Comparison of organ doses estimations in radiology with PCXMC application based on MIRD phantoms and CALDose-X application based on voxel phantoms

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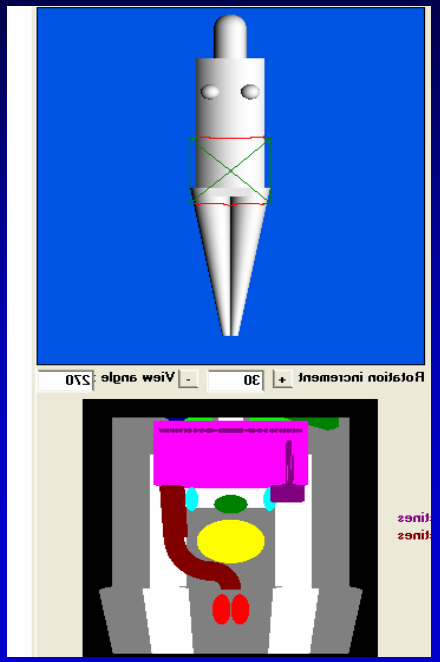
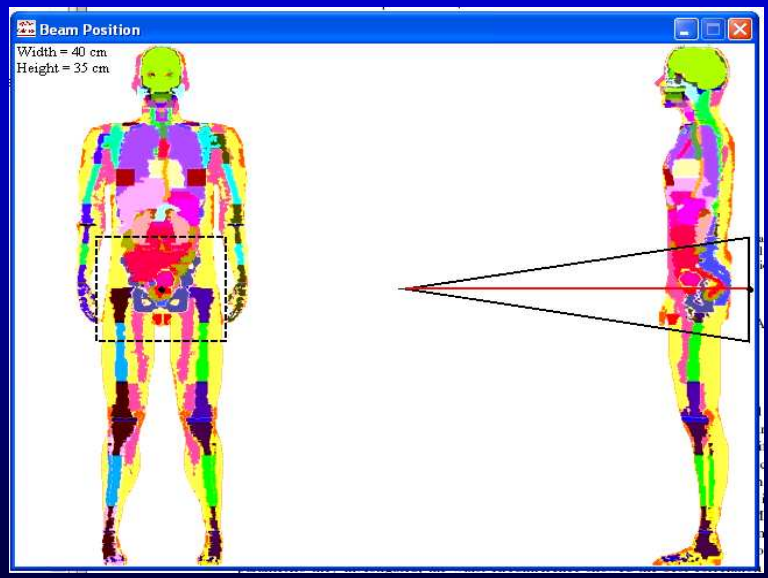
Purpose

•The estimation of organ doses in Radiology is a complicated procedure. The difficulty initially depends on the recording of the geometrical parameters of the examinations, such as X-ray field limits on the patient and focus – surface distance.

•Also, challenging step is the estimation of organ doses which depends on the X-ray spectrum and the absorption of photons within the body.

•The purpose of current study is to estimate doses with software packages PCXMC and CALDose-X and to examine differences.



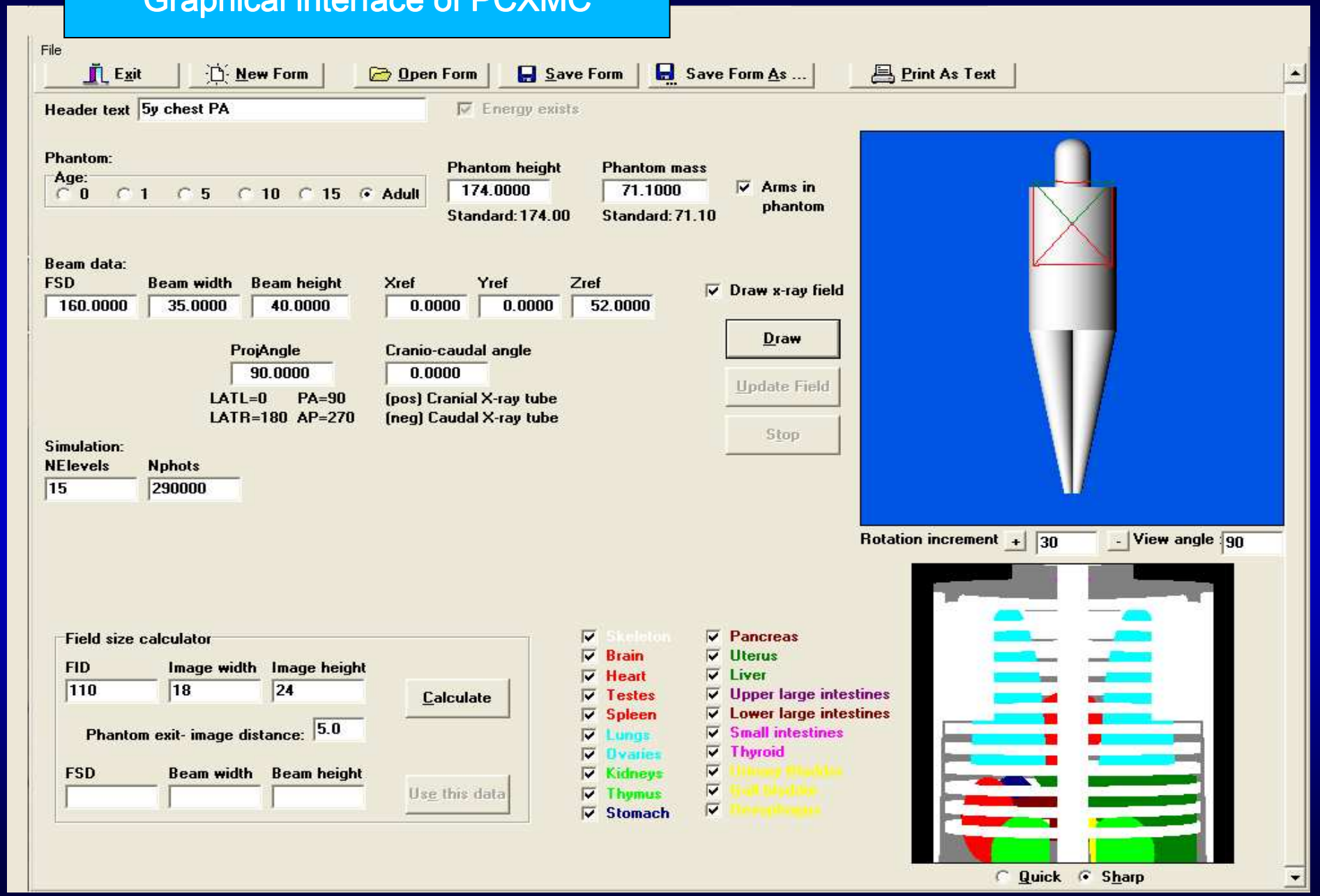


Material and Methods

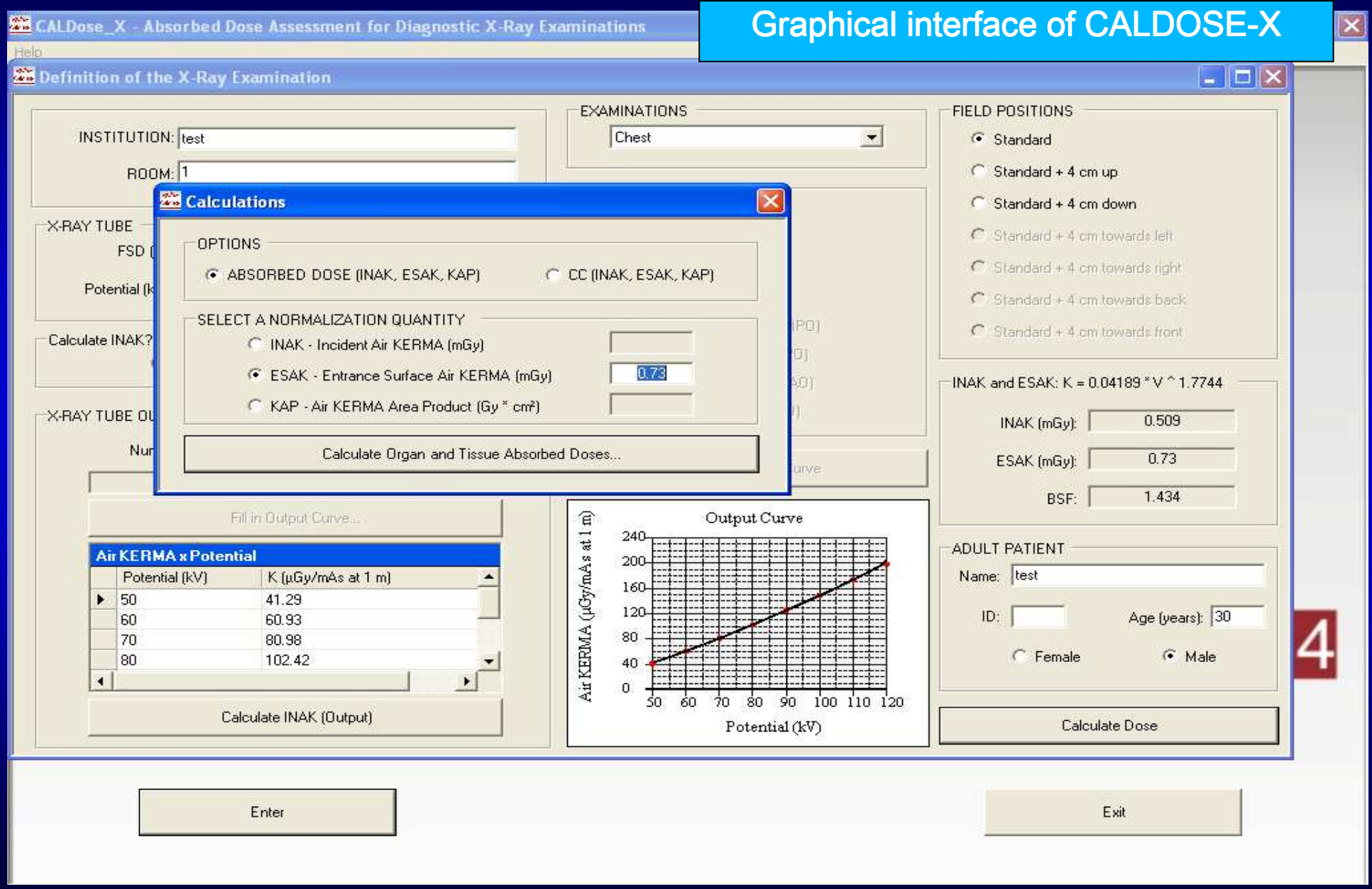
- Monte Carlo simulation by PCXMC [1] simulates body with hermaphrodite MIRD mathematical phantoms. MIRD phantoms have been widely used for many years in numerous studies.
- CALDose-X [2] application uses 2 tomographic phantoms, the male MAX06 and female FAX06 [3], consisted of 1.2mm cubic voxels and anatomical data in accordance to ICRU 70 and 89. These phantoms are used in standard predefined examinations projections and geometries. Field sizes represent commercial x-ray film formats.
- Both applications give the abillity to create x-ray energy spectrum and further to take into account the x-ray output of the radiological unit.
- Adult's radiological examinations were simulated, with the x-ray geometry and x-ray output settings sellected by CALDose-X.
- Cases examined at chest, abdomen, pelvis and lumbar spine.

1. M. Tapiovaara et al. PCXMC: A PC-based Monte Carlo program for calculating patient doses in medical x-ray examinations, report STUK-A139, (Helsinki: Finnish Centre for Radiation and Nuclear Safety) 1997.
2. R. Kramer et al. CALDose-X - a software tool for the assessment of organ and tissue absorbed dose, effective dose and cancer risks in diagnostic radiology. Phys. Med. Biol. 53, 6437-6459, 2008.
3. R. Kramer et al. MAX06 and FAX06: update of two adult human phantoms for radiation protection dosimetry. Phys.Med Biol. 51 3331-3346, 2006.

Graphical interface of PCXMC



Graphical interface of CALDOSE-X



Chest RLAT	PCXMC	CALDose-X male	CALDose-X female	CALDose-X average male- female	PCXMC vs average CALDose-X
organ	Dose/INAK (mSv/mGy)	Dose/INAK (mSv/mGy)	Dose/INAK (mSv/mGy)	Dose/INAK (mSv/mGy)	
Ovaries	0.013				
Active bone marrow	0.085	0.17	0.26	0.215	-153%
Skeleton	0.162				
surface bone cells		0.66	1.12	0.89	
Lungs	0.32	0.15	0.28	0.215	33%
Lower large intestine - colon	0.004	0.05	0.1	0.075	-1775%
Stomach	0.036	0.08	0.11	0.095	-164%
Liver	0.571	0.41	0.59	0.5	12%
Thyroid	0.018	0.01	0.03	0.02	-11%
Oesophagus	0.125	0.06	0.09	0.075	40%
Breasts	0.372	0.59	0.35	0.47	-26%
Urinary bladder	0.003				
Skin	0.146	1.65	1.52	1.585	-986%
Adrenals	0.14	0.11	0.16	0.135	4%
Kidneys	0.178	0.08	0.18	0.13	27%
Pancreas	0.085	0.1	0.15	0.125	-47%
Small intestine	0.063	0.03	0.07	0.05	21%
Upper large intestine -colon	0.106	0.05	0.1	0.075	29%
Spleen	0.02	0.02	0.04	0.03	-50%
Thymus	0.141	0.08	0.23	0.155	-10%
Total Body	0.13	0.14	0.16	0.15	-15%

Abdomen PA	PCXMC	CALDose-X male	CALDose-X female	CALDose-X average male- female	PCXMC vs average CALDose-X
organ	Dose/INAK (mGy/mGy)	Dose/INAK (mGy/mGy)	Dose/INAK (mGy/mGy)	Dose/INAK (mGy/mGy)	
Ovaries	0.354		0.38		
Testes	0.164	0.04			
Active bone marrow	0.656	0.12	0.18	0.15	77%
Skeleton	0.155				
surface bone cells		0.77	0.8	0.785	
Lungs	0.023	0.01	0.01	0.01	57%
Lower large intestine - colon	0.354	0.59	0.56	0.575	-62%
Stomach	0.594	0.44	0.42	0.43	28%
Liver	0.386	0.19	0.23	0.21	46%
Oesophagus	0.011	0.01	0.01	0.01	9%
Breasts	0.008	0.01	0.01	0.01	-25%
Urinary bladder	0.686	0.48	0.43	0.455	34%
Skin	0.174	1.45	1.41	1.43	-722%
Adrenals	0.083	0.14	0.12	0.13	-57%
Kidneys	0.095	0.22	0.18	0.2	-111%
Pancreas	0.248	0.36	0.32	0.34	-37%
Small intestine	0.415	0.64	0.59	0.615	-48%
Spleen	0.153	0.31	0.29	0.3	-96%
Total Body	0.18	0.19	0.22	0.21	-14.5

Pelvis PA	PCXMC	CALDose-X male	CALDose-X female	CALDose-X average male- female	PCXMC vs average CALDose-X
organ	Dose/INAK (mGy/mGy)	Dose/INAK (mGy/mGy)	Dose/INAK (mGy/mGy)	Dose/INAK (mGy/mGy)	
Ovaries	0.34		0.42	0.21	38%
Testes	1.157	0.855		0.4275	63%
Active bone marrow	0.047	0.17	0.31	0.24	-411%
Skeleton	0.095				
surface bone cells		0.87	0.95	0.91	
Lower large intestine - colon	0.351	0.19	0.35	0.27	23%
Stomach	0.046	0.01	0.02	0.015	67%
Liver	0.028		0.01	0.005	82%
Urinary bladder	0.727	0.5	0.55	0.525	28%
Skin	0.164	1.46	1.53	1.495	-812%
Adrenals	0.01		0.01	0.005	50%
Kidneys	0.026	0.03	0.07	0.05	-92%
Pancreas	0.014	0.01	0.02	0.015	-7%
Small intestine	0.342	0.35	0.44	0.395	-15%
Upper large intestine -colon	0.426	0.19	0.35	0.27	37%
Spleen	0.012	0.01	0.02	0.015	-25%
Uterus	0.426		0.35	0.175	59%
Gall bladder	0.082				
prostate		0.41		0.205	
Total Body	0.148	0.13	0.13	0.13	12%

- Dose values in organs out of x-ray limits which were almost zero or had large relative errors (greater than 15%) were not included. Also it should be mentioned that the two application do not use the same number of organs.
- In the majority of the organs differences are significant.
- In the organs at the limits of the X-ray field results show that there is large difference in doses for the same field dimensions, however not monotonically, approaching 90% or larger.
- The difference is smaller (25% on average) in the averaged whole body dose

Conclusions

- Differences on organ dose were expect because of the type and dimensions of phantoms, however mostly depend on whether or not the organ is included within the x-ray field.
- PCXMC and CALDose-X applications are useful tools for dose estimation, regarding the simlicity in their usage.