Recent Progress in Radiation Dosimetry for Epidemiology and Radiological Protection

Dosimetric Quantities and Risk

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Task Group 79 : Use of Effective Dose as a Protection Quantity

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Using Effective Dose : confusion ?

- Absorbed dose, Equivalent dose, Dose equivalent, Effective dose, Committed effective dose, Collective effective dose
- Setting limits to prevent tissue reactions in equivalent dose, Sv
- One set w_T values for all ages, including fetus
- Sex-averaged reference persons
- *E* and risk
- Collective *E* and risk

Protection System

Prevent tissue reactions

➡ gross tissue damage occurring above a dose threshold

Control stochastic effects

➡ cancer and hereditary effects, for which LNT dose-response is assumed

Pub 103 stochastic detriment

Cancer incidence / apply DDREF for solid cancer

- Transfer risks and average across populations
- Adjust for lethality
- Adjust for quality of life
- Adjust for years of life lost
- Add hereditary effects

Detriment (x 10^{-2} per Gy)	Cancer	Hereditary	Total
Worker	4.1	0.1	**4.2**
Public	5.5	0.2	**5.7**

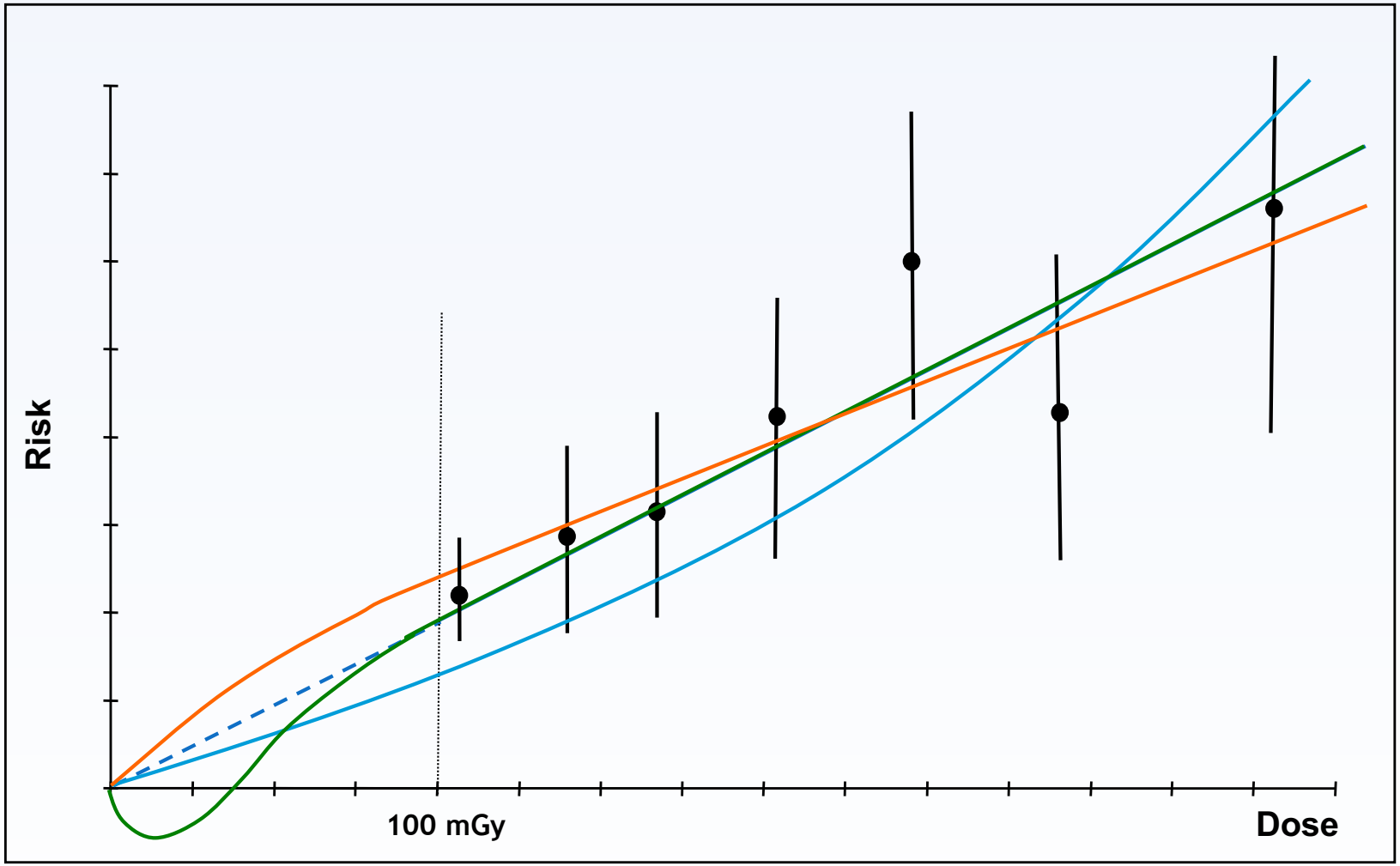
Pub 103: Population stochastic detriment

Tissue	Detriment (x 10^{-4} Gy^{-1})	Relative detriment	Tissue weighting
Oesophagus	13.1	0.023	0.04
Stomach	67.7	0.118	0.12
Colon	47.9	0.083	0.12
Liver	26.6	0.046	0.04
Lung	90.3	0.157	0.12
Bone surface	5.1	0.009	0.01
Skin	4.0	0.007	0.01
Breast	79.8	0.189	0.12
Ovary	9.9	0.017	
Bladder	16.7	0.029	0.04
Thyroid	12.7	0.022	0.04
Bone marrow	61.5	0.107	0.12
Other solid	113.5	0.198	0.12
Gonads (hereditary)	25.4	0.044	0.08*
Total	574	1.000	1.00”

Life-time risk for Euro-American population (% per Gy) : BEIR VII

Cancer site	Age at exposure, years					
	Males			Females		
	0-9	20-29	60-69	0-9	20-29	60-69
Breast	-	-	-	4.9	2.2	0.2
Colon	1.5	1.0	0.3	0.7	0.5	0.1
Liver	0.6	0.3	0.1	0.2	0.2	0.03
Lung	0.7	0.7	0.6	1.4	1.6	1.4
Thyroid	0.2	0.1	0	0.9	0.3	0.01
Leukaemia	1.1	0.8	0.5	0.5	0.5	0.3
All cancers	**10**	**6.2**	**2.2**	**14**	**8.5**	**3.1**

Cancer risk



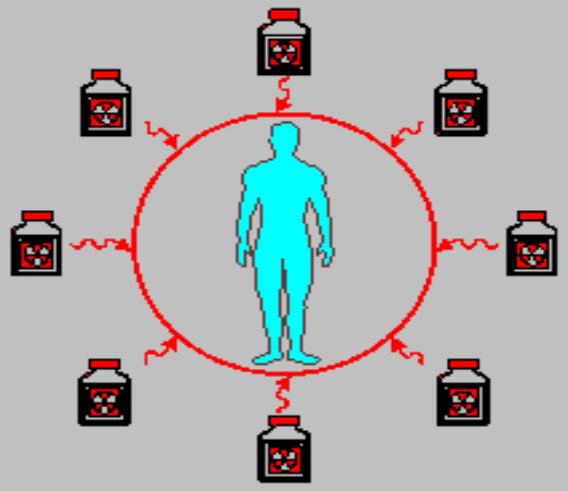
Why Effective Dose ?

- IF all exposure were uniform whole-body low LET gamma rays, effective dose not needed –
  absorbed dose (Gy) OK
- BUT radiations differ in cancer risk per Gy – alpha particles (Gy) = 10 x gamma rays (Gy)
- AND partial body irradiations occur from external and internal sources
- NEED to be able to add all radiation exposures for control / optimisation of protection

Constraints, reference levels, limits

Protection of workers and public primarily using constraints and reference levels applying to doses from a single source

From a single source in normal, emergency, or existing controllable situations by



From all regulated sources in normal situations by

Constraints / reference levels

Limits

Equivalent and effective dose

1. Absorbed dose $D_{T,R}$ in human tissues/organs T, (averaged organ/tissue absorbed dose) **Gy**

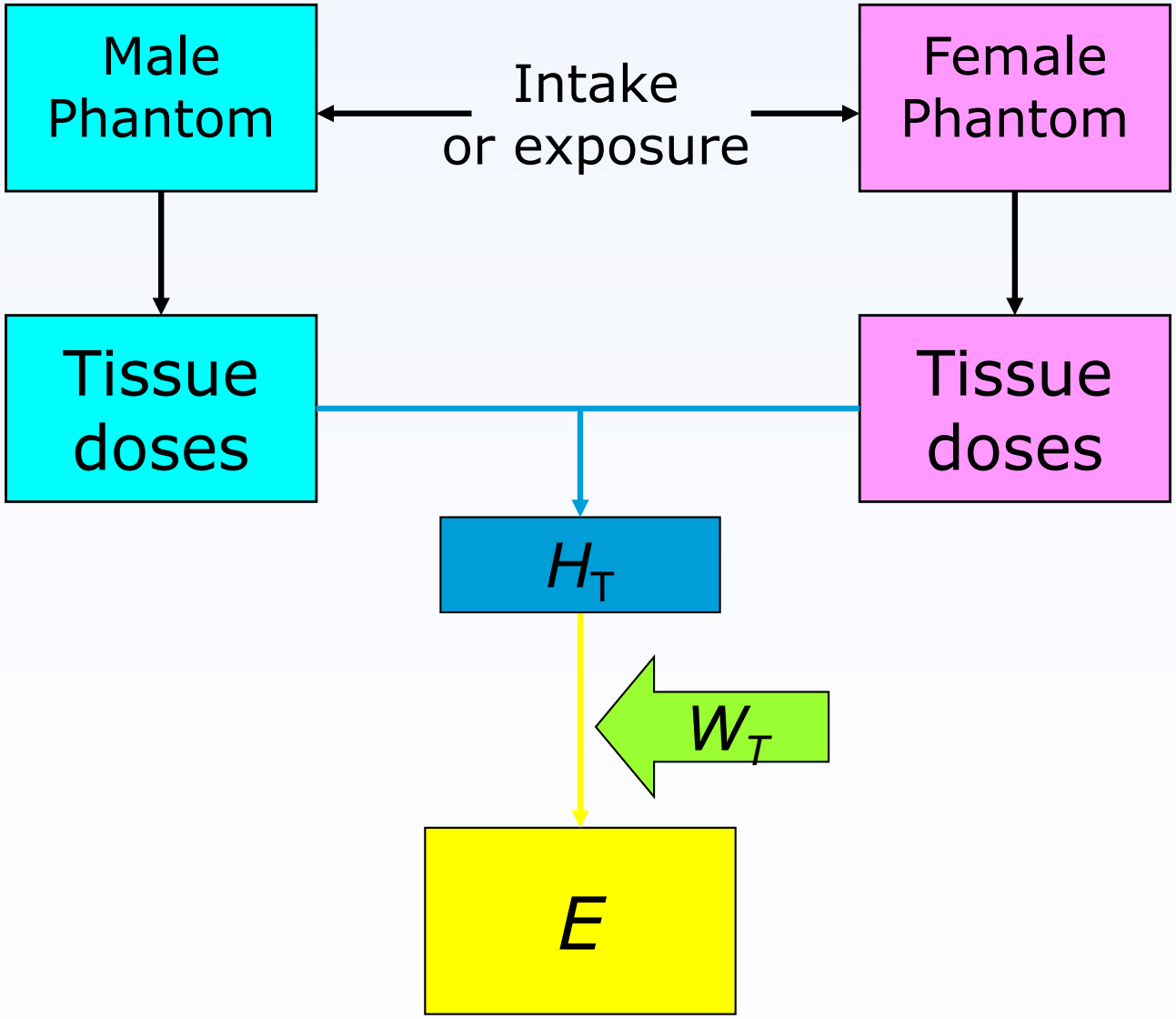
2. Equivalent dose in tissues/organs, **Sv**

   $H_T = \sum_R w_R D_{T,R}$ w_R : radiation weighting factor

3. Effective dose, **Sv**

   $E = \sum_T w_T H_T$ w_T : tissue weighting factor

Male / Female averaging



Use of Effective Dose

- Enables the summation of all radiation exposures by risk adjustment using simplified weighting factors
- Applies to sex-averaged reference persons, and relates to nominal risk coefficients for uniform external low LET radiation exposure
- Applied without uncertainties, assumes LNT dose-response, chronic = acute, internal = external

Proposal : Equivalent dose

Discontinue use of Equivalent Dose as a separate protection quantity

Organ / tissue dose = Gy
Effective dose = Sv

- **Limits to prevent tissue reactions for the eye lens, skin, hands & feet - better as absorbed dose, Gy**
- **Avoids confusion between equivalent dose and effective dose. Eg. iodine-131, *E* = 40 mSv, thyroid dose = 1 Sv.**
- **Avoids confusion between equivalent dose and the operational quantity, dose equivalent, Sv**

ICRP Effective Dose Coefficients

Internal: Sv per Bq intake

External: Sv per fluence or air kerma

- **Workers**
- **Public : Newborn, 1, 5, 10 and 15 y old children, adults**
- **Radionuclide intakes by pregnant and breast-feeding woman : doses to the fetus and infant**

Tissue weighting factors

• *ICRP 60*	0.01	bone surface, skin
	0.05	bladder, breast, liver, oesophagus, thyroid, remainder
	0.12	bone marrow, colon, lung, stomach
	0.2	gonads
• *ICRP 103*	0.01	bone surface, skin, brain, salivary glands
	0.04	bladder, liver, oesophagus, thyroid
	0.08	gonads
	0.12	bone marrow, colon, lung, stomach, breast, remainder

Clarification

- Effective dose is not a scientific quantity that is “correct” for a particular age group
- In public dose assessments, may use three age groups - 1y, 10y and adults - in representative person calculations (Publication 101, ICRP 2006)
- For a few radionuclides, consideration of doses to the fetus may be important (isotopes of P, Ca and Sr)
- Use of constraints and reference levels that apply to all workers and all members of the public, together with optimisation, provides a pragmatic and workable system of protection

Use of *E* in medicine

Currently :

- To **compare techniques**
  (even if exposed organs are not the same)
- Providing broad risk categories for the purpose of **communicating to clinicians and patients**
- To inform decisions on
  - **justification** of patient procedures
  - **planning** requirements in **research studies**
  - evaluation of **unintended exposures**

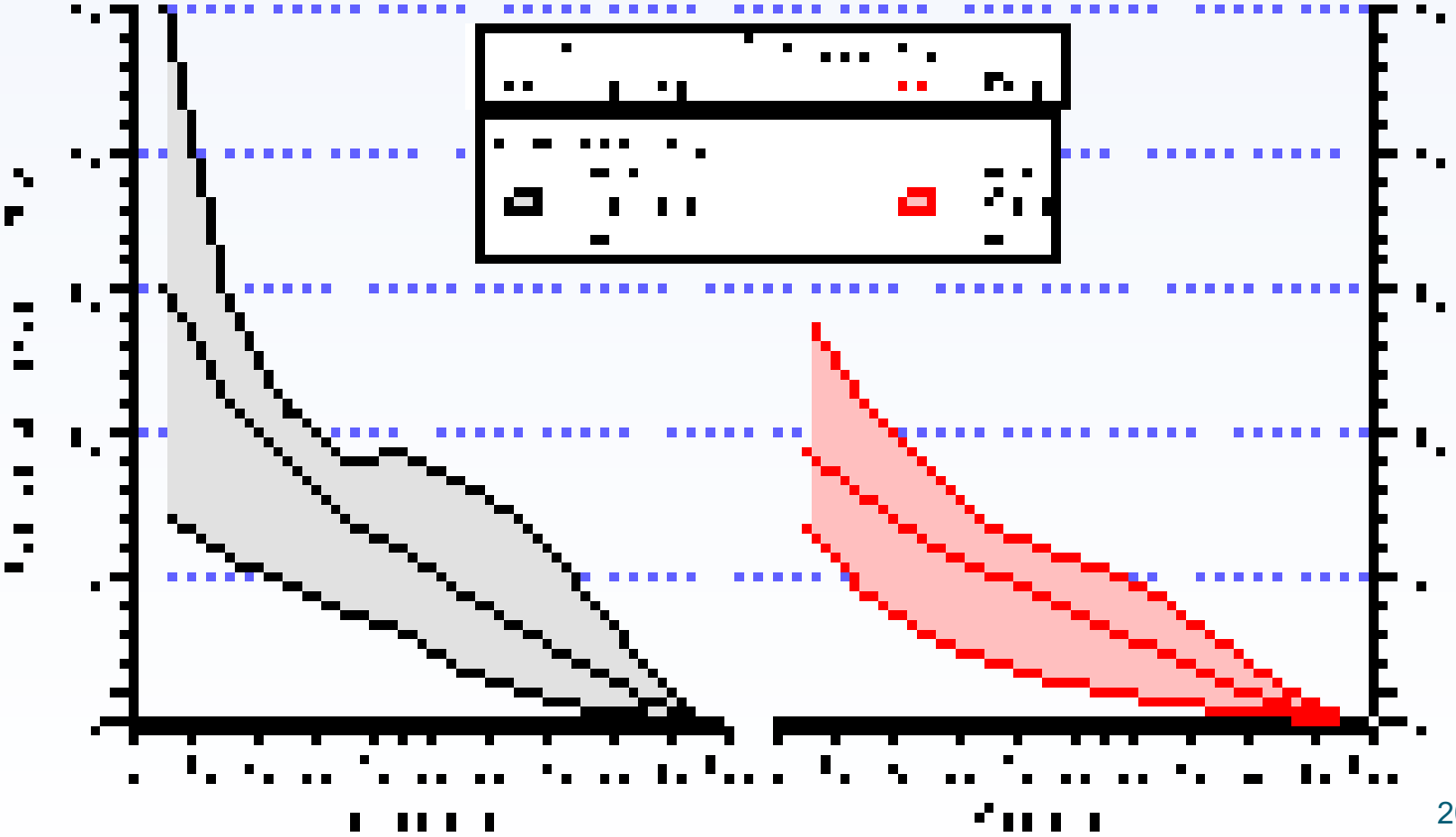
***E* used as an indicator of detriment**

prospectively	**retrospectively**
justification of clinical procedures planning of research	initial assessments after an incident

Risk categories

Effective dose (mSv)	Risk of cancer incidence	Proposed term	Examples of medical radiation procedures
< 0.1	Risk inferred on basis of LNT and risk models	Negligible	Radiographs of chest, femur, limbs, ^{99m}Tc sentinel node imaging, labelling for in vitro counting with ^{14}C and ^{57}Co.
0.1–1		Minimal	Radiographs of spine, abdomen, pelvis, head and cervical spine; labelling for in vitro counting with ^{51}Cr. ^{99m}Tc for imaging lung ventilation and renal imaging.
1–10		Very low	Barium meals, CT scans of the head and combinations of chest, abdomen, and pelvis; barium enemas, cardiac angiography, interventional radiology; ^{99m}Tc myocardial imaging, lung perfusion, imaging of bone lesions; imaging with ^{18}F, ^{123}I, and ^{111}In.
10–100		Low	CT scans of chest, abdomen, and pelvis, double CT scans for contrast enhancement, interventional radiology; ^{67}Ga tumour, and ^{201}Tl myocardial imaging; endovascular aneurysm repair. (10-35 mSv). Renal/visceral angioplasty, Iliac angioplasty, follow-up of endovascular aneurysm repair. (35-100 mSv).
100s	**>**10^{-2} based on epidemiological observation	Moderate	Multiple procedures and follow-up studies.

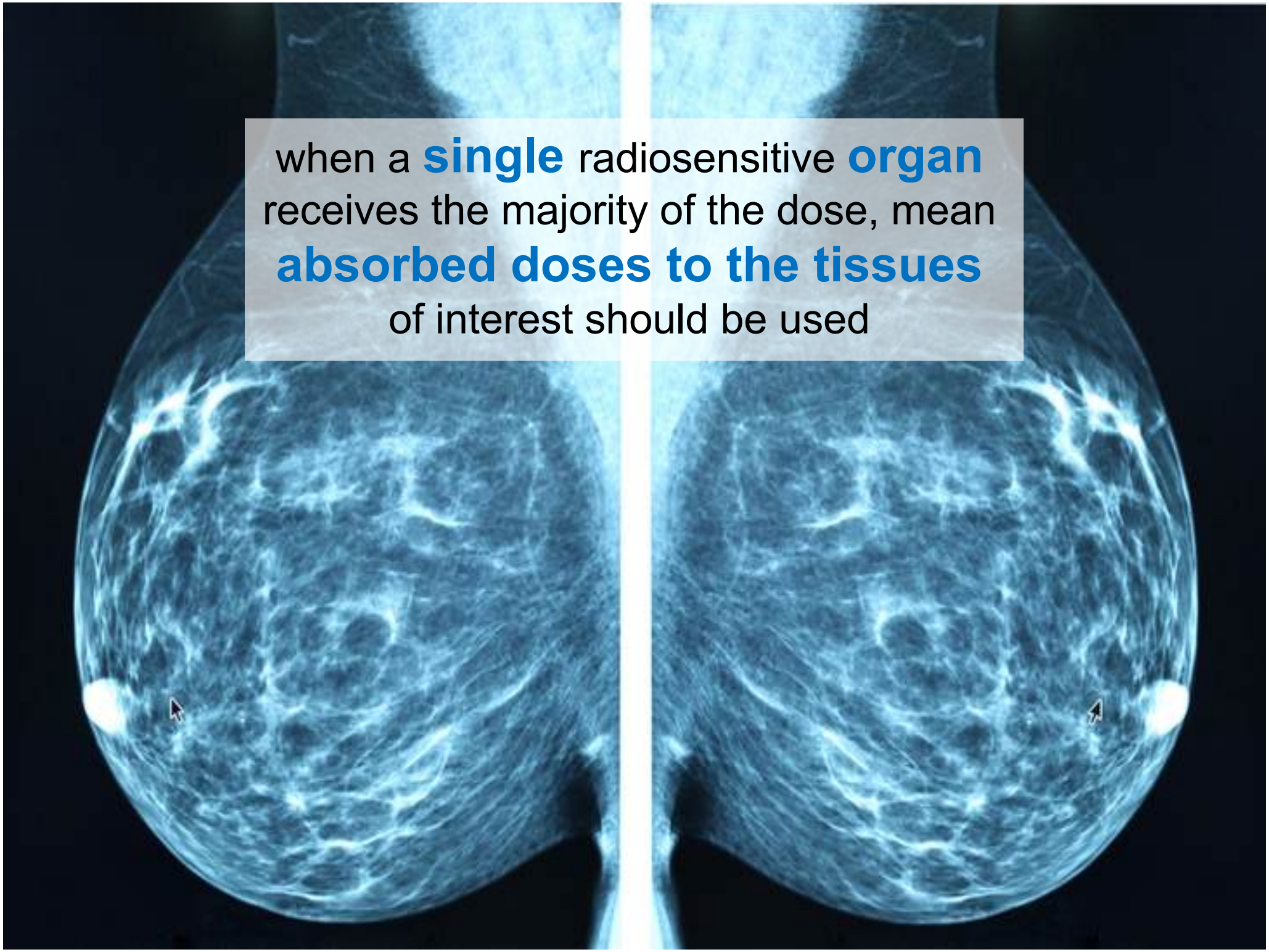
Cancer risk per Sv for medical X-ray examinations



Proposal

Use *E* as an approximate indicator of possible risk from medical examinations

- **MAY apply simple adjustments for age and sex, according to procedure – factors of a few higher in young children and lower at older ages**
- **BUT UNCERTAINTIES should be recognised**
- **AND not a substitute for risk analysis using organ doses in Gy – with consideration of uncertainties**


when a **single** radiosensitive **organ**
receives the majority of the dose, mean
absorbed doses to the tissues
of interest should be used

Collective effective dose

Use of **collective dose** to predict possible **health effects** should be treated with **great caution**

It should be **put into context** and judged in **relation to background** incidence rates

Components of dose integration in **time and space** should be considered

Levels of **exposure** to the public may be **difficult to estimate**

Final Points

- **ICRP will consult in 2018 on its report on the use of Effective Dose**
- **The report is intended to clarify the use of *E* and also includes two proposed changes:**

➢ **Discontinue the use of Equivalent dose as a protection quantity**

➢ **Explicitly recognise Effective dose as an "approximate indicator of possible risk"**

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