



MEDICAL PHYSICS DEPARTMENT
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**MONTE CARLO ESTIMATION OF RADIATION DOSES DURING
PAEDIATRIC BARIUM MEAL AND MICTURATING
CYSTOURETHROGRAPHY EXAMINATIONS.**

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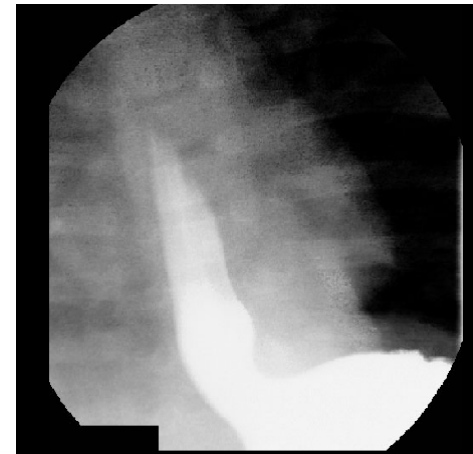
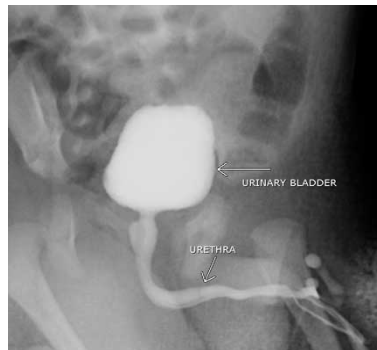
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Introduction:

- ✓ Organ doses are important quantities in assessing the radiation risk. In case of children, the estimation of this risk is of particular concern due to their significant radiosensitivity and the greater health detriment. Barium meal studies are often performed in paediatric radiology in order to assess Gastroesophageal reflux, but also nasopharyngeal reflux, malrotations and vascular rings. Micturating Cystourethrography is involved to assess malformations or functional disorders of the system of urinary excretion. However, both studies use fluoroscopy and multiple radiographs all of which result in high radiation doses to patients.



Purpose:

- ✓ The purpose of this study is to estimate the organ doses and DAP to organ/effective doses conversion factors (CF), to paediatric patients undergoing Barium Meal and Micturating Cystourethrography examinations, by clinical measurements and Monte Carlo simulation.



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      Copyright LANL/UC/DOE - see output file

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warning.      3 materials had unnormalized fractions. print table 49
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      xact is done          ctn =         0.00      nrn =          0

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run terminated when it had used 0.2 minutes of computer time.
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Methods and Materials:

✓ In clinical measurements, dose–area products (DAPs) were assessed during examination of 50 patients undergoing barium meal and 90 patients undergoing Cystourethrography examinations, separated equally within 3 age categories namely newborn, 1 year and 5 years old. Each Micturating Cystourethrography examination included intermittent fluoroscopy at one pelvis (Anterior-Posterior) projection and three radiographs. The Barium Meal examination was divided into four different projections (3 Anterior-Posterior and 1 Left-Lateral projection) each one of which, included fluoroscopy and the corresponding radiograph.

Table1.Mathematical Phantom Physical dimensions

Age	Mass (Kgr)	Height (cm)	Trunk anterior-posterior thickness(cm)	Trunk lateral thickness(cm)
neonatal	3.5	51	9.8	12.7
1 year	9.2	74.4	13	17.6
5 years	19	107	15	22.9

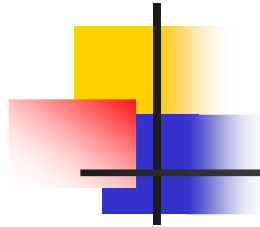


Methods and Materials:

- ✓ Monte Carlo simulation of photon transport in mathematical phantoms (Table 1) was applied using the MCNP5 code, in order to estimate the equivalent organ doses.
- ✓ For every projection, the organ dose conversion factors (organ doses per unit DAP) yielded dividing the Monte Carlo calculated organ doses per starting particle, by the calculated value of DAP per starting particle.
- ✓ The effective dose conversion factor was computed from the equivalent dose assessed for organ or tissue T of the male H_T^M , and the female H_T^F , according to the following equation (1) including the remainder tissues (ICRP 103 Annex A 2006, ICRP Annex B 1996).

$$E = \sum_T W_T \left[\frac{H_T^F + H_T^M}{2} \right] \quad (1).$$

Results



- ✓ DAP to organ and DAP to effective dose conversion coefficients for all projections involved in Barium Meal and Micturating Cystourethrography examinations are presented in Tables 2 and 3.
- ✓ Regarding the Cystourethrography examinations the organs receiving considerable amounts of radiation doses were: the urinary bladder (1.87, 2.43 and 4.7 mSv, the first, second and third value in the brackets corresponds to neonatal, 1 and 5-year old patients respectively), the large intestines (1.54, 1.8, 3.1 mSv), and the small intestines (1.34, 1.56, 2.78 mSv).
- ✓ Organs receiving considerable amounts of radiation during Barium meal examinations were: the stomach (9.81, 9.92, 11.5 mSv), the gall bladder (3.05, 5.74 7.15 mSv) and the pancreas (5.8, 5.93, 6.65 mSv) depending upon the age of the child.

Table 4 .Barium Meal carried out to neonatal, 1 and 5 year-old patients.
Dap and Effective doses presented separately for the radiography and fluoroscopy projections

	Age: neonatal		Age: 1 year old		Age: 5 years old	
	Dap measurement (mGy*cm ²)	Effective dose (mSv)	Dap measurement (mGy*cm ²)	Effective dose (mSv)	Dap measurement (mGy*cm ²)	Effective dose (mSv)
Sum of Radiography projections	70	0.25	96.476	0.17	205	0.21
Sum of Fluoroscopy projections	1515	5.20	1797.724	3.00	2643	2.62
Complete examination	1585	5.44	1894.200	3.17	2848	2.83

Results

Table 2. Barium Meal examination carried out to neonatal, 1 and 5 years old patients, DAP-normalized data ($\mu\text{Sv mGy}^{-1} \text{cm}^{-2}$)

projection	AP1 Radiography			AP1 Fluoroscopy			AP2 Radiography			AP2 Fluoroscopy			LLAT3 Radiography			LLAT3 Fluoroscopy			AR3 Radiography			AR3 Fluoroscopy			COMPLETE EXAMINATION								
	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5			
Age (years old)	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5
KVp	70	70	75	60	60	65	70	75	75	65	65	75	70	75	80	70	75	80	70	75	80	70	70	80									
SSD (cm)	95.2	92.0	90.0	95.2	92.0	90.0	95.2	92.0	90.0	95.2	92.0	90.0	92.3	87.4	82.1	92.3	87.4	82.1	95.2	92.0	90.0	95.2	92.0	90.0									
mAs/radiography min/fluoroscopy	4.9	5.5	4.8	0.30	0.48	0.65	5	6.4	4.9	1.28	0.4	1.21	5.0	7.7	5.4	0.85	0.99	1.73	4.8	6.8	5.1	1.40	1.08	0.88									
Dap measurement (mGy cm^2)	13.4	35.7	18.4	82.5	237.0	154.9	17.8	54.3	24.3	377.2	239.1	364.9	20.1	59.2	28.5	552.8	1264.5	853.6	18.8	56.5	25.2	502.9	902.2	424.3	1586	2849	1894						
organ/tissue	DAP-normalized data ($\mu\text{Sv mGy}^{-1} \text{cm}^{-2}$)																																
Stomach	4.12	1.05	0.30	3.78	0.48	0.25	7.09	5.35	4.09	6.80	4.87	4.09	5.69	5.86	4.03	5.69	5.86	4.03	6.68	6.35	5.12	6.68	6.09	5.12	6.18	5.24	4.04						
Liver	3.89	1.35	0.52	3.55	2.01	0.45	5.62	2.98	1.39	5.39	2.69	1.39	2.03	1.40	0.70	2.03	1.40	0.70	5.91	3.06	1.00	5.91	2.93	1.00	4.24	2.08	0.85						
Lungs	5.92	2.90	1.49	5.44	1.29	1.30	5.85	3.09	1.54	5.61	2.78	1.54	3.40	0.87	0.71	3.40	0.87	0.71	3.97	1.47	0.72	3.97	1.40	0.72	4.27	1.45	0.86						
Pancreas	3.96	1.11	0.35	3.48	0.66	0.28	4.57	3.09	2.21	4.29	2.65	2.21	4.14	3.61	2.16	4.14	3.61	2.16	4.30	3.45	2.45	4.30	3.22	2.45	4.20	3.06	2.08						
Spleen	2.6	0.50	0.16	2.27	0.20	0.12	3.40	1.93	1.21	3.17	1.63	1.21	6.60	6.52	1.98	6.60	6.52	1.98	3.20	2.47	1.74	3.20	2.29	1.74	4.37	3.94	1.64						
Breasts	10.20	4.06	0.57	9.95	4.10	0.49	10.10	4.96	3.98	9.96	4.79	3.98	4.82	0.22	0.23	4.82	0.22	0.23	8.80	0.50	0.22	8.80	0.47	0.22	7.72	1.57	0.64						
Gall bladder	2.35	0.34	0.06	2.07	0.14	0.04	5.76	3.99	1.08	5.47	3.55	1.08	3.15	2.45	0.79	3.15	2.45	0.79	5.70	5.04	1.74	5.70	4.78	1.74	4.51	3.03	1.07						
Oesophagus	3.49	2.21	1.59	3.00	2.49	1.31	3.36	2.02	1.21	3.12	1.71	1.21	2.60	0.70	0.57	2.60	0.7	0.57	1.82	0.94	0.52	1.82	0.87	0.52	2.51	1.11	0.69						
Bones	3.07	2.24	1.37	2.81	1.40	1.25	3.59	2.71	1.54	3.42	2.50	1.54	4.92	1.95	0.99	4.92	1.95	0.99	3.83	2.21	1.20	3.83	2.10	1.20	4.06	2.06	1.14						
Remaining organs	1.94	0.50	0.17	1.68	0.67	0.13	3.02	1.83	0.94	2.82	1.57	0.94	3.85	2.83	1.04	3.85	2.83	1.04	3.61	2.54	1.34	3.61	2.38	1.34	3.39	2.27	1.04						
Effective doses	3.57	1.51	0.48	3.35	1.26	0.41	3.80	2.16	1.44	3.66	1.97	1.44	2.92	1.59	0.92	2.92	1.59	0.92	3.82	1.80	1.12	3.82	1.71	1.12	3.43	1.67	0.99						

Results

Table 3. Cystourethrography examination carried out to neonatal, 1 and 5 years old patients, DAP-normalized data ($\mu\text{Sv mGy}^{-1} \text{cm}^{-2}$)

projection	AP1 Radiography			AP1 Fluoroscopy			AP2 Radiography			AP2 Fluoroscopy			AR3 Radiography			AR3 Fluoroscopy			COMPLETE EXAMINATION		
	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5
Age (years old)	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5	0	1	5
KVp	65	70	75	60	65	75	65	70	75	60	70	75	65	70	75	60	65	70			
SSD (cm)	95.2	92.0	90.0	95.2	92.0	90.0	95.2	92.0	90.0	95.2	92.0	90.0	95.2	92.0	90.0	95.2	92.0	90.0			
mAs/radiography min/fluoroscopy	4.7	5.2	6.2	0.54	0.43	0.57	4.7	5.2	6.2	0.33	0.33	0.51	4.7	5.2	6.1	0.35	0.44	0.42			
Dap measurement (mGy cm ²)	9.5	19.0	55.0	80.8	133.2	409.6	10.7	20.8	52.0	46.1	105.2	391.7	10.0	21.2	51.5	48.4	122.5	264.7	205	422	1225
organ/tissue	DAP-normalized data ($\mu\text{Sv mGy}^{-1} \text{cm}^{-2}$)																				
Stomach	7.29	2.40	1.79	7.00	2.27	1.79	7.92	3.17	1.81	7.61	3.17	1.81	6.88	1.99	1.24	6.60	1.88	1.17	7.10	2.42	1.64
Small intestine	6.80	4.05	2.26	6.42	3.77	2.26	6.77	3.85	2.25	6.39	3.85	2.25	7.05	3.69	2.45	6.66	3.44	2.29	6.54	3.71	2.27
upper large intestine	7.74	4.63	2.53	7.36	4.34	2.53	7.70	4.42	2.54	7.32	4.42	2.54	8.03	4.21	2.64	7.64	3.95	2.48	7.49	4.26	2.53
Lower large intestine	6.02	3.54	1.79	5.68	3.29	1.79	5.96	3.34	1.82	5.63	3.34	1.82	6.24	3.27	1.85	5.89	3.04	1.72	5.78	3.24	1.79
Liver	4.90	1.42	1.05	4.69	1.34	1.05	5.36	1.84	1.05	5.14	1.84	1.05	4.53	1.32	0.75	4.34	1.24	0.70	4.74	1.46	0.96
Pancreas	4.32	6.31	3.79	4.05	5.99	3.79	4.84	5.98	3.74	4.53	5.98	3.74	3.41	5.52	4.26	3.19	5.24	4.07	3.98	5.76	3.85
Urinary bladder	9.33	4.23	1.79	8.97	3.97	1.79	9.29	4.57	1.77	8.93	4.57	1.77	9.73	3.48	1.87	9.35	3.26	1.77	9.12	3.93	1.78
Gall bladder	7.36	0.07	0.04	6.99	0.06	0.04	7.48	0.09	0.04	7.10	0.09	0.04	7.49E	0.06	0.03	7.11	0.05	0.03	7.11	0.07	0.04
Bones	4.83	1.82	0.86	4.46	1.64	0.86	4.93	1.78	0.86	4.56	1.78	0.86	4.92	1.93	0.84	4.55	1.75	0.76	4.57	1.74	0.84
Remaining organs	4.37	1.95	1.09	4.10	1.81	1.09	4.58	2.09	1.08	4.29	2.09	1.08	4.20	1.70	1.06	3.94	1.57	0.99	4.14	1.82	1.06
Effective doses	3.29	1.57	0.94	3.12	1.47	0.94	3.41	1.65	0.94	3.24	1.65	0.94	3.26	1.40	0.89	3.09	1.30	0.83	3.17	1.48	0.91

Conclusions

- ✓ For both examinations and all ages the DAP to organ/effective doses conversion factors conversion values are decreased with age.
- ✓ The main contributors to the total organ or effective doses are the fluoroscopy projections. This is obvious in Tables 4 and 5 in which, for every age group, the DAP measurements and the corresponding effective doses are added and presented separately for the radiography and fluoroscopy projection. Consequently, the fluoroscopy time is very important parameter concerning the total dose contribution.

Table 5. Cystourethrography carried out to neonatal, 1 and 5 year-old patients.
Dap and Effective doses presented separately for the radiography and fluoroscopy projections

	Age: neonatal		Age: 1 year old		Age: 5 years old	
	Dap measurement (mGy*cm ²)	Effective dose (mSv)	Dap measurement (mGy*cm ²)	Effective dose (mSv)	Dap measurement (mGy*cm ²)	Effective dose (mSv)
Sum of Radiography projections	30	0.10	61	0.09	158	0.15
Sum of Fluoroscopy projections	175	0.55	360	0.53	1066	0.97
Complete examination	205	0.65	422	0.62	1224	1.12

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