

Evaluation of radiation risk: organ dose approach versus effective dose approach

Mikhail Balonov

Institute of Radiation Hygiene

St. Petersburg, RUSSIA

On behalf of ICRP TG 79

Contents

- Intro: Radiation risk and Radiation protection
- Assessment methodology
- X-ray organ and effective doses
- Risk assessed from organ doses and risks
- Risk assessed from effective dose
- Comparison of risks assessed by two methods
- Example of a national guidance based on effective dose with age correction
- Summary

Radiation risk as inherent part of protection system

- Concept of radiation risk is basic concept of modern radiation protection system
- Concept and quantity of acceptable risk is the basis for current dose limits, see ICRP-26, 1977, and ICRP-60, 1990.
- As soon as dose limits have been established and reconfirmed in ICRP-103, 2007, risk value is not considered any more as radiological criterion.

Radiation risk as radiological criterion

- Almost not used since replaced by effective dose limits, see e.g. ICRP-103, BSS, etc.
- Few exceptions:
 - Justification of medical exposures
 - (Informing of patients and the public in some countries)
 - Protection against potential exposure

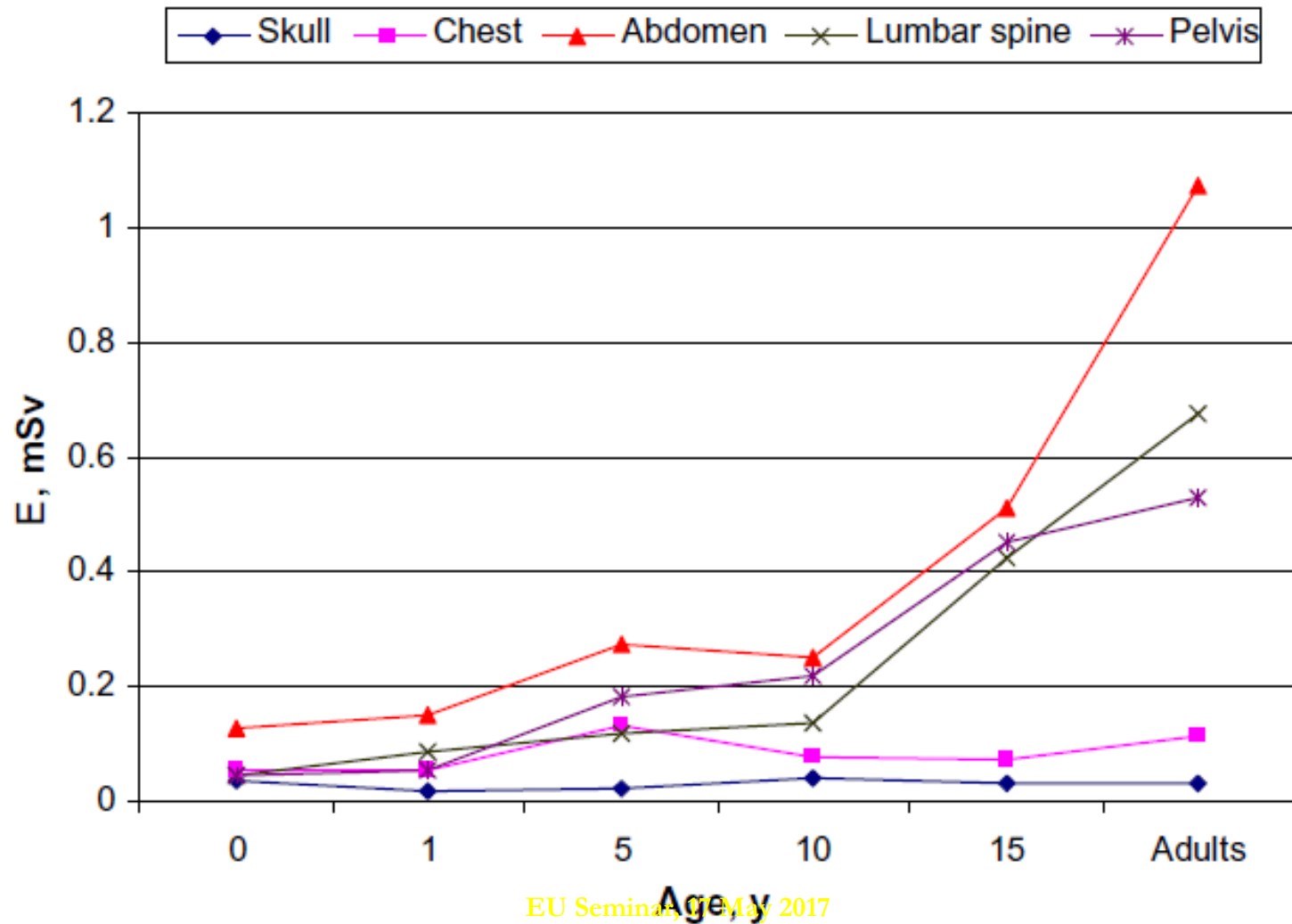
Medical exposure (ICRP-103, -105)

- “Risk assessment for medical uses of IR is best evaluated using risk values for the tissues at risk, and for age/sex distribution of patients.”
- However, for practical purposes:
 - Can simple age/sex adjustments to the nominal risk per unit E be helpful?
 - We did that analysis in independent way at IRH, St. Petersburg, Russia, and HPA, Chilton, UK

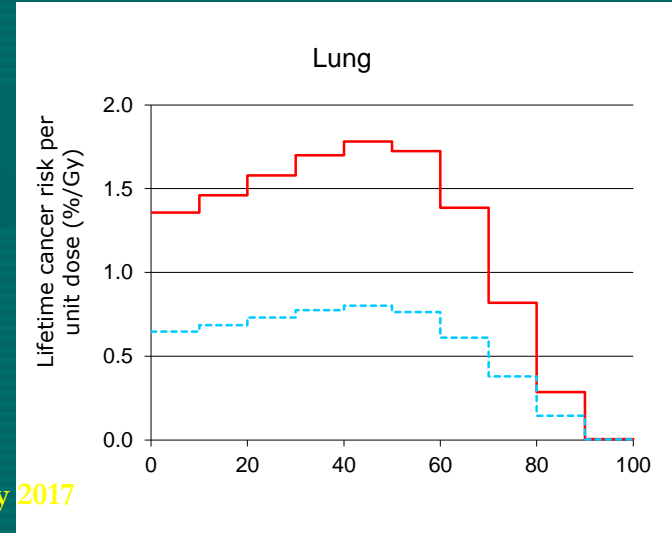
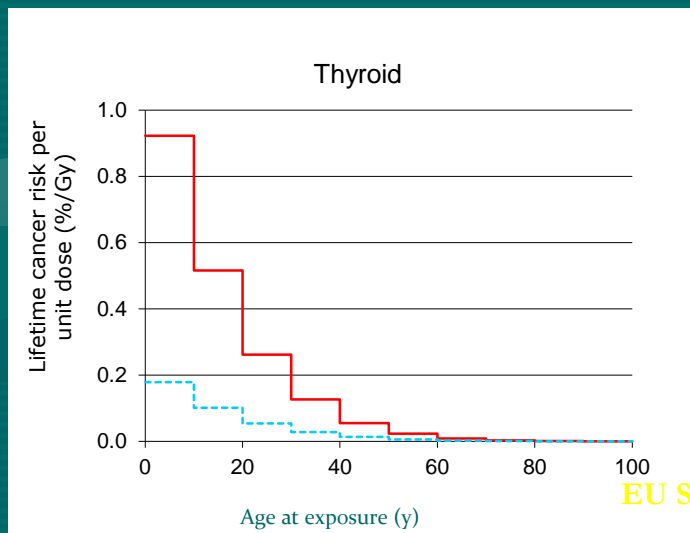
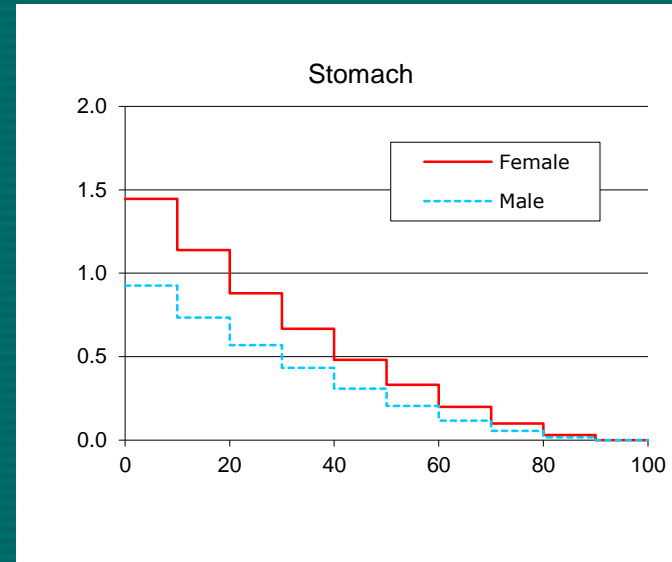
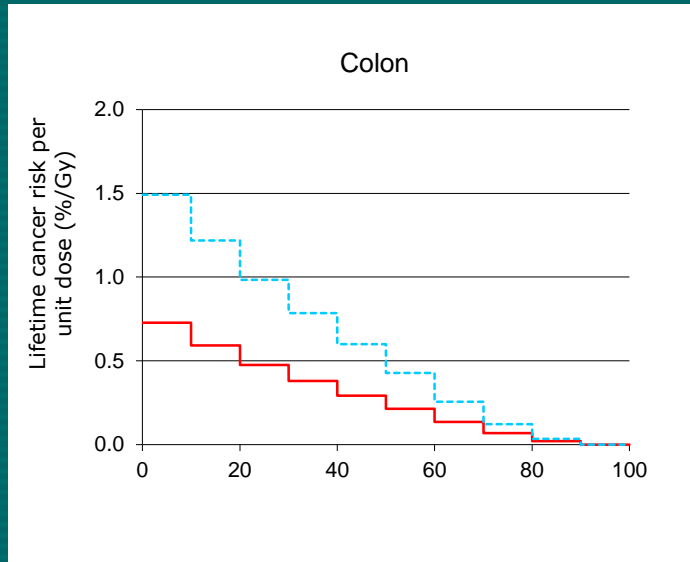
IRH Methodology

- Organ and effective doses calculated by means of special codes for six X-ray radiography examinations for six ICRP age groups of reference persons
- ICRP 103/UNSCEAR 2006 risk models used to calculate age/sex-specific lifetime detriment-adjusted risk coefficients
- Risks from six X-ray radiography examinations for twelve age/sex groups of patients 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



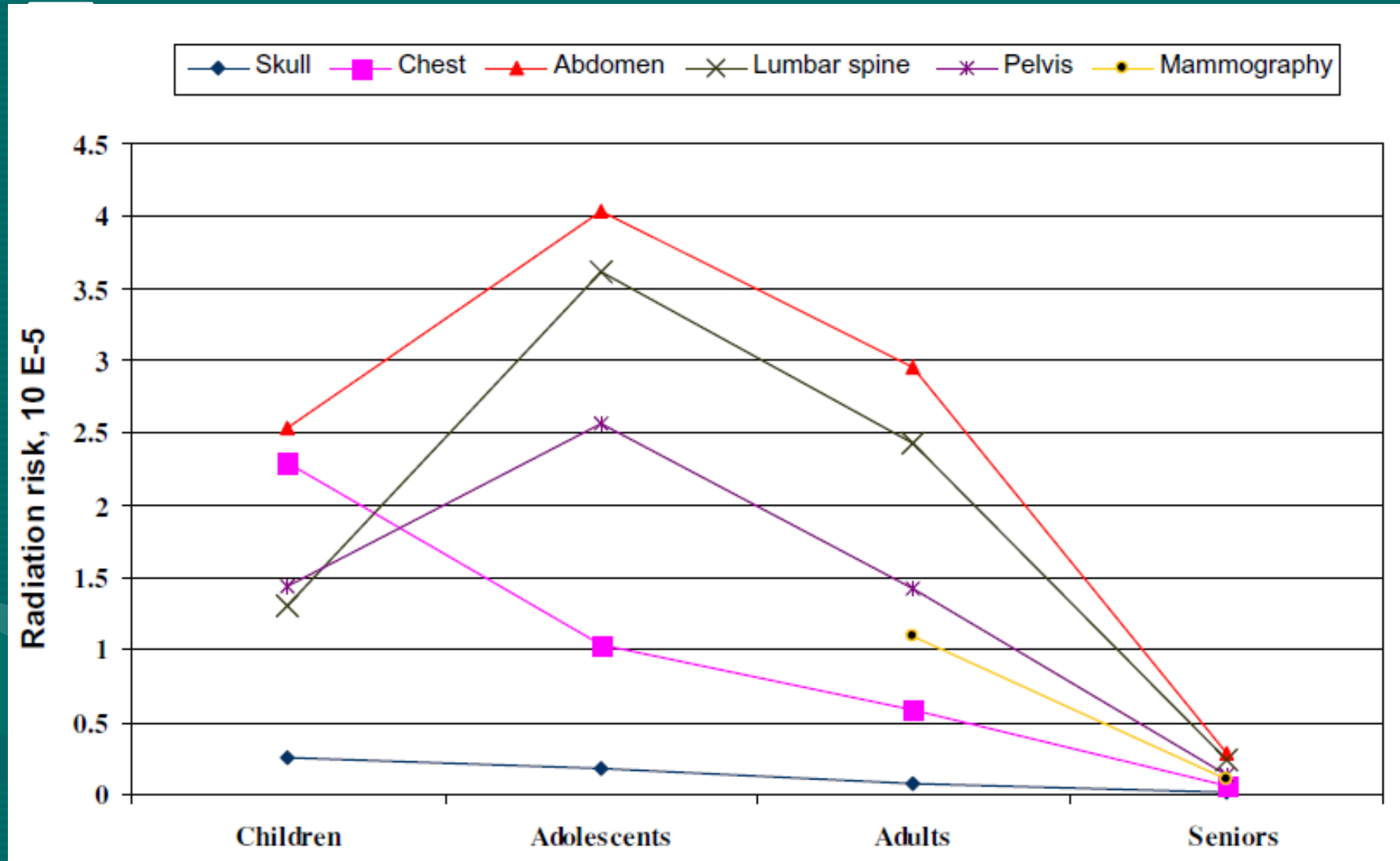
Lifetime Risk of Cancer Incidence (%/Gy, ICRP-103) by Age & Sex [Wall 2011]



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 per Examination of Various Age Groups of Females due to Radiography



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

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* [Wall et al 2011]

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

Discussion - 1

- 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 examinations the simplified risk assessment based on E underestimated risk in children (0-9 y) by a factor of 1.5 to 4 and overestimated risk for senior patients (60+) by about an order of magnitude.

Discussion - 2

- Underestimation factor of two to four for children and young women could be easily corrected by appropriate age/sex dependent factor.
- Risk overestimation for senior patients might be either considered as cautious approach to protection or also corrected.
- Those considerations might support the use of effective dose for practical purposes with simple adjustment of the nominal risk per unit E as a function of age and sex.
- The simplified approach might be applicable for conditions where high precision is not necessary, i.e. justification and information.

Implementation example: Russian Guidance MR 2.6.1.0098-15
“Radiological Support for Justification of Radiodiagnostic Examinations”

Based on effective dose with age correction!

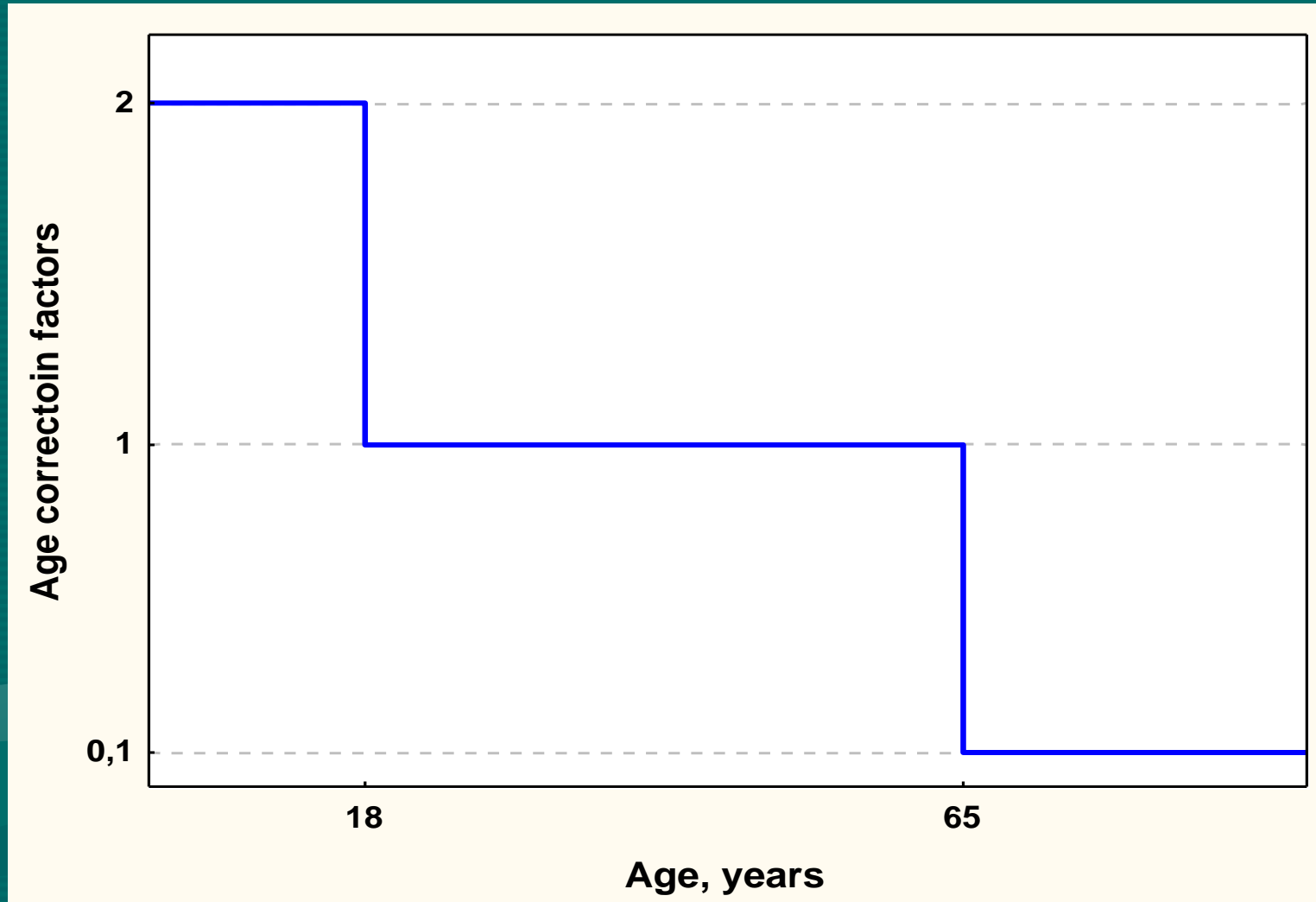
Contents

- 1. General provisions, including risk classification**
- 2. Radiation risk dependence on dose, organ/tissue, age and gender**
- 3. Risk assessment in X-ray examinations**
- 4. Risk assessment in nuclear medicine**
- 5. Weighting of risks and justification of diagnostic examinations**

Classification of long term stochastic risks in medical radiology [ICRP, NCRP, C. Martin]

Life-time carcinogenic or inherited risk	Risk class
< 1 per 1000 000	Negligible
< 1 per 100 000	Minimal
< 1 per 10 000	Very low
< 1 per 1 000	Low
< 1 per 300	Moderate

Age-dependent risk correction factor



Ranges of effective dose corresponding to various risk classes for 3 age groups

Risk class	Effective dose range, mSv		
	Children (< 18 y)	Adults (18-64 y)	Seniors (65y +)
Negligible ($< 10^{-6}$)	$< 0,01$	$< 0,02$	$< 0,2$
Minimal ($< 10^{-5}$)	$0,01 - 0,1$	$0,02 - 0,2$	$0,2 - 2$
Very low($< 10^{-4}$)	$0,1 - 1$	$0,2 - 2$	$2 - 20$
Low ($< 10^{-3}$)	$1 - 10$	$2 - 20$	$20 - 200$
Moderate ($< 3 \cdot 10^{-3}$)	$10 - 30$	$20 - 60$	$200 - 500$

Classification of CT examinations by radiation risks of patients of various age groups

(example, in total 6 tables for various examinations)

Radiation risk	Age groups		
	Children (<18 y)	Adults (18-64 y)	Seniors (65+ y)
Very low (10^{-5} - 10^{-4})	—	—	Scull; Chest; Abdomen; Pelvis and Thigh
Low (10^{-4} - 10^{-3})	Scull; Chest; Abdomen	Scull; Chest; Abdomen; Pelvis and Thigh	—

Summary

- Effective dose was not intended to provide a measure of risk associated with medical radiological examinations.
- However, it might be used in this role for practical purposes following simple adjustment of nominal risk coefficient for age (and sex?).
- Similar views expressed in ICRP TG 79 draft report ‘The Use of Effective Dose as a Risk-related Radiological Protection Quantity’.

Thank you for your attention!

