Effective dose and risks from medical X-ray procedures

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Limitations of effective dose as risk-related quantity

- To be used just for regulatory purposes.
- An effective dose value assigned to an individual is the effective dose of a reference person under considered exposure situation. It is not individual dose with regard of age, sex, anatomical and physiological properties, behaviour, etc.
- Difficulties in using *E* for comparison of different sources of exposure or population groups with various age-sex characteristics, e.g. in medical exposure.

Medical exposure (ICRP-103, -105)

- Effective dose is used to compare diagnostic procedures, hospitals, etc. It is appropriate when patients are similar with regard to age and sex.
- However, age and sex distributions of patients can be quite different from those of general population. Therefore, *E* should not be used to compare doses from medical exposure to doses from other sources.
- ICRP-103: "Risk assessment for medical uses of ionizing radiation is best evaluated using appropriate risk values for the individual tissues at risk, and for the age and sex distribution of the individuals undergoing the medical procedures. "

However, for practical purposes:

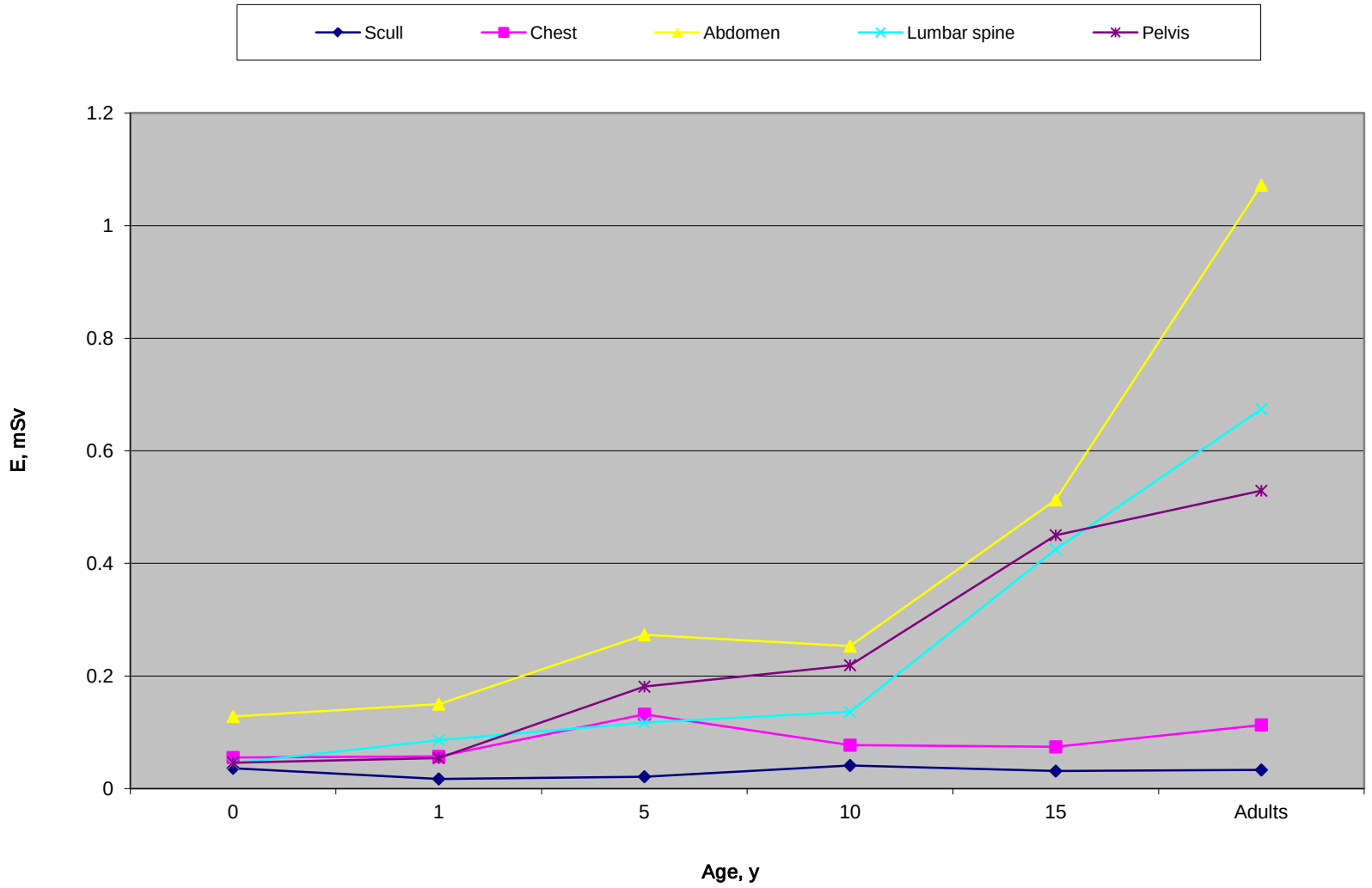
- Can simple adjustments be made to the nominal risk per unit *E* as a function of age and sex?
- We did that analysis in indpendent way at IRH, St. Petersburg, Russia, and HPA, Chilton, UK:
  - '*Age and Sex Dependence of the Stochastic Health Effects Due to Radiography*' M. Balonov, V. Golikov, S. Kalnitsky and A. Bratilova. Med Radiology and Rad Safety, v. 56, No 4 (2011), in Russian.
  - '*Radiation risks from medical x-ray examinations as a function of the age and sex of the patient*' BF Wall, R Haylock, JTM Jansen, MC Hillier, D Hart and PC Shrimpton. HPA-CRCE-028 (2011).

Methodology

Methodologically similar but not identical dose and risk calculations were performed at two institutions:

- Organ and effective doses calculated for a range of x-ray examinations – IRH and HPA
- ICRP 103/UNSCEAR 2006 risk models used to calculate age/sex-specific lifetime detriment-adjusted risks - IRH
- ICRP 103 risk models used to calculate age/sex-specific lifetime risks of cancer incidence and genetic effects for Western population – HPA
- Risks from individual procedures calculated and compared using:
  - organ doses and age/sex-specific risk coefficients
  - effective doses and nominal risk coefficients

Typical X-Ray age-depended patient doses in St. Petersburg



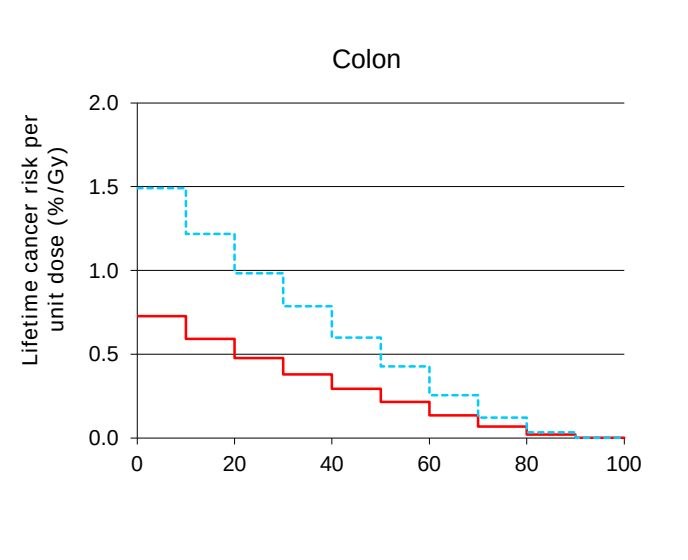
Typical UK Patient Doses From Common X-Ray Examinations - Range

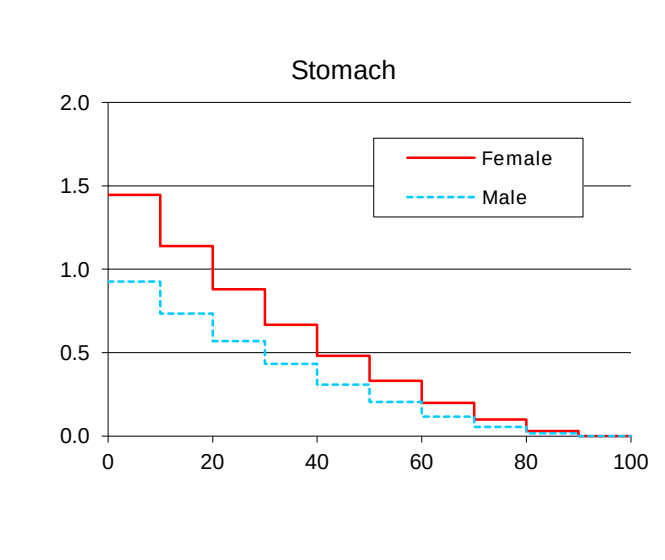
Examination	Effective dose (mSv)		Highest organ dose	
	E-60	E-103	Organ	mGy
Radiography				
Foot	0.0002	0.0002	Skin	0.007
Head (skull)	0.05	0.068	Salivary glands	1.3
IVU	2.3	2.1	Stomach	6.9
Fluoroscopy				
Ba follow	1.5	1.3	Kidneys	6.1
Coronary angiography	3.9	3.9	Lungs	15
CT				
Head	1.6	1.4	Brain	45
Chest+Abdo+Pelvis	9.2	10	Thymus	15

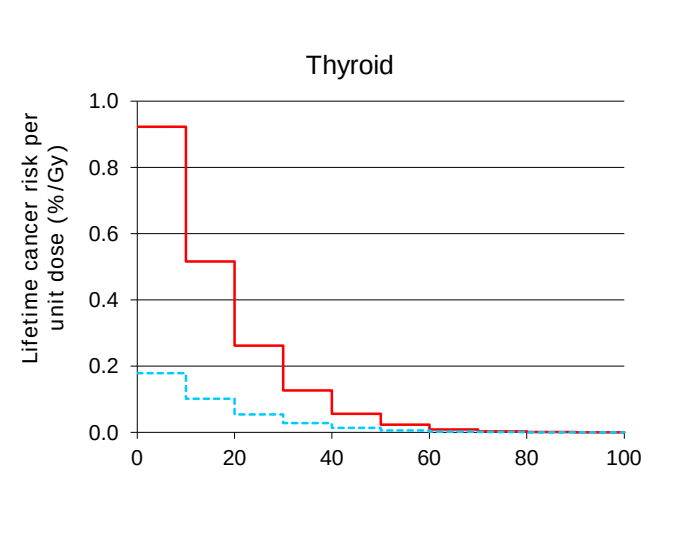
Detriment-adjusted risk coefficients $r(A, T)$, 10^{-4} Sv^{-1}, for women (ICRP-103/UNSCEAR-2006)

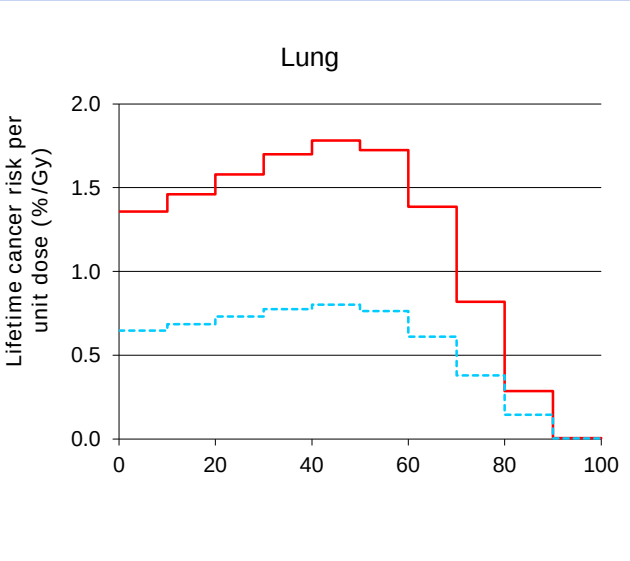
Organ/Tissue (T)	Age group, years (A)								
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	>70	0-85
Oesophagus	34,1	23,4	18,1	13,5	9,2	5,6	2,9	1,0	**13,6**
Stomach	194,5	133,3	103,1	76,7	52,7	31,8	16,3	5,4	**77,5**
Colon	72,8	49,9	38,6	28,7	19,7	11,9	6,1	2,0	**29,0**
Liver	42,7	29,2	22,6	16,8	11,6	7,0	3,6	1,2	**17,0**
Lungs	303,0	207,6	160,5	119,5	82,1	49,5	25,3	8,4	**120,7**
Bone surface	12,8	8,8	6,8	5,0	3,5	2,1	1,1	0,4	**5,1**
Skin	10,0	6,9	5,3	4,0	2,7	1,6	0,8	0,3	**4,0**
Breast	400,8	274,7	212,4	158,1	108,6	65,5	33,5	11,2	**159,7**
Ovary	49,7	34,1	26,3	19,6	13,5	8,1	4,2	1,4	**19,8**
Bladder	39,7	27,2	21,0	15,6	10,7	6,5	3,3	1,1	**15,8**
Thyroid	51,7	35,4	27,4	20,4	14,0	8,4	4,3	1,4	**20,6**
RBM	133,5	91,5	70,8	52,7	36,2	21,8	11,2	3,7	**53,2**
Remainder	258,8	177,3	137,1	102,1	70,1	42,3	21,7	7,2	**103,1**
Gonads (her.)	53	50	50	50	0,0	0,0	0,0	0,0	**25,4**
Total	1657,1	1149,3	900,0	682,7	434,6	262,0	134,2	44,7	**664,6**

Lifetime Risk of Cancer Incidence (% / Gy to Organ) by Age & Sex – ICRP-103







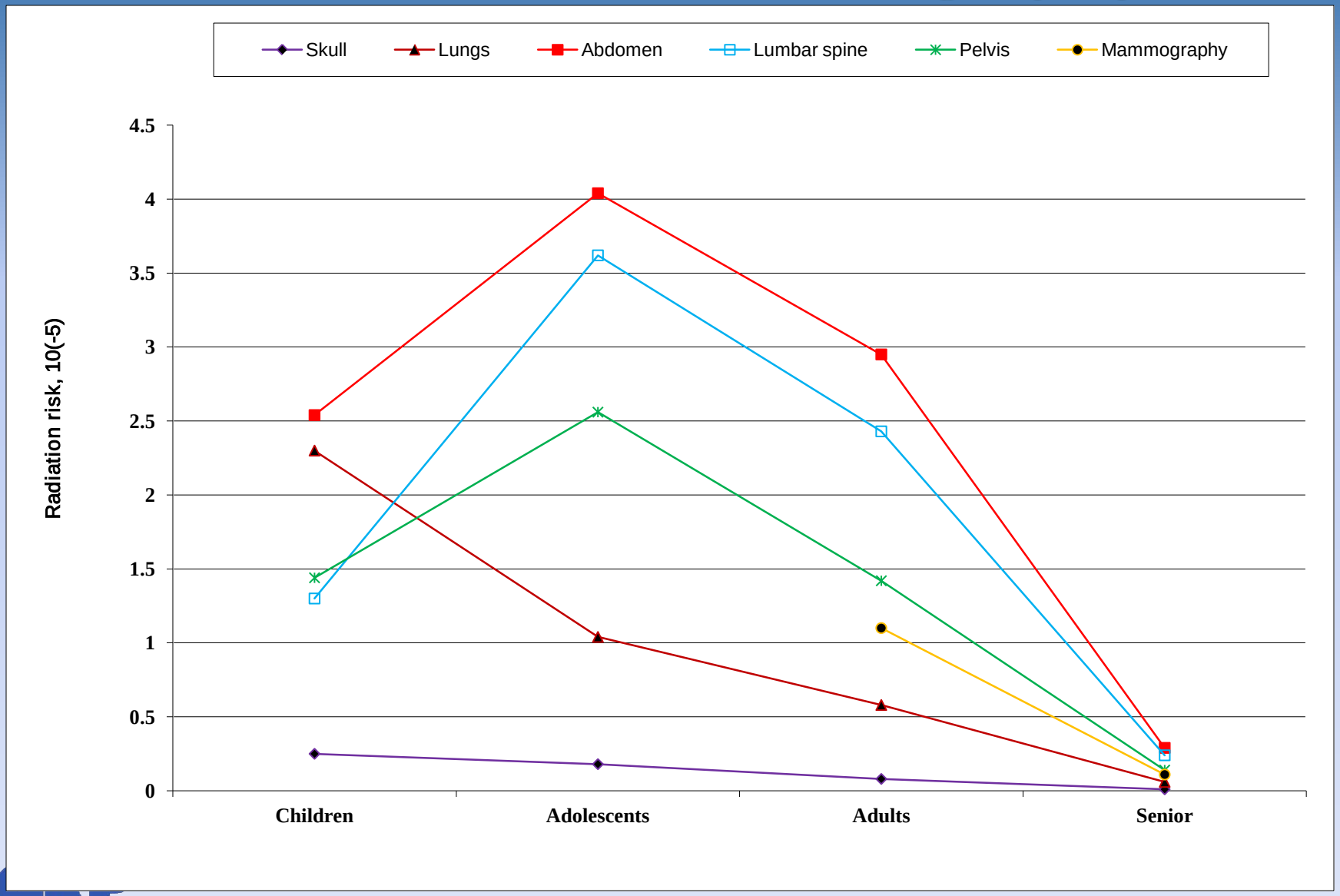


Total Lifetime Risk of Cancer Incidence Per X-Ray Exam by Age & Sex - HPA

Typical risk per million (10^{-6})

Examination	Sex	Age at exposure (y)				
		0-9	20-29	40-49	60-69	80-89
Chest	M	1.3	0.9	0.7	0.5	0.1
Chest	F	1.9	1.4	1.2	0.8	0.2
Head	M	12	5.9	3.2	1.3	0.3
Head	F	11	5.3	2.9	1.0	0.2
Ba follow	M	170	100	66	30	6.4
Ba follow	F	140	91	61	28	5.4
Coronary angiography	M	330	250	210	150	41
Coronary angiography	F	430	370	370	270	66
CT ches+abdo+pelvis	M	960	630	440	240	58
CT chest+abdo+pelvis	F	1500	910	640	360	80

Lifetime Risk of Various Age Groups of Female Patients due to Radiography - IRH



Ratio of risks from radiography calculated for various sex-age groups to risks based on effective dose - IRH

Radio-graphy	F/M	Risk ratio: Organ dose/Effective dose		
		Children (0-9 y)	Girls (0-9 y)	Adult F (20 +)
Skull	**1.2-1.3**	**1.4**	**1.6**	**0.5**
Thorax	**1.9-3.2**	**2.6**	**4.0**	**1.0**
Abdominal cavity	**1.1-1.2**	**1.7**	**1.9**	**0.6**
Lumbar spine	**1.1**	**2.0**	**2.0**	**0.7**
Pelvis	**0.8-0.9**	**1.7**	**1.5**	**0.5**
Mammo-graphy	--	--	--	**2.0**

Ratio of risks (range) from X-ray examinations calculated for various sex-age groups to risks based on *E* - HPA

Exami-nation	Age band, years		
	0-9	30-39	60-69
Radio-graphy (8)	1.4-3.6	0.5-2.2	0.2-1.4
Fluoro-scopy (5)	1.5-3.5	0.9-2.3	0.4-1.7
CT (5)	1.5-3.3	1.1-2.1	0.5-1.1

Broad Risk Bands for Typical Lifetime Cancer Incidence from X-Ray Examinations

Examination	Sex	Typical total lifetime cancer risk (30- 39 y age band)
Cervical spine, Chest Knee, Foot	M, M B, B	NEGLIGIBLE RISK Less than 1 in a million
Head Cervical spine, Chest	B F, F	MINIMAL RISK 1 in a million to 1 in 100,000
Thoracic spine Abdomen, Pelvis Lumbar spine Ba follow CT head	B B, B B B F	VERY LOW RISK 1 in 100,000 to 1 in 10,000
IVU Ba enema Angiography CT head CT trunk	B B B M B	LOW RISK 1 in 10,000 to 1 in 1,000

Discussion

- The significant sex- and age-dependence of radiogenic risk for different cancer types is an important consideration for radiologists when planning X-ray examinations.
- As expected, for some procedures and doses the simplified approach for risk assessment based on *E* underestimated risk in children (0-9 y) by a factor of 1.5 to 4 and overestimated risk for elder patients (60+) by about an order of magnitude.
- Is an risk underestimation factor of two to four for children and young women worth of development of more complicated assessment procedure?
- As for risk overestimation for senior patients by an order of magnitude, that might be considered as cautious approach to protection against medical exposure.

Summary

While effective dose was not intended to provide a measure of risk associated with medical radiological examinations, it may be appropriate to use it following simple adjustments to the nominal risk per unit effective dose to account for age (and sex?) differences.

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