Impact of ICRP-89 Based Models on Dose Estimates for Radiopharmaceuticals and CT Exams

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Vanderbilt University Nashville, TN, USA

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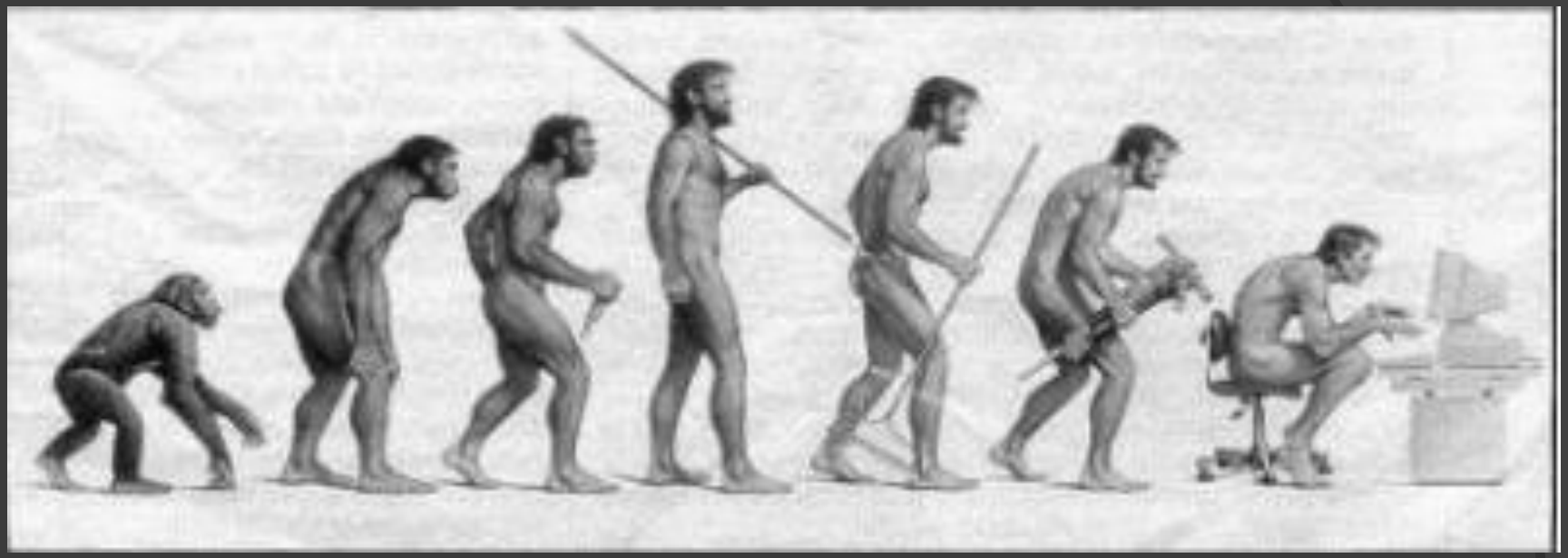
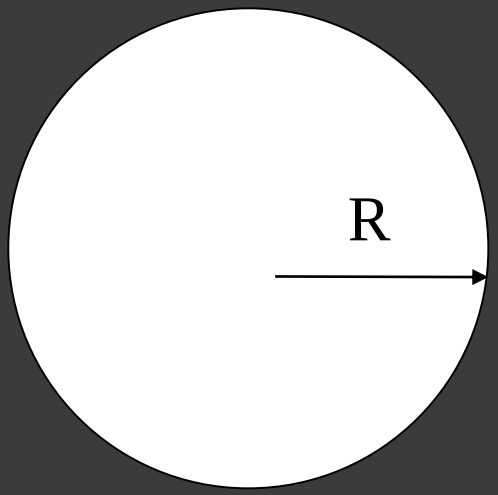
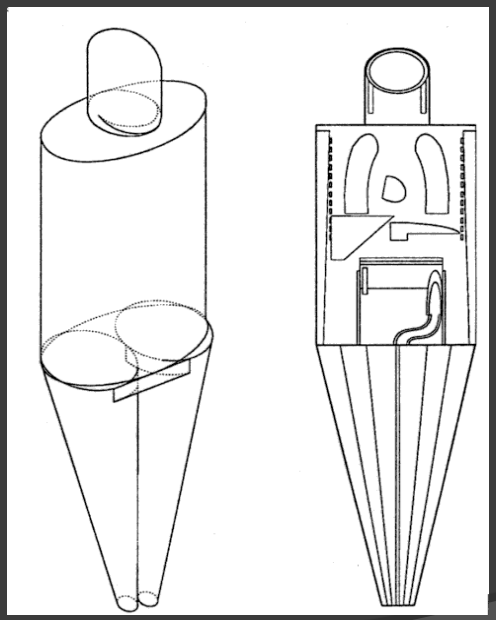
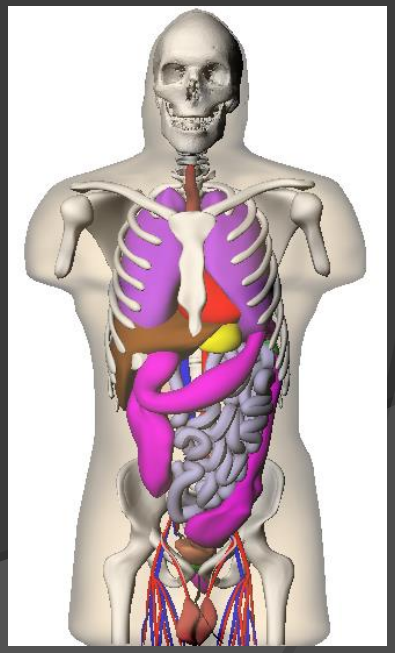
Radiation Protection Association

Glasgow, Scotland, May 14, 2012

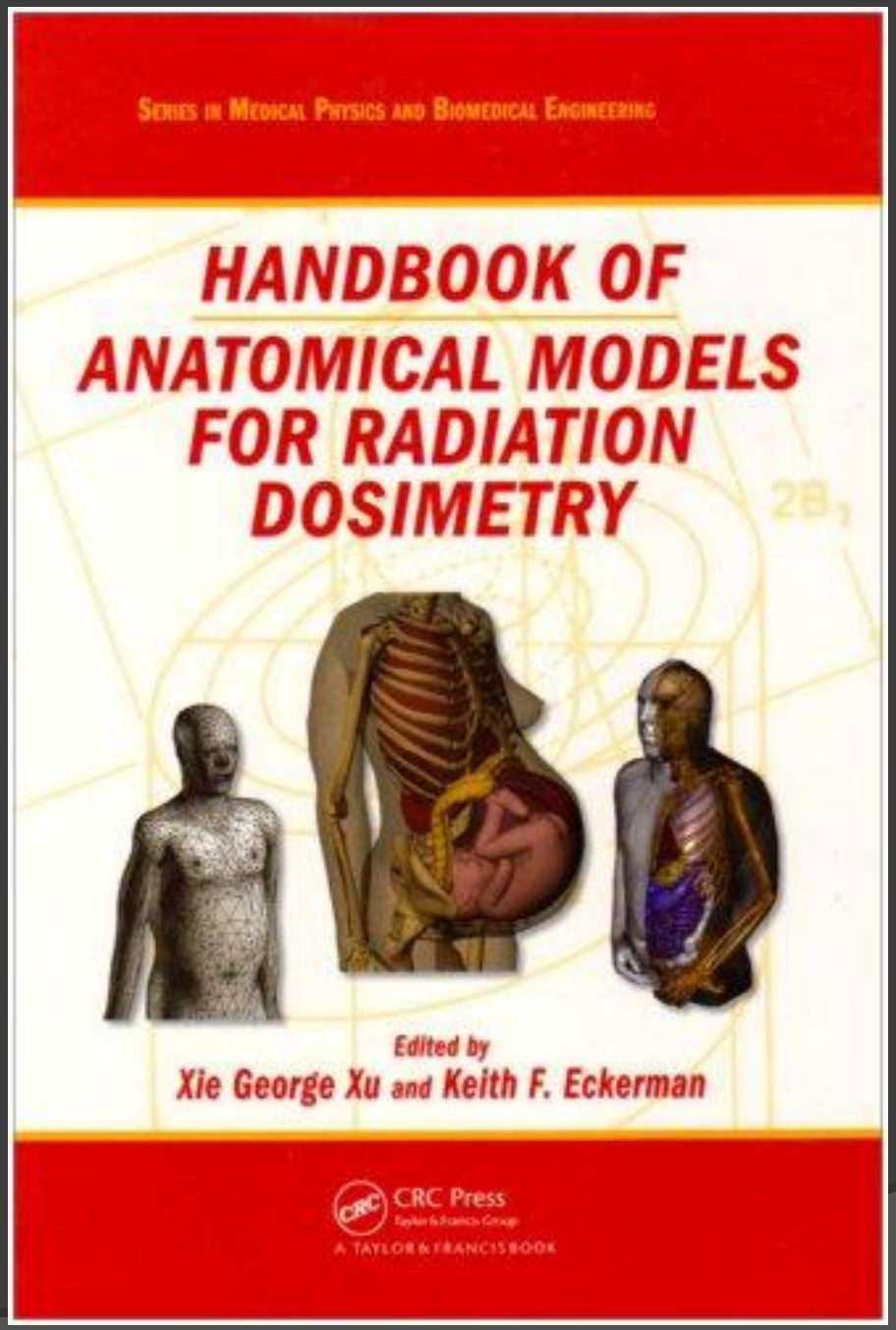








1959 **1975** **2001**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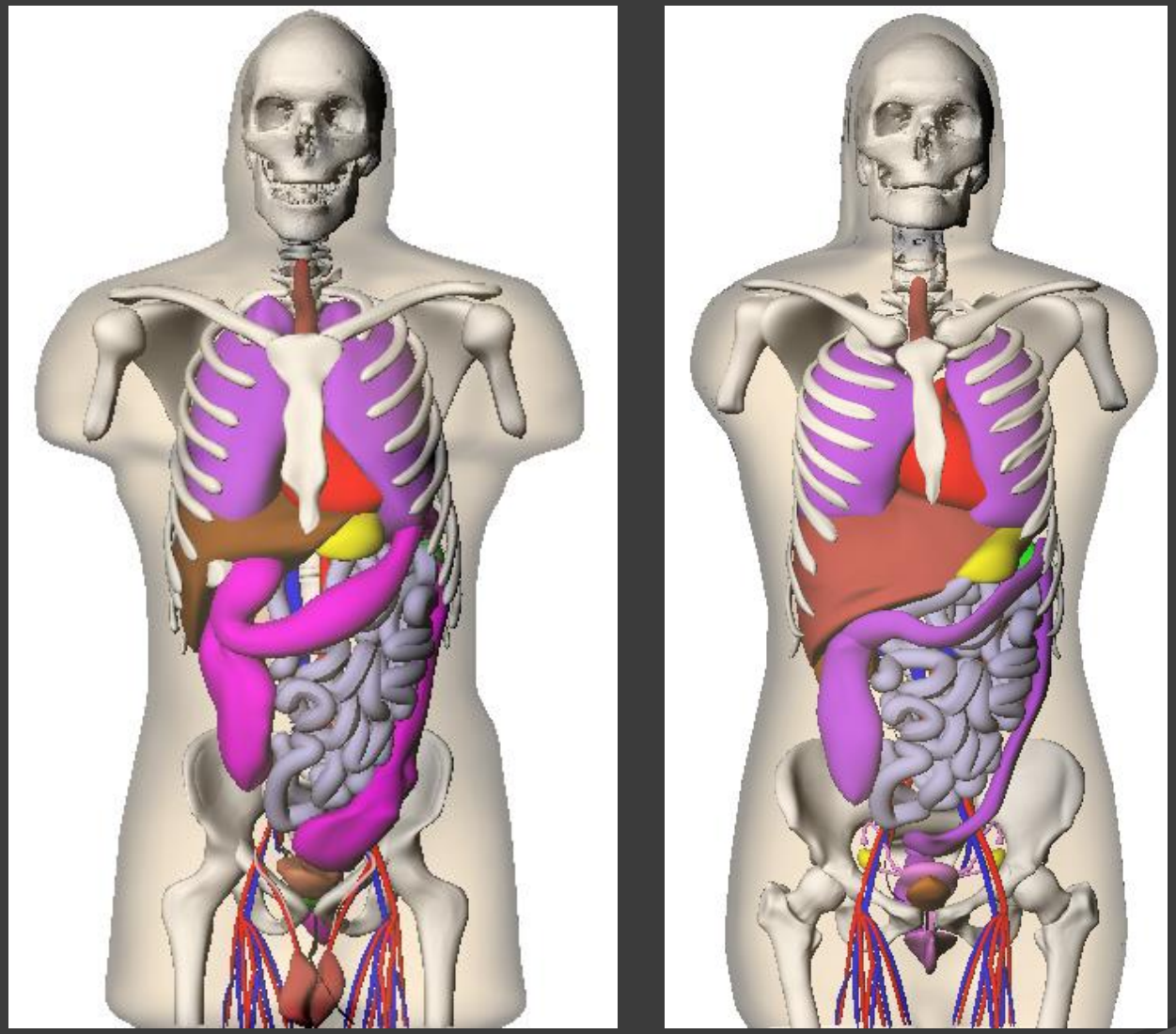
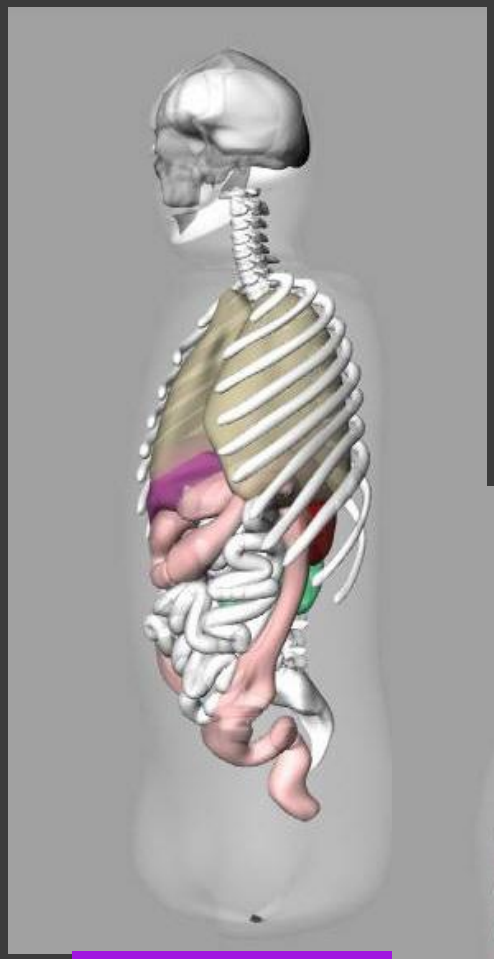


Anterior views of the NURBS models of the adult male (left) and adult female (right)



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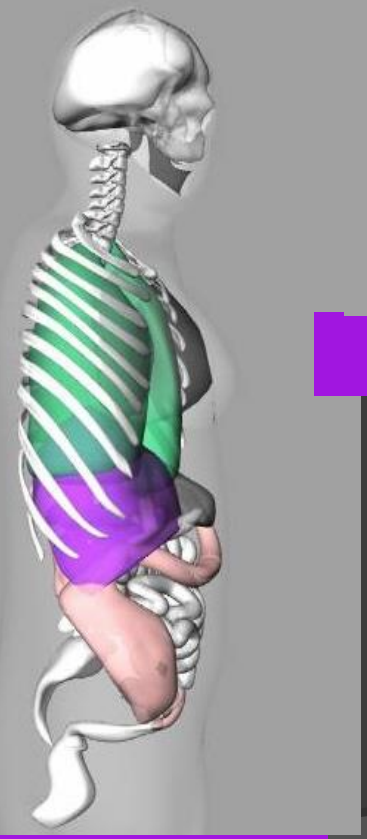

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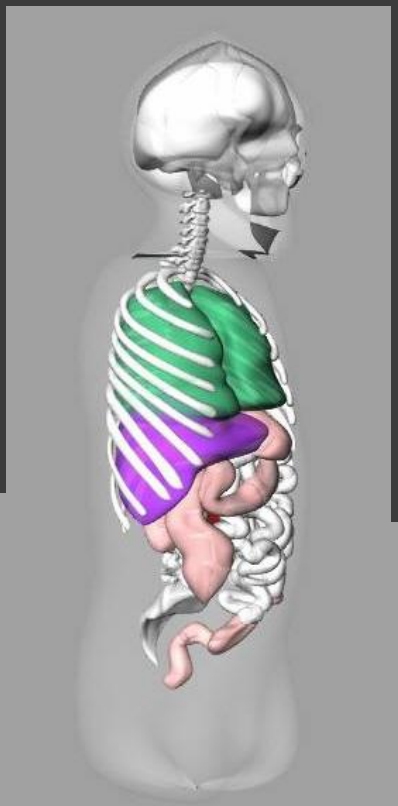
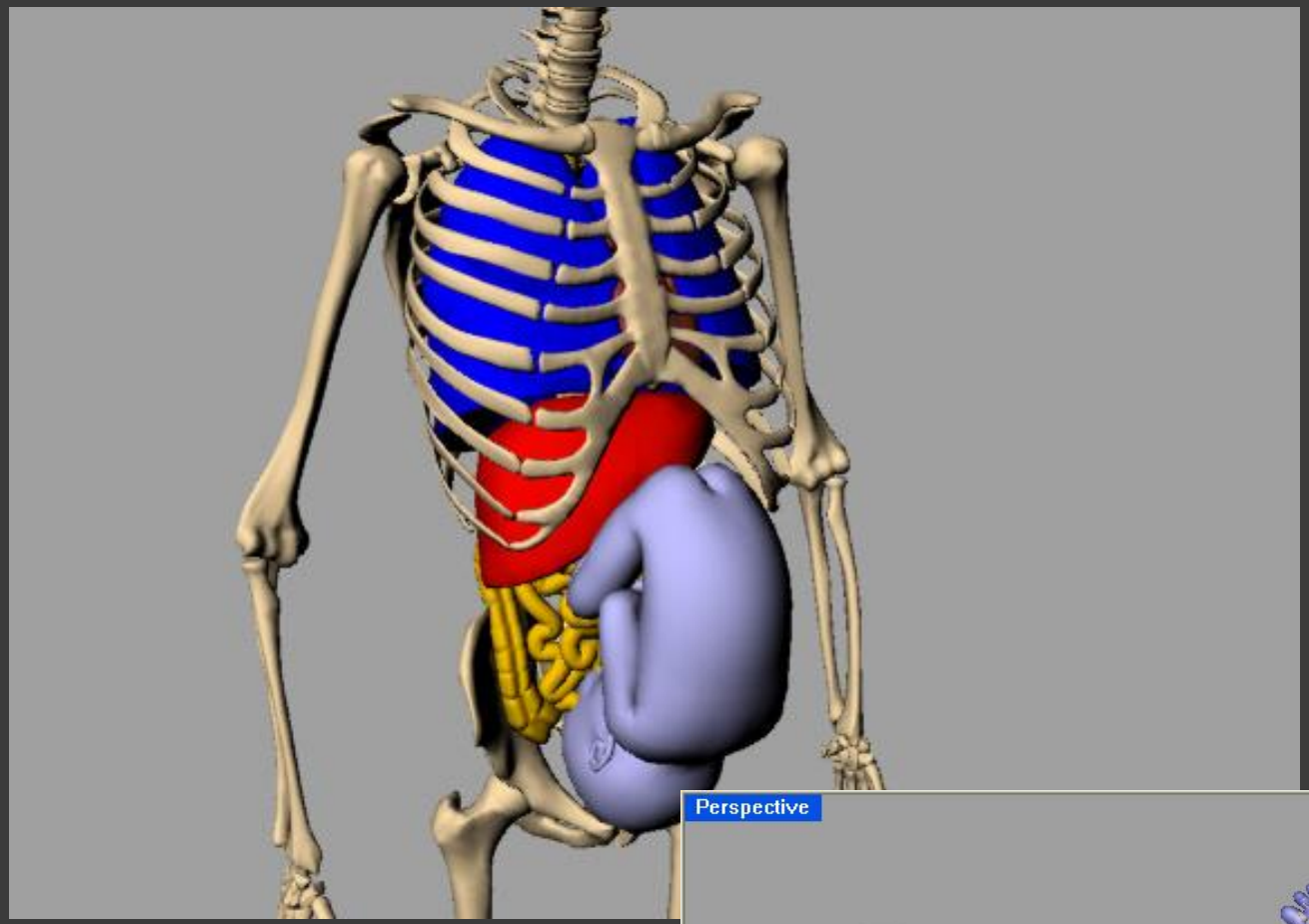


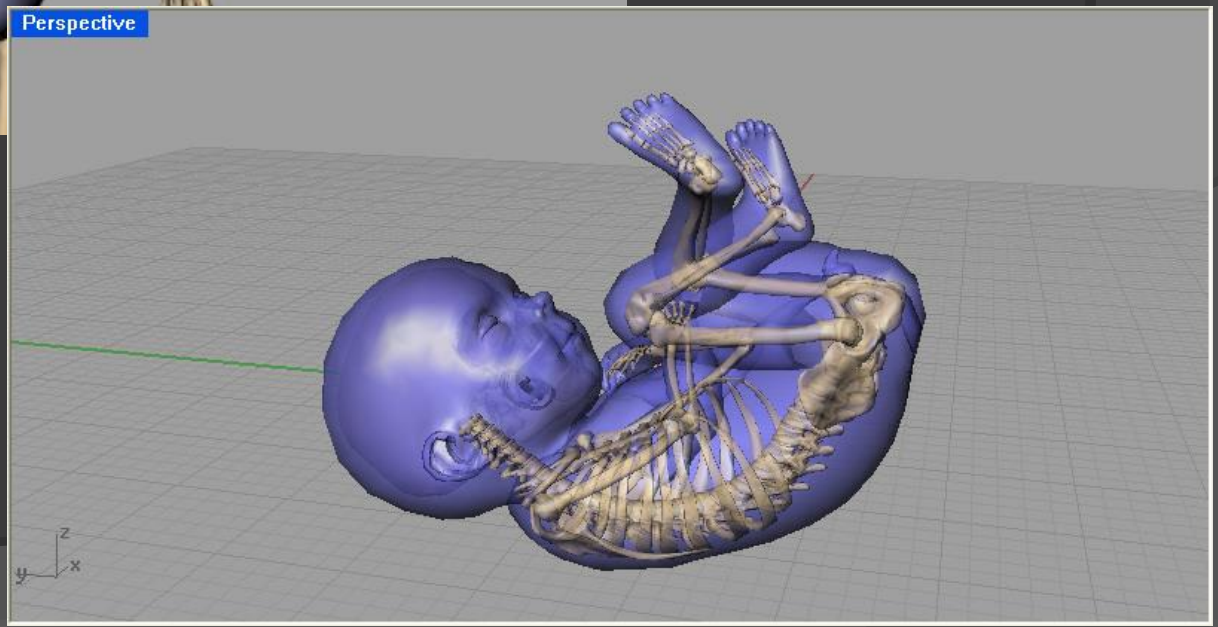
10-yr-old Male

10-yr-old Female

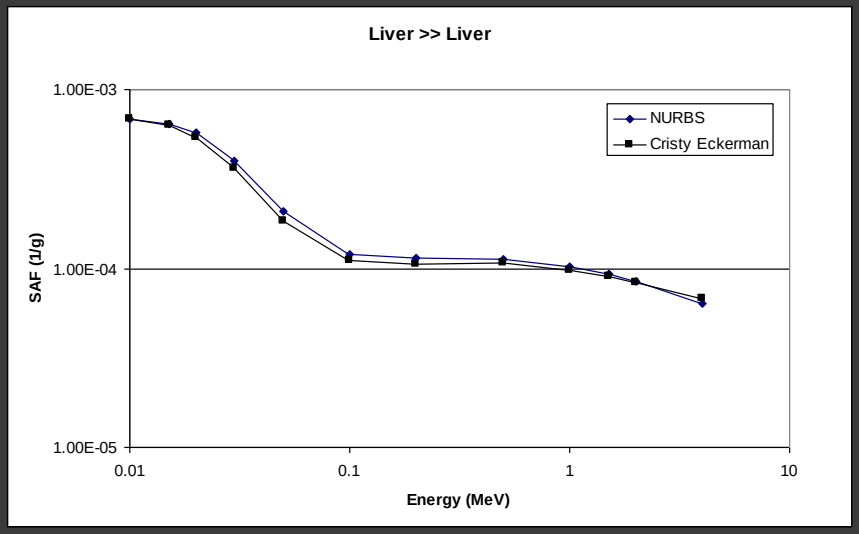
5-yr-old Male

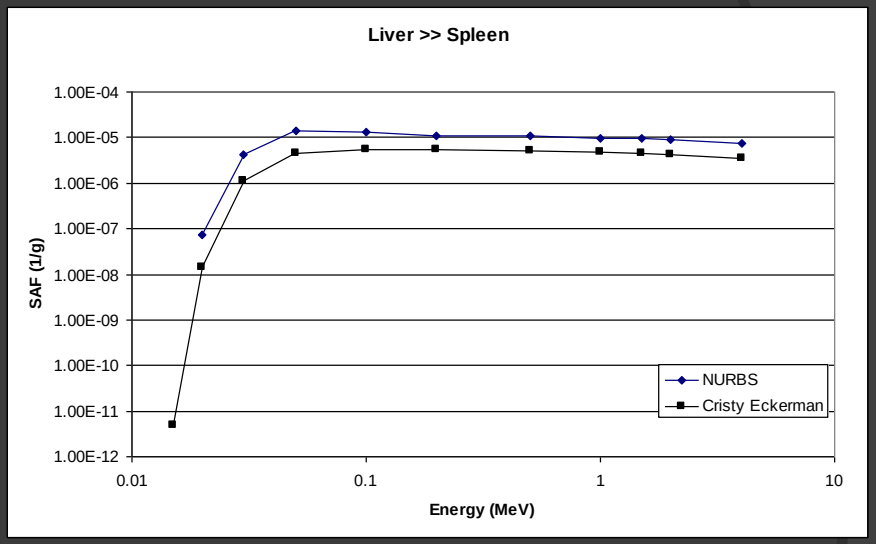


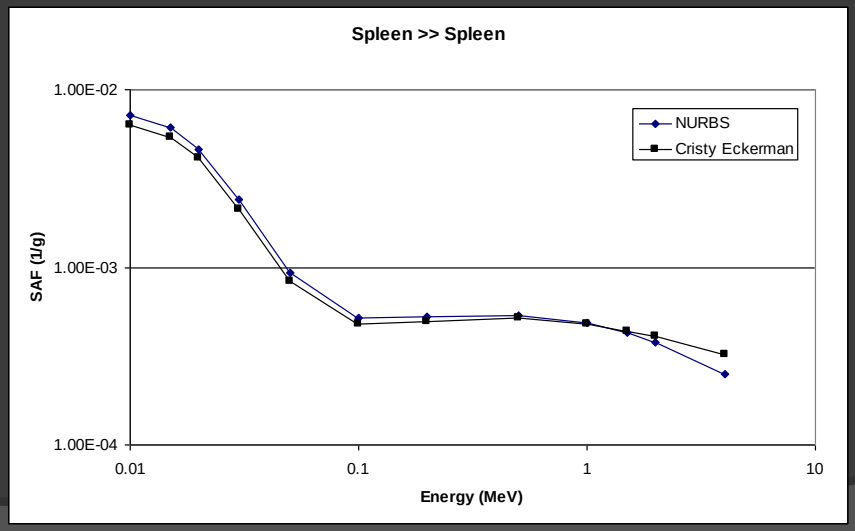
Xu et al., Rensselaer Polytechnic Institute, Troy, NY

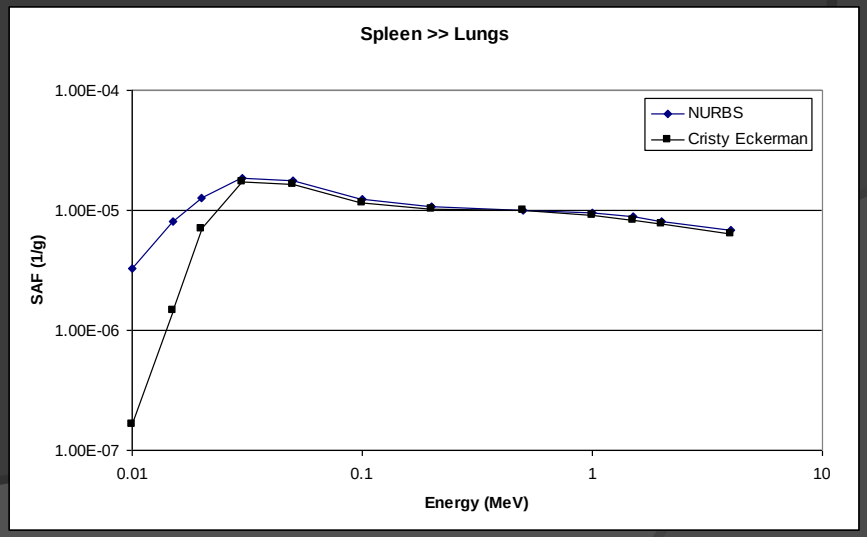


Selected photon SAF values, adult female

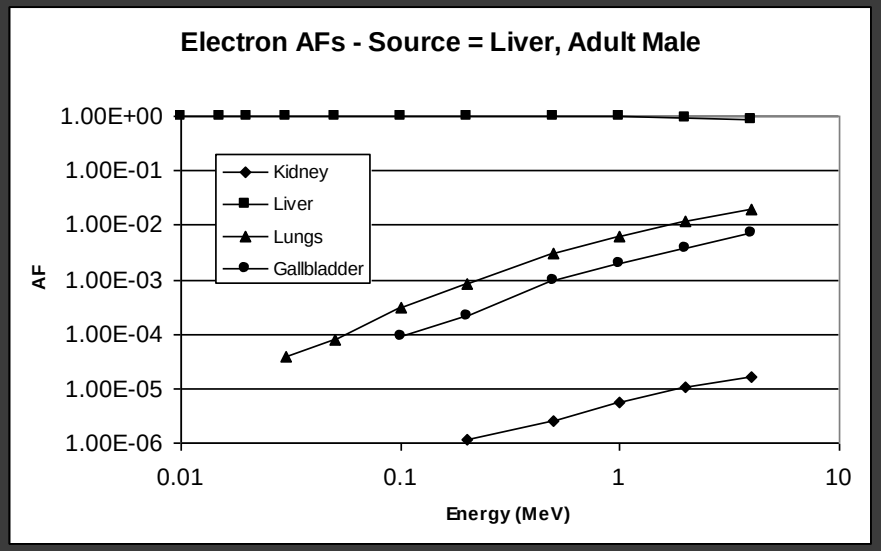


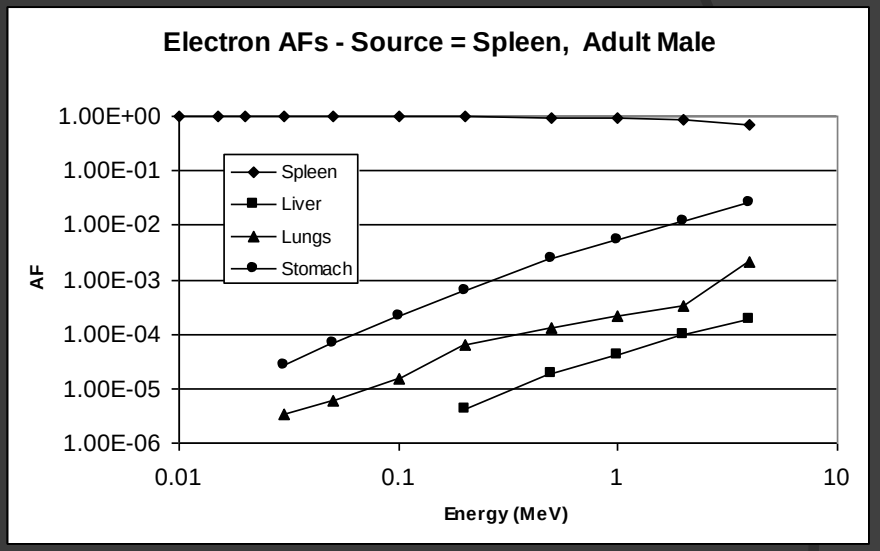


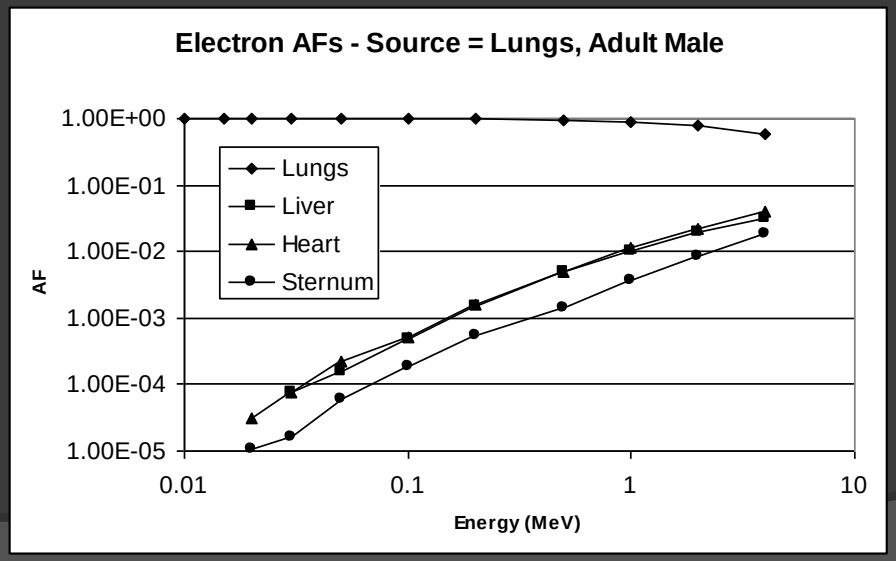


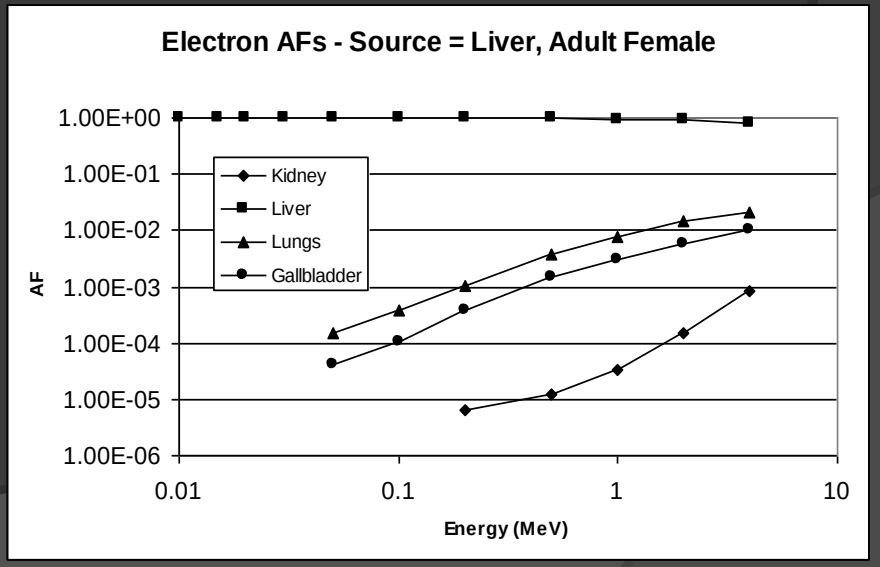


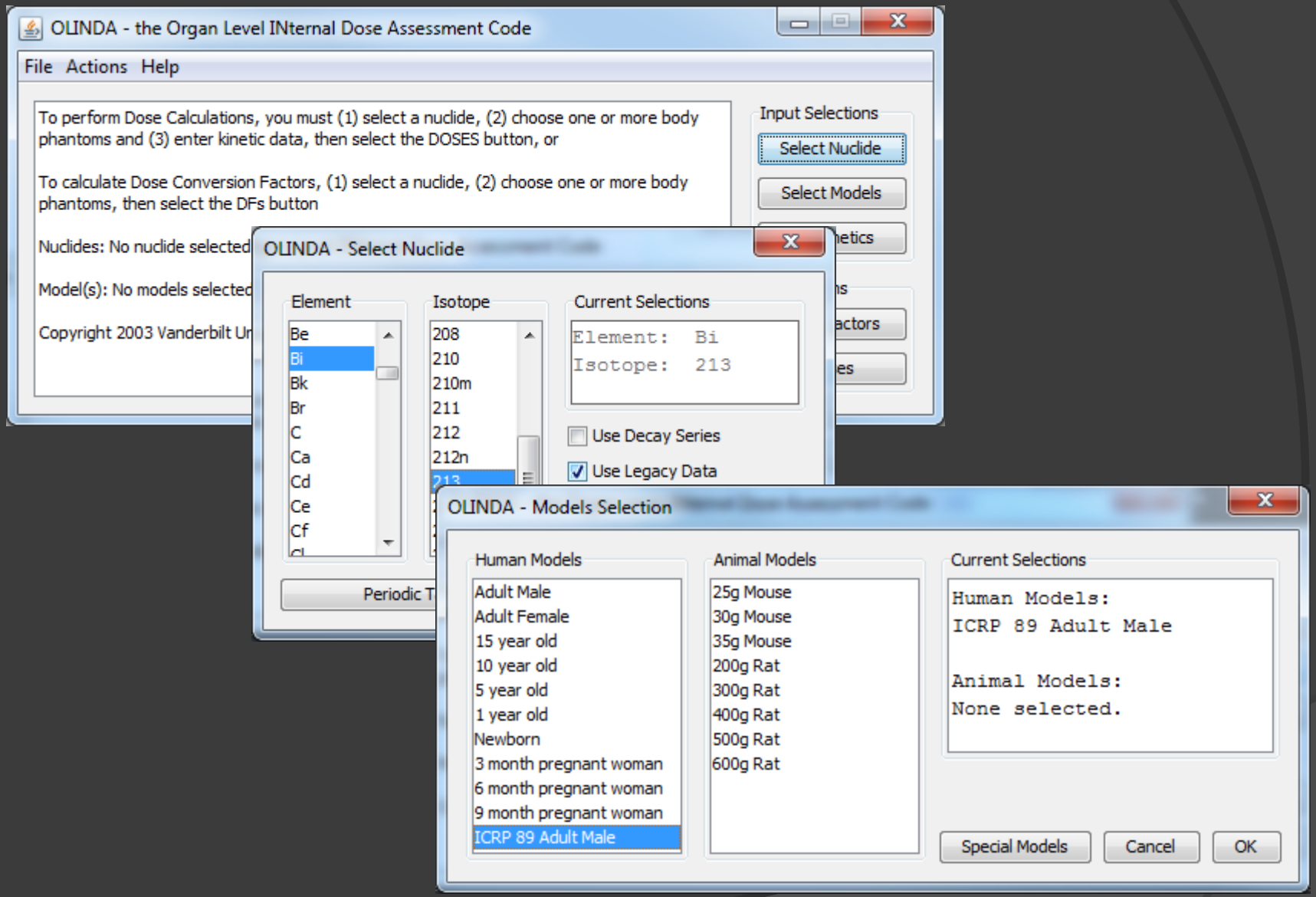
Selected electron SAF values

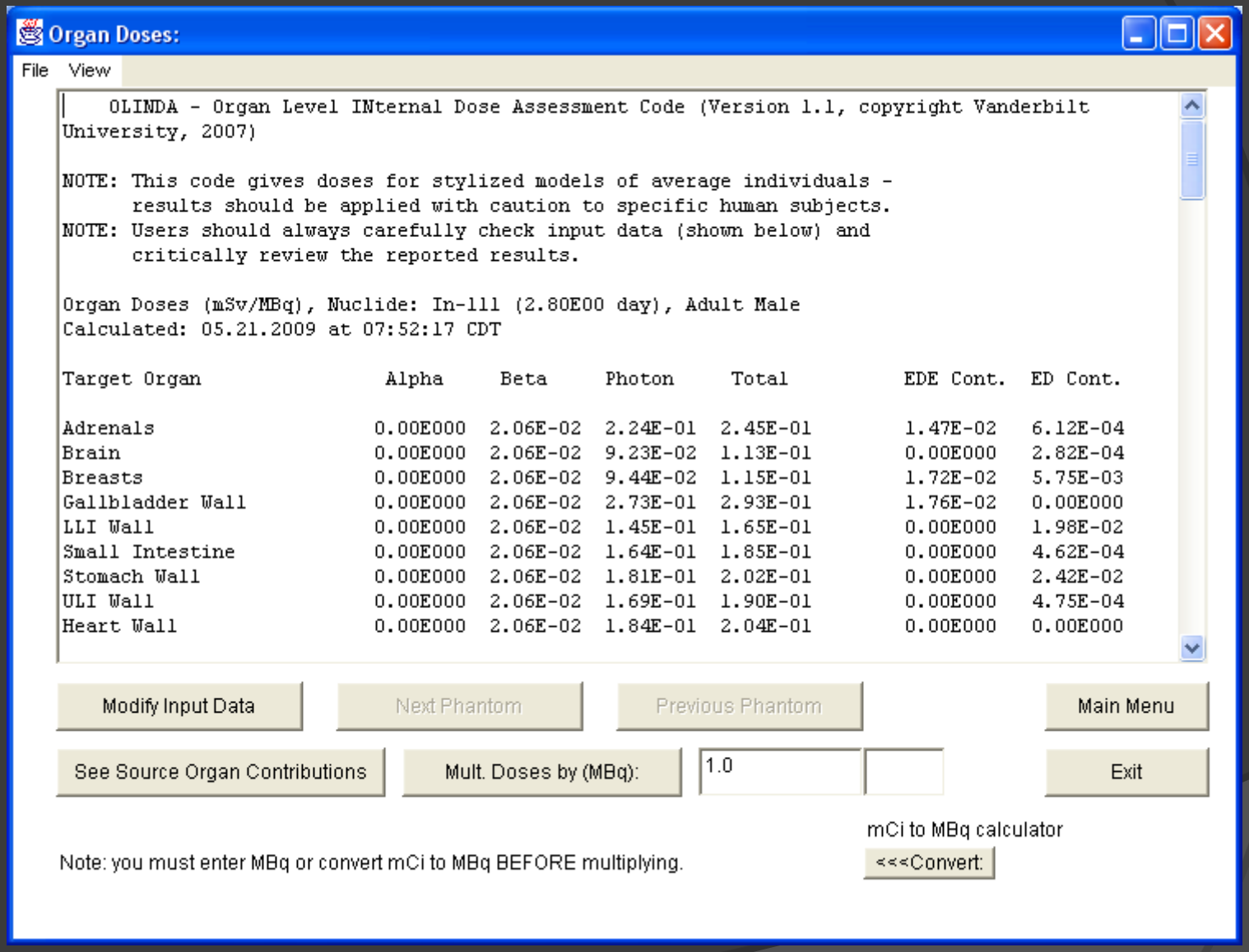




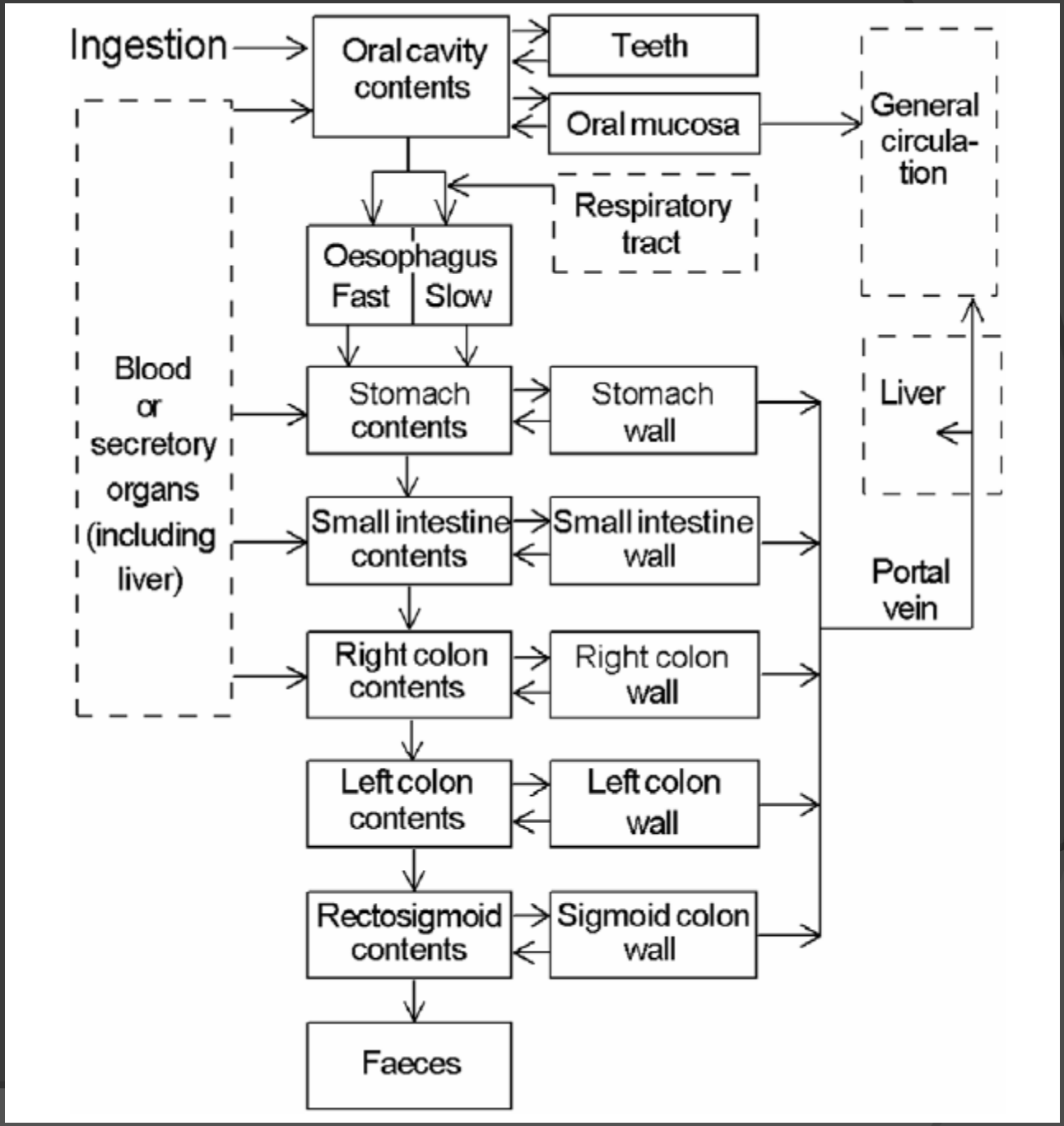





OLINDA - the Organ Level INternal Dose Assessment Code
File Actions Help
To perform Dose Calculations, you must (1) select a nuclide, (2) choose one or more body phantoms and (3) enter kinetic data, then select the DOSES button, or
To calculate Dose Conversion Factors, (1) select a nuclide, (2) choose one or more body phantoms, then select the DFs button
Nuclides: No nuclide selected
Model(s): No models selected
Copyright 2003 Vanderbilt Un
Input Selections
Select Nuclide
Select Models
OLINDA - Select Nuclide
Element
Be
Bi
Bk
Br
C
Ca
Cd
Ce
Cf
Isotope
208
210
210m
211
212
212n
213
Current Selections
Element: Bi
Isotope: 213
Use Decay Series
Use Legacy Data
OLINDA - Models Selection
Human Models
Adult Male
Adult Female
15 year old
10 year old
5 year old
1 year old
Newborn
3 month pregnant woman
6 month pregnant woman
9 month pregnant woman
ICRP 89 Adult Male
Animal Models
25g Mouse
30g Mouse
35g Mouse
200g Rat
300g Rat
400g Rat
500g Rat
600g Rat
Current Selections
Human Models:
ICRP 89 Adult Male
Animal Models:
None selected.
Special Models
Cancel
OK


Organ Doses:
File View
OLINDA - Organ Level INternal Dose Assessment Code (Version 1.1, copyright Vanderbilt University, 2007)
NOTE: This code gives doses for stylized models of average individuals - results should be applied with caution to specific human subjects.
NOTE: Users should always carefully check input data (shown below) and critically review the reported results.
Organ Doses (mSv/MBq), Nuclide: In-111 (2.80E00 day), Adult Male
Calculated: 05.21.2009 at 07:52:17 CDT
Target Organ Alpha Beta Photon Total EDE Cont. ED Cont.
Adrenals 0.00E000 2.06E-02 2.24E-01 2.45E-01 1.47E-02 6.12E-04
Brain 0.00E000 2.06E-02 9.23E-02 1.13E-01 0.00E000 2.82E-04
Breasts 0.00E000 2.06E-02 9.44E-02 1.15E-01 1.72E-02 5.75E-03
Gallbladder Wall 0.00E000 2.06E-02 2.73E-01 2.93E-01 1.76E-02 0.00E000
LLI Wall 0.00E000 2.06E-02 1.45E-01 1.65E-01 0.00E000 1.98E-02
Small Intestine 0.00E000 2.06E-02 1.64E-01 1.85E-01 0.00E000 4.62E-04
Stomach Wall 0.00E000 2.06E-02 1.81E-01 2.02E-01 0.00E000 2.42E-02
ULI Wall 0.00E000 2.06E-02 1.69E-01 1.90E-01 0.00E000 4.75E-04
Heart Wall 0.00E000 2.06E-02 1.84E-01 2.04E-01 0.00E000 0.00E000
Modify Input Data
Next Phantom
Previous Phantom
Main Menu
See Source Organ Contributions
Mult. Doses by (MBq):
1.0
Exit
mCi to MBq calculator
Note: you must enter MBq or convert mCi to MBq BEFORE multiplying.
<<<Convert:

ICRP 100 – New Human Alimentary Tract (HAT) model



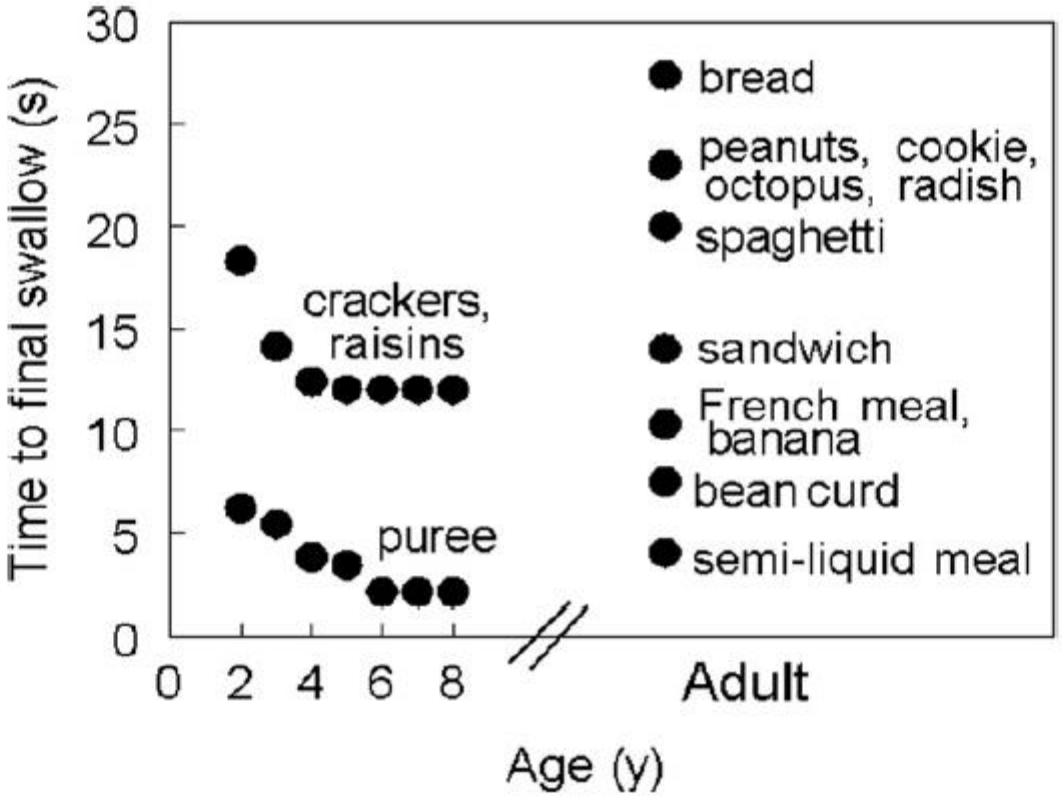


Fig. 6.1. Differences in residence times in the mouth with age and food type. Based on data summarised in Annex C.

Intestinal Surgery…Ouch!

ICRP 100:
Right colon = Ascending plus right half of transverse colon
Left colon = Left half of transverse colon + descending colon

ICRP 30:
Upper Large Intestine = Ascending plus transverse
Lower Large Intestine = Descending plus sigmoid colon

ICRP 100

	Adult Males	Adult Females	15-yr olds	10-yr olds	5-yr olds	1-yr olds	Newborns
Stomach	1.17	1.58	1.17	1.17	1.17	1.17	1.25
Small Intestine	4	4	4	4	4	4	4
Right Colon	12	16	11	11	11	10	8
Left Colon	12	16	11	11	11	10	8
Rectosigmoid	12	16	12	12	12	12	12
Total	41	54	39	39	39	37	33

ICRP 30

Age	Total GI Transit time (h)
Adults	42
15-yr olds	42
10-yr olds	42
5-yr olds	33
1-yr olds	8.5
Newborns	6.5

Oral administration of Tc-99m, Adult Male, Bq-hr/Bq:

ICRP 100

	Solids	Caloric Liquids	Noncaloric Liquids	Total Diet
Esophagus (40 g)	0.00325	0.00208	0.00208	0.00286
Stomach (150/250 g)*	1.09	0.690	0.473	1.03
Small Intestine (650/350 g)	2.39	2.52	2.59	2.41
Right Colon (150/150 g)	3.01	3.17	3.26	3.03
Left Colon (150/75 g)	1.26	1.33	1.37	1.27
Rectosigmoid (70/75 g)	0.530	0.558	0.573	0.534

ICRP 30

Stomach (158/260 g)	0.897
Small Intestine (677/423 g)	2.45
Upper Large Intestine (220/232 g)	3.19
Lower Large Intestine (167/143 g)	1.56

* = wall/content masses

Tissue Weighting Factors for the ‘Effective Dose’

Organ	ICRP 30	ICRP 60	ICRP 102
Gonads	0.25	0.20	0.08
Red Marrow	0.12	0.12	0.12
Colon		0.12	0.12
Lungs	0.12	0.12	0.12
Stomach		0.12	0.12
Bladder		0.05	0.04
Breasts	0.15	0.05	0.12
Liver		0.05	0.04
Esophagus		0.05	0.04
Thyroid	0.03	0.05	0.04
Skin		0.01	0.01
Bone Surfaces	0.03	0.01	0.01
Salivary glands, brain			0.01
Remainder	0.30	0.05	0.12

New Organs!!

- Esophagus
- Prostate gland
- Salivary glands
- Eyes
- GI tract regions redefined

Radiation Dose Estimates (mSv/MBq) for F-18 FDG

Biokinetic data: ICRP 106 recommended model

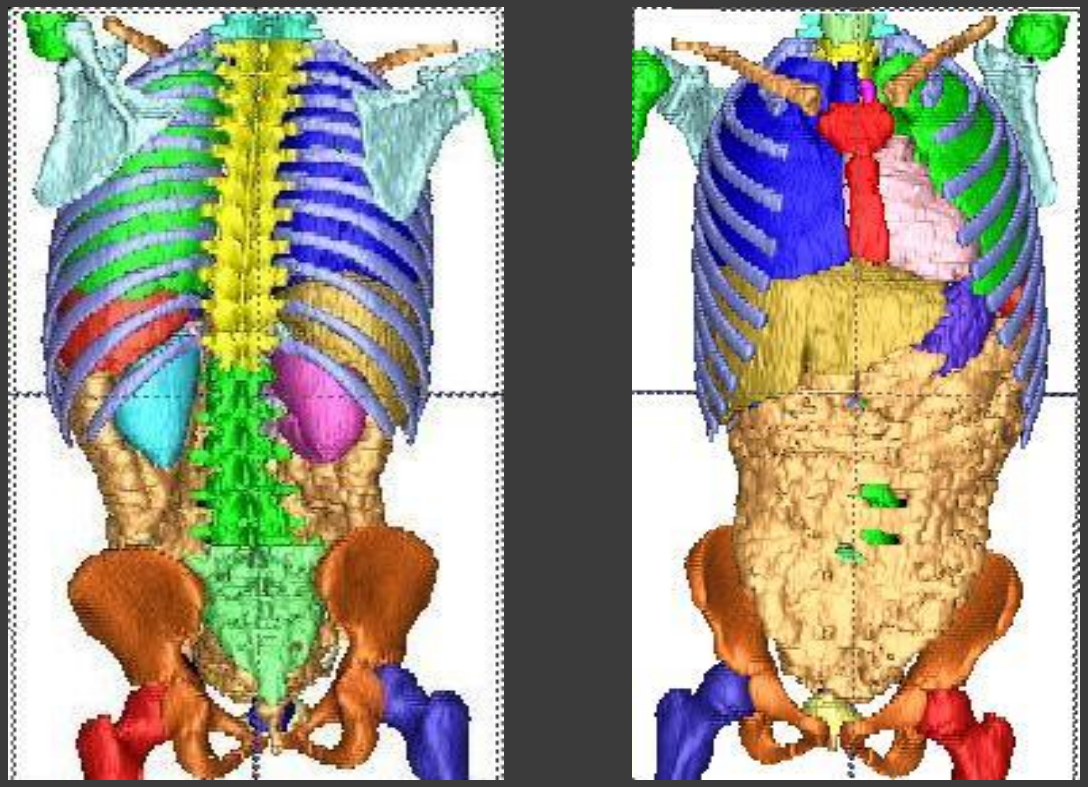
Physical models: RADAR ICRP 89 Reference Phantom Series

Effective doses: ICRP 103 weighting factors

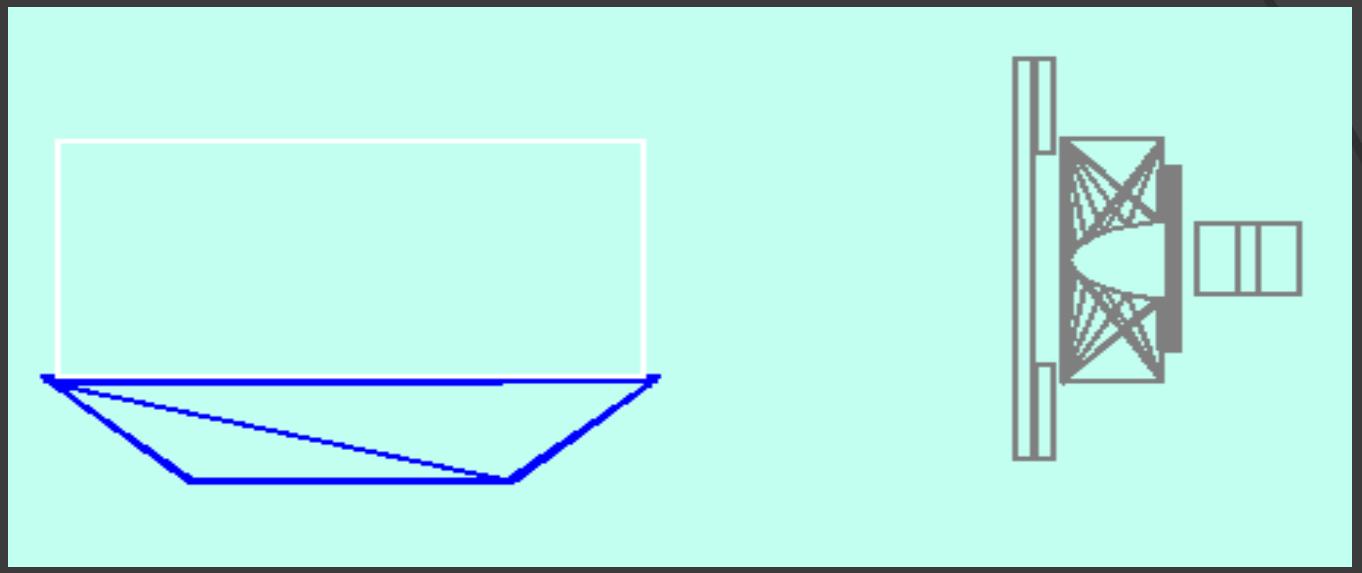
	Males				
	Adult	15-yo	10-yo	5-yo	1-yo
Adrenals	1.35E-02	1.73E-02	2.57E-02	4.07E-02	7.06E-02
Brain	3.56E-02	3.65E-02	3.79E-02	4.21E-02	5.79E-02
Breasts	7.01E-03	8.95E-03	- - -	- - -	- - -
Esophagus	1.28E-02	1.63E-02	2.61E-02	4.21E-02	7.73E-02
Eyes	1.03E-02	1.26E-02	1.88E-02	2.94E-02	5.14E-02
Gallbladder Wall	1.42E-02	1.70E-02	2.56E-02	3.77E-02	6.46E-02
Left colon	1.15E-02	1.35E-02	2.23E-02	3.44E-02	6.01E-02
Small Intestine	1.24E-02	1.55E-02	2.49E-02	3.89E-02	6.78E-02
Stomach Wall	1.25E-02	1.55E-02	2.37E-02	3.71E-02	6.44E-02
Right colon	1.18E-02	1.45E-02	2.26E-02	3.55E-02	6.16E-02
Rectum	1.58E-02	1.90E-02	3.26E-02	4.80E-02	7.42E-02
Heart Wall	6.35E-02	8.73E-02	1.40E-01	2.24E-01	3.79E-01
Kidneys	2.05E-02	2.53E-02	3.49E-02	5.54E-02	8.76E-02
Liver	2.21E-02	2.92E-02	4.28E-02	6.19E-02	1.03E-01
Lungs	1.76E-02	2.29E-02	3.74E-02	5.92E-02	1.12E-01
Pancreas	1.28E-02	1.62E-02	2.52E-02	3.94E-02	7.12E-02
Prostate	1.83E-02	2.21E-02	5.51E-02	4.97E-02	6.97E-02
Salivary Glands	1.14E-02	1.42E-02	2.17E-02	3.35E-02	5.88E-02
Red Marrow	9.75E-03	1.47E-02	2.23E-02	3.08E-02	5.48E-02
Osteogenic Cells	1.53E-02	2.07E-02	3.17E-02	4.51E-02	8.58E-02
Spleen	1.05E-02	1.34E-02	2.07E-02	3.39E-02	6.03E-02
Testes	1.02E-02	1.29E-02	2.44E-02	3.11E-02	5.54E-02
Thymus	1.33E-02	1.72E-02	2.48E-02	4.01E-02	7.07E-02
Thyroid	1.01E-02	1.29E-02	2.08E-02	3.39E-02	6.18E-02
Urinary Bladder Wall	1.36E-01	1.69E-01	2.55E-01	3.47E-01	4.62E-01
Effective Doses	1.73E-02	2.21E-02	3.26E-02	4.76E-02	7.83E-02

Comparison of Effective Doses (mSv/MBq administered) for selected radiopharmaceuticals for five reference phantoms.

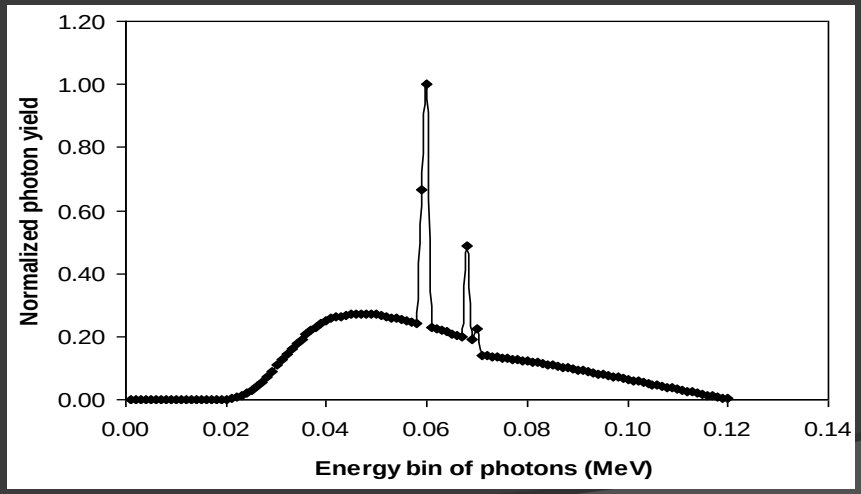
		Adult	15-yr	10-yr	5-yr	1-yr
^{18}FDG	Old	1.86E-02	2.39E-02	3.58E-02	5.29E-02	8.90E-02
	New	1.73E-02	2.21E-02	3.26E-02	4.76E-02	7.83E-02
	Ratio	9.30E-01	9.25E-01	9.11E-01	9.00E-01	8.80E-01
^{11}C Acetate	Old	3.03E-03	3.77E-03	5.70E-03	8.60E-03	1.59E-02
	New	2.88E-03	3.72E-03	5.41E-03	8.20E-03	1.38E-02
	Ratio	9.50E-01	9.87E-01	9.49E-01	9.53E-01	8.68E-01
^{99m}Tc MAA	Old	1.17E-02	1.64E-02	2.35E-02	3.54E-02	6.56E-02
	New	1.10E-02	1.40E-02	2.21E-02	3.31E-02	5.85E-02
	Ratio	9.40E-01	8.54E-01	9.40E-01	9.35E-01	8.92E-01
111In Octreotide	Old	5.15E-02	6.76E-02	1.01E-01	1.49E-01	2.42E-01
	New	5.09E-02	6.34E-02	9.19E-02	1.30E-01	2.02E-01
	Ratio	9.88E-01	9.38E-01	9.10E-01	8.72E-01	8.35E-01
^{123}I BMIPP	Old	1.51E-02	1.92E-02	2.94E-02	4.44E-02	8.05E-02
	New	1.49E-02	1.94E-02	2.79E-02	4.08E-02	7.13E-02
	Ratio	9.87E-01	1.01E+00	9.49E-01	9.19E-01	8.86E-01



Segmented organs in 9-year-old female patient

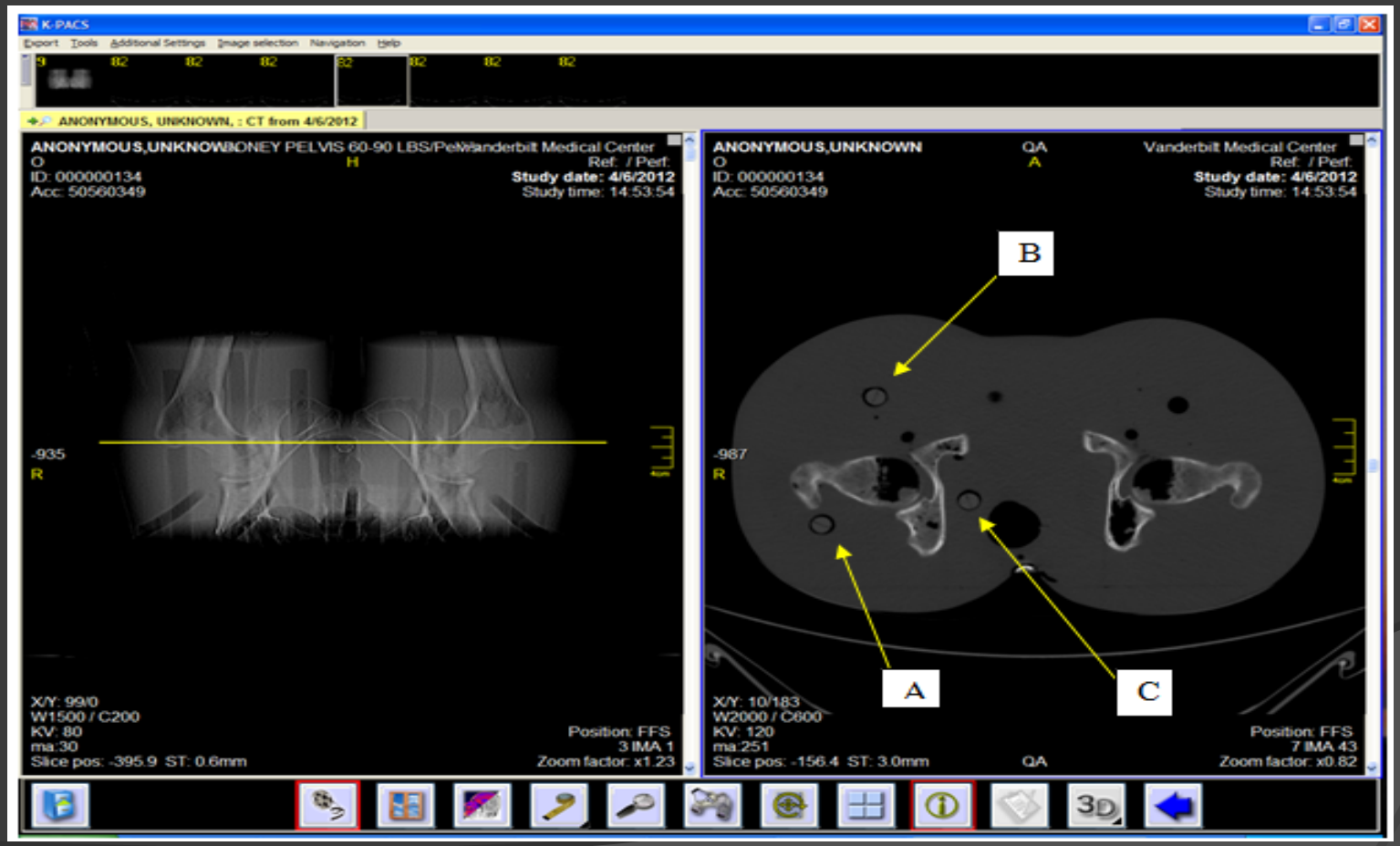


Graphic representation of the rotating CT source created in the GEANT4 environment for estimation of CT doses to subjects. The CT head is at the right, the trapezoidal structure at the bottom is the imaging table and the rectangular space above is where voxelized patient structures are located.



Photon energy spectrum generated by the GEANT4 source module, using 120 keV electrons as the source.

Optically Stimulated Luminescence (OSL) CT dosimeters © Landauer, Inc.



Patient demographics and examination details for pediatric subjects receiving CT examinations

Subject No.	Age, gender	Exam type	mAs	pitch
1	6 mo male	CAP	100	1.176
2	1 yo male	CAP	100	1.176
3	2 yo male	CAP	100	1.176
4	4 yo male	CAP	107	0.924
5	5 yo male	CAP	75	0.924
6	6 yo male	CAP	110	0.906
7	8 yo male	CAP	117	1.176
8	8 yo male	CAP	88	0.924
9	10 mo female	AP	60	1.176
10	4 yo female	CAP	110	0.906
11	9 yo female	CAP	180	0.906
12	14 yo female	CAP	160	1.077

All studies: 120 kVp. CAP=Chest/Abdomen/Pelvis, AP=Abdomen/Pelvis

Doses to selected organs and effective doses for pediatric subjects receiving CT examinations

	Organ doses (mGy) and Effective Doses (mSv)					
Subject	1	2	3	4	5	6
Adrenals	12.5	10.5	11.2	15.1	10.6	13.4
Esophagus	11.1	10.3	10.5	14.6	10.4	13.8
Intestine	12.8	11.5	8.9	16.4	11.0	16.0
Kidneys	12.6	11.3	12.0	15.7	11.0	15.8
Liver	12.1	11.4	11.4	15.1	11.0	15.4
Lungs	12.4	11.4	11.6	15.8	11.3	15.3
Stomach	12.9	11.4	11.4	16.5	11.1	15.6
Spleen	12.4	11.0	12.1	16.4	11.0	14.9
Thymus	11.5	11.0	10.8	14.6	10.4	15.1
Thyroid	8.7	9.5	9.4	12.2	7.6	13.0
$CTDI_{vol}$	7	7	7	7.49	5.3	6.5
ED ICRP 60	10.5	9.6	9.4	13.3	8.9	12.7
ED ICRP 103	10.6	9.7	9.5	13.4	9.0	12.8
CTDIvol	7.0	7.0	7.0	7.5	6.5	6.5
ImPACT scaled ED	17.2	15.8	14.6	18.7	12.3	15.8

	Organ doses (mGy) and Effective Doses (mSv)`					
Subject	7	8	9	10	11	12
Adrenals	10.5	10.3	3.5	15.8	23.4	13.9
Esophagus	10.9	10.8	2.3	14.8	22.5	12.9
Intestine	11.8	11.9	3.0	17.1	24.0	14.8
Kidneys	11.8	11.4	3.2	16.7	25.6	15.3
Liver	12.0	12.1	3.7	16.2	24.1	15.9
Lungs	12.1	12.1	9.0	15.8	24.6	14.3
Stomach	11.7	11.7	3.3	17.2	23.9	16.1
Spleen	11.5	11.2	3.6	15.0	23.2	14.9
Thymus	11.1	12.0	0.0	14.9	0.0	13.1
Thyroid	10.2	8.5	0.0	15.6	23.2	0.0
$CTDI_{vol}$	8.19	6.2	4.2	6.5	10.6	11.2
ED ICRP 60	12.0	9.6	2.5	14.0	24.4	14.5
ED ICRP 103	10.8	9.7	2.6	14.2	22.1	14.4
CTDIvol	8.2			6.5	10.6	11.2
ImPACT scaled ED	14.3	13.7	7.1	16.8	23.2	15.4

Doses to selected organs and effective doses for NURBS models, with comparison to selected pediatric patient data

	10-yo female phantom	9-yo female patient	Ratio	15-yo female phantom	14-yo female patient	Ratio
Adrenals	25.0	23.4	0.94	13.7	13.9	1.01
Brain	4.1	4.0	0.99	2.5	1.9	0.74
Esophagus	26.0	22.5	0.86	14.3	12.9	0.90
Intestine	25.0	24.0	0.96	13.9	14.8	1.06
Heart	27.6	27.4	0.99	19.8	14.7	0.74
Kidneys	26.1	25.6	0.98	14.4	15.3	1.06
Liver	26.5	24.1	0.91	14.7	15.9	1.08
Lungs	28.0	24.6	0.88	15.6	14.3	0.92
Stomach	26.6	23.9	0.90	14.6	16.1	1.10
Spleen	26.1	24.0	0.92	14.6	14.9	1.02
ED ICRP 60	25.72	23.51	0.91	14.20	14.55	1.02
ED ICRP 106	25.02	21.52	0.86	14.07	14.50	1.03

	5-yo male phantom	5-yo male patient	Ratio	5-yo male phantom	6-yo male patient	Ratio
Adrenals	9.5	10.6	1.12	14.2	13.4	0.94
Brain	2.3	0.9	0.41	2.3	1.4	0.61
Esophagus	9.4	10.4	1.10	14.1	13.8	0.98
Intestine	10.0	11.0	1.10	14.9	16.0	1.07
Heart	27.0	11.0	0.41	27.0	16.4	0.61
Kidneys	9.9	11.0	1.11	14.8	15.8	1.07
Liver	10.0	11.0	1.10	14.9	15.4	1.03
Lungs	10.6	11.3	1.07	15.8	15.3	0.97
Stomach	10.0	11.1	1.11	14.9	15.6	1.05
ED ICRP 60	9.35	9.04	0.97	14.0	12.6	0.90
ED ICRP 106	9.34	9.86	1.06	14.0	13.7	0.98

Conclusions

- A new generation of reference phantoms, based on the ICRP 89 reference masses has replaced the geometric phantoms of the 1980's and 1990's.
- More organs are available, and the phantoms are more realistic.
- Impacts on radiopharmaceutical dose estimates will be minor.
- Calculation of better doses for CT imaging will be available.