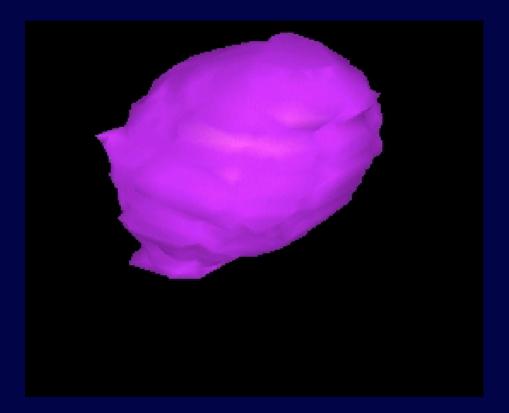


Thyroid





Bladder





Gonads





Heart Wall



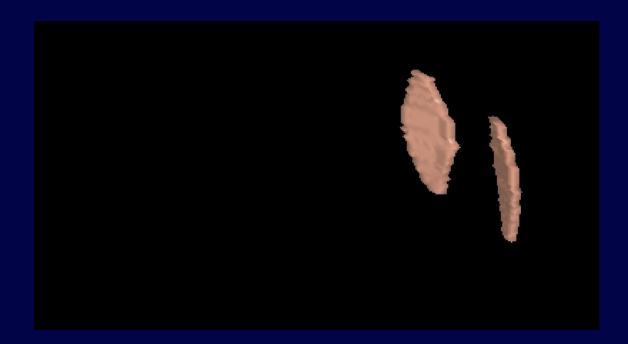


Oral Mucosa



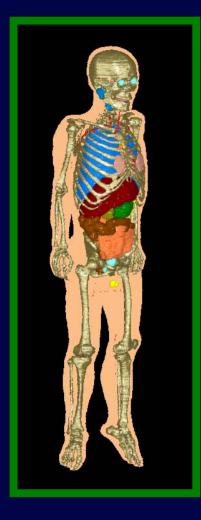


Breast - Defined

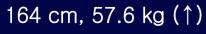




Reconstructed Model

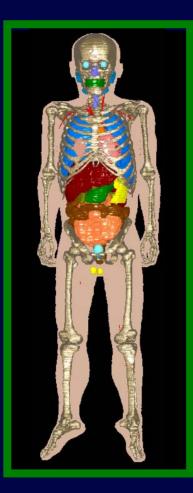


Organ	Mass (g)	Organ	Mass (g)
Thyroid	18.8	Bladder	39.2
Lens	0.9	Thymus	28.7
Prostate	13.0	Muscle	19934.3
Salivary glands	75.8	Pancreas	108.5
Adrenal	8.5	Gonads	24.3
Oesophagus	34.0	Small intestine	253.1
Spleen	980.4	Colon	352.2
Stomach	164.8	Eyes	19.2
Lung	1476.9	Kidney	384.2
Red bone marrow	929.9	Extrathoracic tissue	63.0
Bone	7293.7	Gall bladder	104.4
Skin	3656.9	Heart wall	513.1
Brain	1701.6	Oral mucosa	19.1
Liver	1931.3	Blood	220.3





Adjustment – Height







171 cm (2.0854 mm)



Adjustment - Bone Mass



8.6 kg (1.875 mm x 1.875 mm)





9.6 kg (1.981 mm x 1.981 mm)



Adjustment - Organs and Tissues

Reference

- Individual organs adjusted to the Reference Korean data
- Reference Asian data used for prostate, (urinary) bladder, adrenals, colon, small intestine

Larger Organs

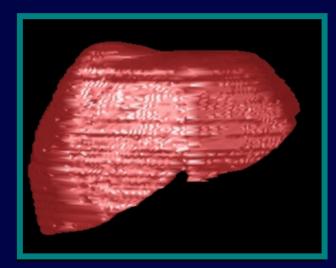
- Adjusted by erosion (Inner Grow, Photoshop 7.0)
- Eroded region filled with adipose tissue

Smaller Organs

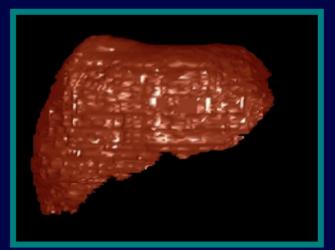
Adjusted by dilation (Outer Grow, Photoshop 7.0)



Adjustment – Liver



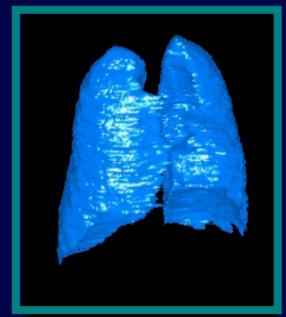






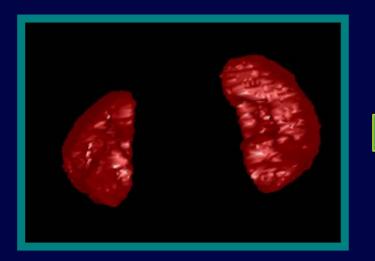








Kidneys







Spleen – Problem!



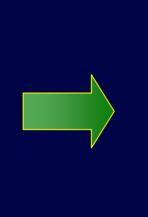






Stomach









Intestines



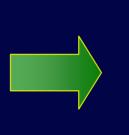






Bladder

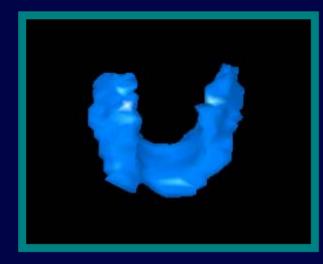


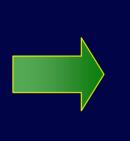






Thyroid

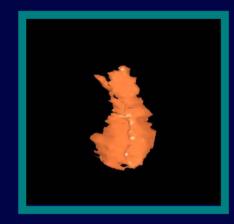








Thymus

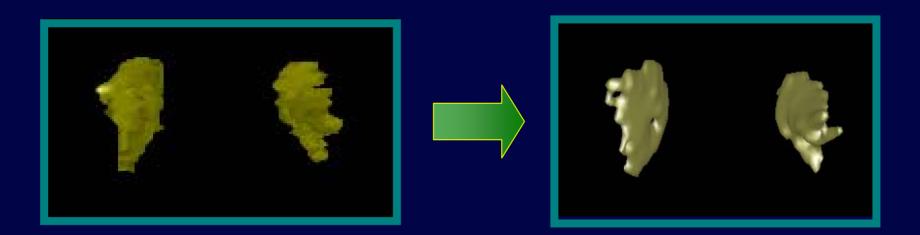






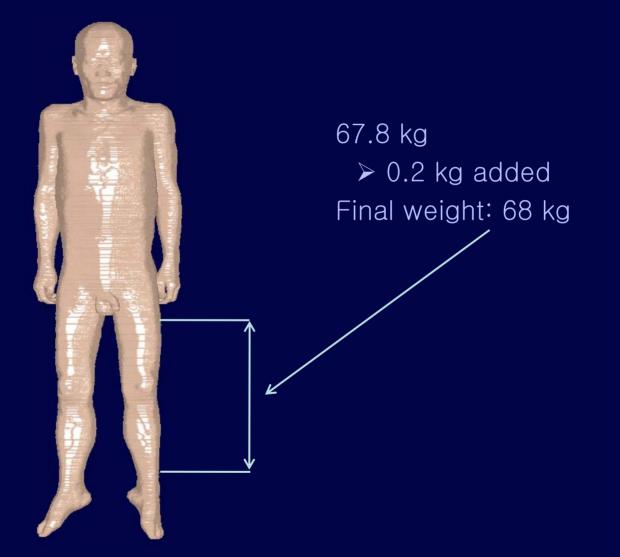


Adrenals



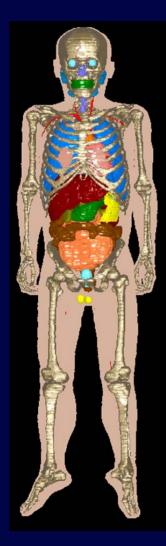


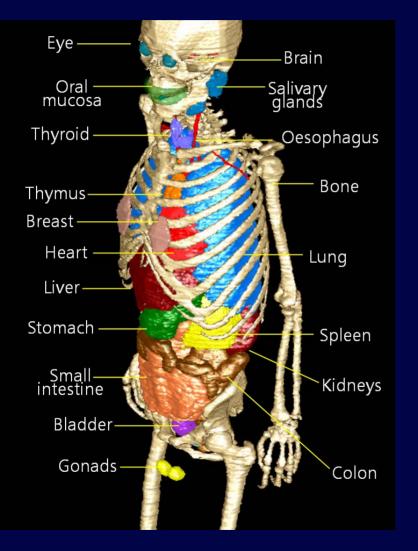
Weight Tuning





HDRK-Man





171 cm, 68 kg Voxel resolution: 1.981 x 1.981 x 2.0854 mm³ Voxel array: 247 x 141 x 850 (29,602,9507⊮) >X : 489.307 mm >Y : 279.321 mm >Z : 1772.59 mm 30 organs segmented



HDRK-Man (Continued)



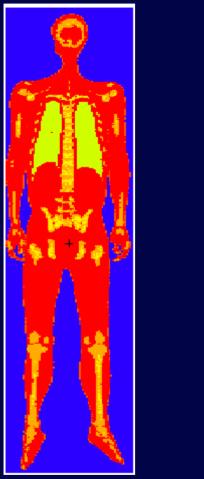


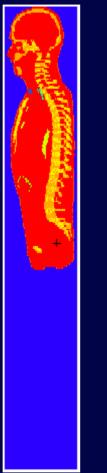
The Reference Asian data were used for the organs and tissues for which the Reference Korean data are not available

HDRK-Man Organ Masses

Organ		Mass (g)			Mass (g)			
	HDRK- Man	Reference Korean	Difference	Organ	HDRK- Man	Reference Korean	Difference	
Bone	9607	9649	-0.4%	Small intestine	602	590 ^a	2.0%	
Liver	1474	1438	2.5%	Oesophagus	40	40	0.0%	
Lung	1156	1123	2.9%	Adrenals	14	14 ^a	0.0%	
Brain	1620	1522	6.4%	Skin	4260	2400	77.5%	
Kidneys	359	338	6.2%	Extrathoracic region	73	-	-	
Spleen	177	170	4.1%	Thyroid	15	15	0.0%	
Stomach	141	140	0.7%	Bone-marrow (red)	1068	1000	6.8%	
Pancreas	126	130	-3.1%	Prostate	12	12ª	0.0%	
Thymus	39	40	-2.5%	Blood	254	-	-	
Gonads	28	29	-3.4%	Salivary glands	87	82	6.1%	
Eyes	21	20	5.0%	Gall bladder	13	13	0.0%	
Lens	0.51	0.4	27.5%	Oral mucosa	21	-	-	
Muscle	23300	25000	-6.8%	Heart wall	391	380	2.9%	
Bladder	42	40ª	5.0%	Breast	23.3	22	5.9%	
Colon	343	330 ^a	3.9%	Adiposetissue	23400.2	11000	112.7%	

HDRK-Man in MCNPX





00723/06 16-03:20 BUBLE-Man Voccel phantem VP N2 DV LF origin .1 .2 zeem 5. 60 probif = 00723/06 16-03:25:4													
number over planes eel probid = 00/23/06 10:29:14 she baris: xr she (0.00000, 1.00000) she (1.00000, 1.00000) she (1.00000, 1.00000) she (2.5.57, 25.7) 5.7, 7.00, 00 she she reil 15 she she she she <td< td=""><td></td><td></td><td></td><td>UP</td><td>RT</td><td>DN</td><td>E.F.</td><td>origin</td><td>.1</td><td>. 2</td><td>Zean</td><td>5.</td><td>10</td></td<>				UP	RT	DN	E.F.	origin	.1	. 2	Zean	5.	10
pyrbid z 00/22/06 24.29:14 imp barini xx kne (1.00000, 0.00000) c000000) (0.00000, 1.000000) c000000) ixisin vol (-3.07, 3.37, 140.00) fol ixisin max y i y i r max iiii fol iiiii fol iiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiiii	RDRK-Man voxel	phantom											
serie XY (************************************													cel
<pre> f f concord de c</pre>		23/06 14:29:14											ing
(0.00000, 2.000000) evisin: (-3.07, 3.37, 240.00) extent = (25.52, 29.52) Efft cel 15 cell 15 xyz z -3.07, 3.37, 240.00 ctason zoulze 0 wo finez Persteriyt Avents xy z z -3.07, 2.37, 240.00 ctason zoulze 0 wo finez Persteriyt Avents tazzz sur off click here or picture or mena N			0)										rhe
evisiti (-3.07, 3.37, 140.00) vol extent = (23.58, 23.52) fel . mat . . .	(0.000000, 1.0												
extent = (23.58, 23.58) fcl . fcl . max . gd . fcl . gd . gd . fcl . gd													den
fil max put max put fil max fug usu ext pid dec u lat fill fill fill fill max fug usu ext pid dec u lat fill													vel
rdit cel 15 cell 15 xyz = -3.07, 3.37, 140.00 cRRSUR SCALES 0 No Linex pestevrigt RCTATE color mat LEVIE xy YZ 12X LABEL sur off clik here or picture or menu N		•	-										fel
Zéit cel 15 cell 15 xyz z -3.07, 3.57, 140.00 constant for any solution of the solution	-												mas
Zéit cel 15 cell 15 xyz z -3.07, 3.57, 140.00 constant for any solution of the solution													pwt
Edit cel 15 cell 15 xyz z -3.07, 3.57, 140.00 conson scales 0 we lines postacript ROTATE color mat LEVEL xy y yz xx LABEL sur off click here or picture or menu w													
Edit cel 15 cell 15 xyz z -3.07, 3.57, 140.00 CGRSUR SCALEE 0 No Linex PostSorript ROTATE COLOR mat LEYEL XY YZ XX LABEL sur off click here or picture or menu N						1							
Edit cel 15 cell 15 xyz = -3.07, 3.57, 140.00 CGRSUR SCALEZ 0 No Lines Postacript ROTATE cOLOR mat LEYZL xy y7 x7 xx LBEL sur off click here or picture or menu N								\sim		. 7			tng
Edit cel 15 cell 15 xyz = -3.07, 3.57, 140.00 CGRSUR SCALEZ 0 No Linex Postacript ROTATE cOLOR mat LEYZL xy y7 x7 xx LBEL sur off click here or picture or menu N							N 🥗 -		HHT				
Edit cel 15 cell 15 xyz = -3.07, 3.37, 140.00 CGRSUR SCALEZ 0 No Linex Postacript ROTATE COLOR mat LEYZL XY YZ XX LAEEL sur off click here or picture or menu N							.		N N		N.	- 👝 🕗	ext
Idit cell 15 a cell 15 lat xyz -3.07, 3.57, 140.00 fill CGRSOR SCALEZE No Lines jik nona PostSoript ROTATZ so nona COLOR mot LEYZL poe xy YZ IX fel LABZL sur off fal click here or picture or menu N N							•		+		11	- 🕶 🗡	pd
Idit cell 15 a cell 15 lat xyz -3.07, 3.57, 140.00 fill CGRSOR SCALEZE No Lines jik nona PostSoript ROTATZ so nona COLOR mot LEYZL poe xy YZ IX fel LABZL sur off fal click here or picture or menu N N									- N				der
cell 15 lat xyz = -3.07, 3.37, 140.00 fill cGRSOR SCALEZ 0 No Lines PostSorrig t ROTATE cOLOR mat LEYZL nonu XY YZ LABZL sur LABZL sur click here or picture or menu N												and the second second	
xyz = -3.07, 3.37, 140.00 fill CGRSUR SCALEE 0 No Lines iik Postăcript ROJATE cour off XY YZ XX tal LAEEL sur off is click here or picture or menu N	Edit cel	Edit cel 15										æ	
CGR80R SCALES Ø No Lines ijk Postševigt ROTATE nonu COLOR mat LEYEL pac XY YZ XX tal LABEL sur off JAR Click here or picture or menu N		Cell	15						2				lat
Pertferrigt R07A72 R07A72 R07A02 C0L0R mat L2V2L Par XY YZ XX tal LABEL sur off FAR Click here or picture or menu N N	хуz = -3.07,	3.37, 14	0. 00										£111
COLOR mat LEVEL pace XY YZ LX tal LABEL sur off sur Click here or picture or menu N	CORSOR	SCALES 0 NO	Lines										ijk
COLOR mat LEVEL pace XY YZ LX tal LABEL sur off sur Click here or picture or menu N	PostSerie t	ROTATE											DODI
rry YZ ZX teal LABEL sur off Glick here or picture or menu N													
LABEL sur off AAR Click here or picture or menu N	COLOR mat		LEVEL										pac
MR Click here or picture or menu N	XY	YZ	2.X										tal
Click here or picture or menu N	LABEL	540*	eff.										
Click here or picture or menu N													
click here of picture of menu													PAR
click here of picture of menu													
Redrow Plot> End	Click here or p	icture or menu											
								Redraw		Plot>		End	



Monte Carlo Dose Calculations

Calculated Values

- Dose conversion coefficients (organ-averaged absorbed doses per unit air kerma free-in-air, D_T/K_a)
- Compared with the reported values from other models (KTMAN-2, Rex, VIP-Man)

Considered Geometries

- Antero-posterior (AP), postero-anterior (PA), left-lateral (LLAT), right-lateral (RLAT)
- ◆ 0.015, 0.03, 0.04, 0.05, 0.08, 0.2, 0.4, 0.6, 0.8, 2, 8, 10 MeV (12 photon energies)

Dose Scoring

- F6 tally (MeV/g) assuming CPE
- Statistical error <5 % (except for 0.015 MeV)



Percent Dose Deviation

Definition

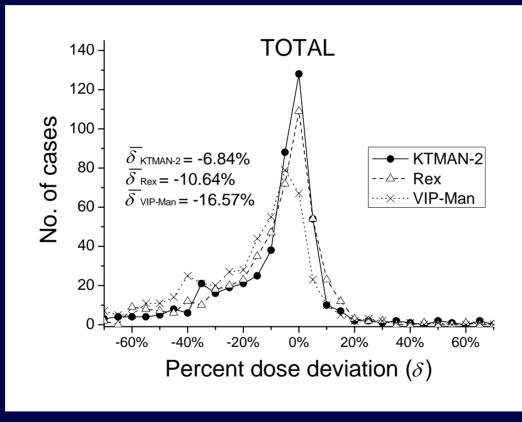
$$\delta = \frac{D_{M} - D_{HDRK-Man}}{D_{HDRK-Man}} \times 100\%$$

- It shows how much the dose conversion coefficient calculated by the voxel model M deviates from the value which calculated by HDRK-Man.
 - \rightarrow + value: D_M > D_{HDRK-Man}
 - ► value: D_M < D_{HDRK-Man}



Organ Dose Comparison

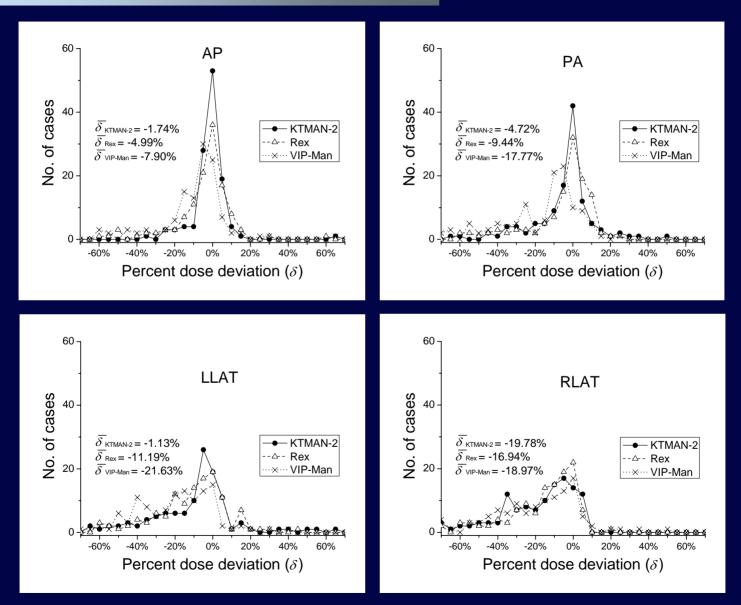




Considered: 4 irradiation geometries, 11 photon energies (0.03 - 10 MeV), 11 major organs, total 484 cases



Organ Dose Comparison (Continued)



Radiation Interactions and Dosimetry Laboratory

Summary

HDRK-Man

- Using high-resolution color photographic slice images
- Body height, weight, skeleton mass, organ dimensions adjusted to the Reference Korean data
- HDRK-Man adequately represents the average Korean workers

Medical Applications

- More precise model is needed
- Unadjusted model can be used instead

Higher voxel resolution

- Voxel resolution can be increased by factor of 10 for any part of the model
- Example

≻Eye: 0.1981 mm x 0.1981 mm x 0.20854 mm

➢ Remainder: 1.981 mm x 1.981 mm x 2.0854 mm

Radiation Interactions and Dosimetry Laboratory

Thank you …

