Use of effective dose in medical exposure

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ICRP Committee 3

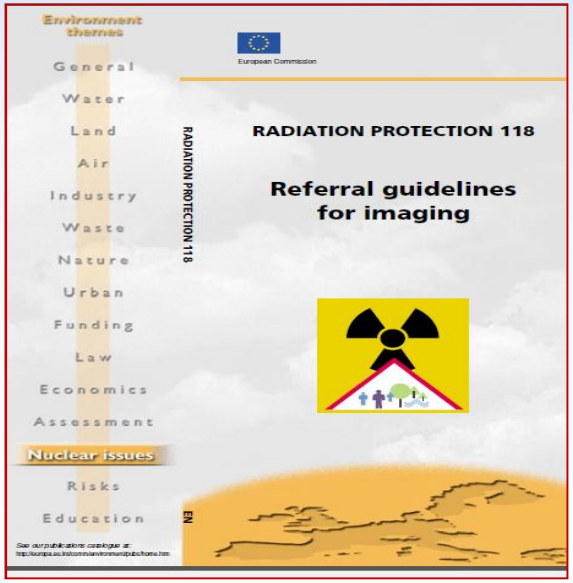
Overview of the use of effective dose in medical exposure

Effective dose has been useful for **protection in imaging** medical exposure

- In justification of medical procedures
- In optimization of protection by comparing exposures:
  - Among hospitals, countries
  - For the same type of examination
  - From alternative examinations
- In establishing dose constraints for comforters and volonteers in biomedical research

In justification

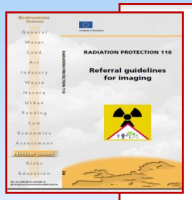
For the justification of medical exposure, referral criteria exist



CLINICAL PROBLEM	INVESTIGATION {DOSE}	RECOMMENDATION {GRADE}	COMMENT
Orbital lesions **A15**	*CT (II) or MRI (0)*	Specialised investigation (B)	CT provides better anatomical detail, particu bony structures (e.g. nasolacrimal duct). MR radiation dose to lens (but contraindicated wi ferromagnetic FB suspected). Consider US fo intra-ocular lesions.
Orbits Metallic FB (before MRI) **A16**	*XR orbits (I)*	Indicated (B)	Especially for those who have worked with r materials, power tools, etc. Some centres use (see Trauma Section K for acute injury.
Visual disturbances **A17**	*SXR (I)*	Not indicated routinely (C)	Plain XRs rarely contributory. Specialists ma CT or MRI.
Epilepsy (adult)	*SXR (I)*	Not indicated routinely (B)	Evaluation requires specialist expertise. Late seizures should normally be investigated but may be unnecessary if clearly alcohol-relatec
(for children see Section M) **A18**	*CT (II), MRI (0) or NM (III)*	Specialised investigation (B)	Partial/focal seizures may require detailed ev if surgery is being considered. Ictal SPECT r likelihood of localising focus. Interictal funct imaging also important. Much depends on lo which will determine combinations of proced

Typical effective doses from diagnostic medical exposures in the 1990s

Diagnostic procedure	Typical effective dose (mSv)	Equivalent No. of chest x-rays	Approximate equivalent period of natural background radiation (1)
X-ray examinations:			
Limbs and joints (except hip)	<0.01	<0.5	<1.5 days
Chest (single PA film)	0.02	1	3 days
Skull	0.07	3.5	11 days
Thoracic spine	0.7	35	4 months
Lumbar spine	1.3	65	7 months
Hip	0.3	15	7 weeks



Barium swallow	1.5	75	8 months
Barium meal	3	150	16 months
Barium follow through	3	150	16 months
Barium enema	7	350	3.2 years
CT head	2.3	115	1 year
CT chest	8	400	3.6 years
CT abdomen or pelvis	10	500	4.5 years
Radionuclide studies:			
Lung ventilation (Xe-133)	0.3	15	7 weeks
Lung perfusion (Tc-99m)	1	50	6 months
Kidney (Tc-99m)	1	50	6 months
Thyroid (Tc-99m)	1	50	6 months
Bone (Tc-99m)	4	200	1.8 years
Dynamic cardiac (Tc-99m)	6	300	2.7 years
PET head (F-18 FDG)	5	250	2.3 years

Broad categories

TABLE Classification of the typical effective doses of ionising radiation from common imaging procedures

Class	Typical effective Dose (mSv)	Examples
0	0	US, MRI
I	<1	CXR, limb XR, pelvis XR
*II**	1–5	IVU, lumbar spine XR, NM (e.g. skeletal scintigram), CT head & neck
III	5–10	CT chest and abdomen, NM (e.g. cardiac)
IV	>10	Some NM studies (e.g. PET)

* The average annual background dose in most parts of Europe falls in Band II.

Optimization

Comparisons of effective dose

- The same type of examination with the same technique, but taken in different rooms, hospitals, or countries
- The same type of examination obtained with different techniques or projections
- Different types of examinations (for example a nuclear medicine with a CT examination)

Optimization situation 1: same type of examination, same exposure technique

- The dose distribution inside the body is similar
- There is no need to calculate organ doses nor effective dose to compare

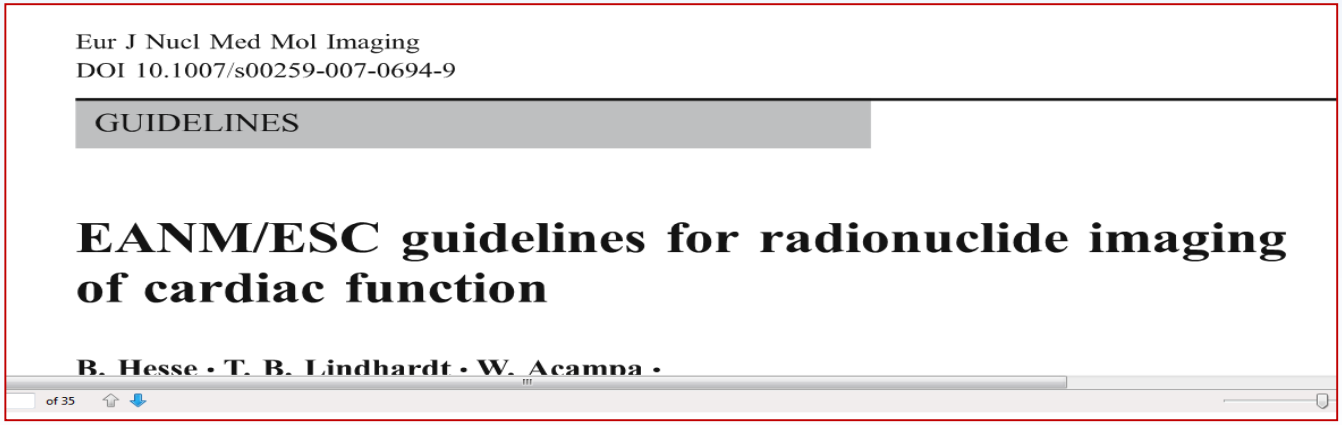
- Comparisons can be made directy in terms of measurable quantities. Examples:
  - entrance surface air kerma,
  - air kerma-area product,
  - administered activity of radiopharmaceutical

Optimization situation 2: comparing different techniques

- Different exposure factors, different projections, different radiopharmaceuticals
- The dose distribution is different
- In this situation effective dose is appropriate for comparison

Professional guidelines relating to optimization

European Association of Nuclear Medicine



Eur J Nucl Med Mol Imaging
DOI 10.1007/s00259-007-0694-9

GUIDELINES

EANM/ESC guidelines for radionuclide imaging of cardiac function

B. Hesse · T. B. Lindhardt · W. Acampa ·

of 35

400,000 particles will result in obstruction of only a very small fraction of pulmonary vessels. A reduction in the number of particles administered to between 100,000 and 200,000 is recommended in patients with known pulmonary hypertension, right to left heart shunt or after a single

suggested. Perfusion-only scans should be performed on day 1, using a reduced dose of ^{99m}Tc-MAA. In most patients PE can be excluded on the basis of a normal perfusion pattern. When the perfusion pattern is abnormal but not diagnostic of PE, subcutaneous low molecular

Table 1 Data on radiation exposure in adults

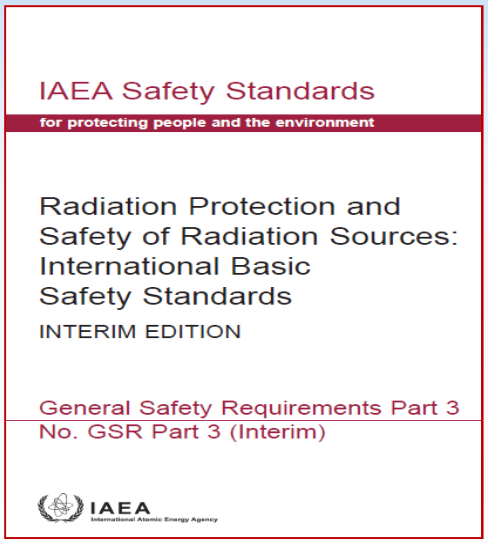
Reference	Radiopharmaceutical	Administered activity (MBq)	Critical organ, dose (mGy/MBq)	Effective dose (mSv/MBq)
[71]	^{99m}Tc-MAA	40–120	Lungs, 0.067	0.017
[72]	^{99m}Tc-DTPA	20–30	Bladder, 0.047	0.007
[73]	Technegas	20–30	Lungs, 0.11	0.015
[74]	^{81m}Kr	40–400	Lungs, 0.0068	0.0007

Critical organ, dose (mGy/MBq)	Effective dose (mSv/MBq)
Lungs, 0.067	0.017
Bladder, 0.047	0.007
Lungs, 0.11	0.015
Lungs, 0.0068	0.0007

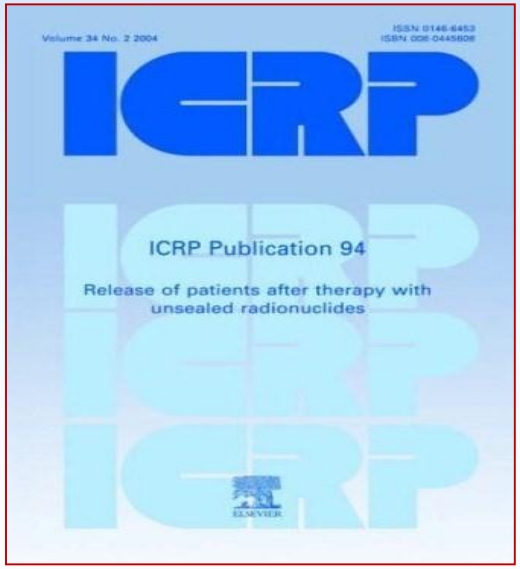
Dose constraints for comforters and volunteers

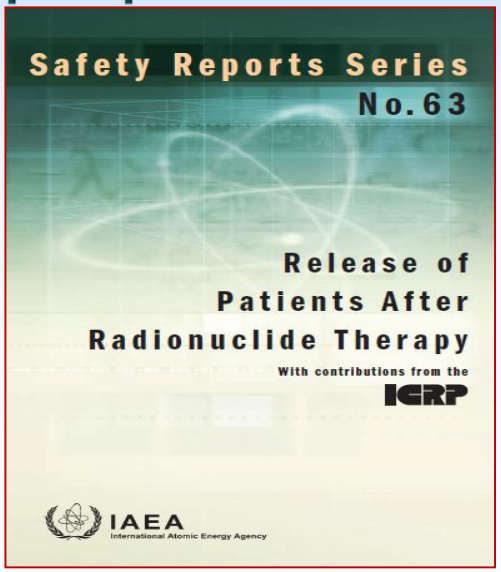
Dose constraints to comforters

- International Safety Standards establish requirements on constraints for comforters and volonteers in biomedical research, when the exposed individual does not directly benefit from the exposure

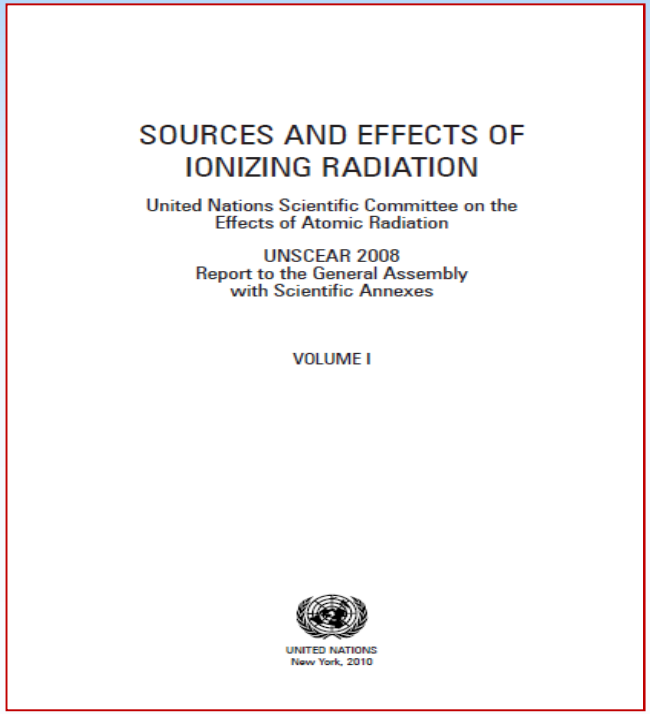


Guidance based on efective dose is used for this purpose





Are there other uses of effective dose other than strictly radiation protection?


SOURCES AND EFFECTS OF
IONIZING RADIATION
United Nations Scientific Committee on the
Effects of Atomic Radiation
UNSCEAR 2008
Report to the General Assembly
with Scientific Annexes
VOLUME I
UNITED NATIONS
New York, 2010

Effective dose for summarizing uses of radiation and contributions to total exposure

- Average effective dose per procedure
- Collective effective dose for a given procedure or practice or for the whole x-ray diagnostic or nuclear medicine
- Per caput doses, by dividing collective effective dose by the population

Effective dose, collective effective dose UNSCEAR 2000

Table 29
Some reported annual individual and collective effective doses from diagnostic medical x-ray examinations [a]
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures unless otherwise indicated

Country	*Effective dose (mSv)*		*Collective effective dose (man Sv)*	*Ref.*
	Per examination	*Per caput*		
Health-care level I				
Australia	1.3	0.8	13 000	[W34]
Bulgaria	1.28	0.75	6 400	-
Canada	1.05	0.94	26 200	[A15]
China, Taiwan Province	0.43	0.23	4 700	[L23]
Denmark	0.7	0.36	1 820	-
Finland	0.63	0.45	2 270	-
France	-	1.0	57 660	[S50]
Germany	1.5	1.9	153 360	-
Netherlands	1.0	0.6	9 000	-
Poland	1.2	0.8	32 300	-
Portugal	0.83	0.71	7 000	[F11]
Romania	1.35	0.61	13 800	-
Russian Federation	0.7	0.9	128 000	-
Sweden	1.2	0.68	6 000	-
Ukraine	0.83	0.50	26 250	[K18]

Example 2: contribution to collective (effective) dose (UNSCEAR 2000)

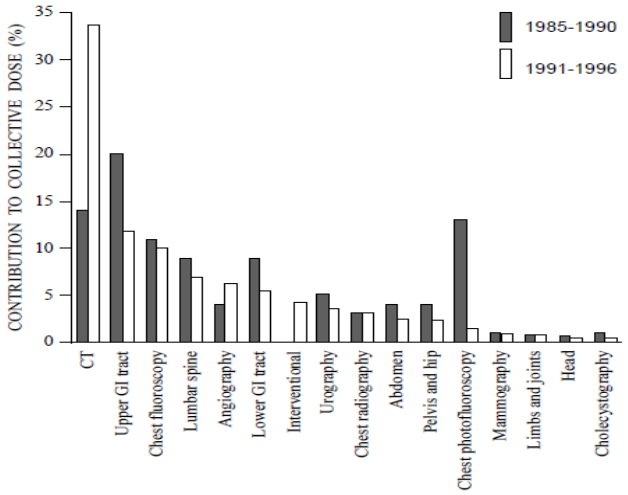


Figure V. Percentage contributions by examination type to global collective dose from medical x-ray examinations: comparison of data for 1955-1990 and 1991-1996.

Per caput dose (collective effective dose divided by the total population, UNSCEAR 2000)

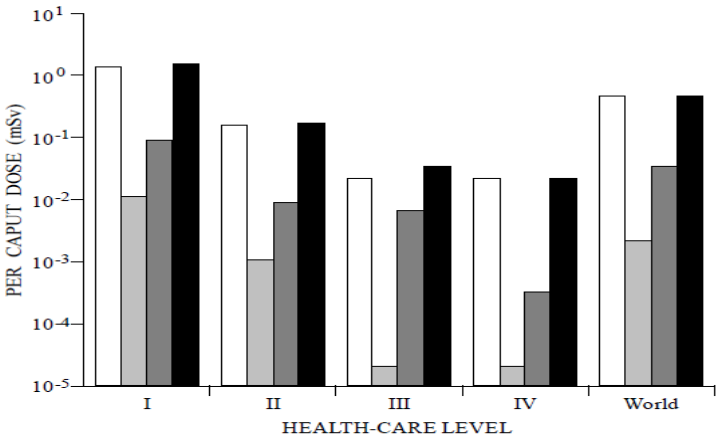


Figure IX. Estimated global annual per caput doses from medical diagnostic radiological procedures (1991-1996). *The four columns in each group represent medical x rays, dental x rays, nuclear medicine (diagnosis), and all diagnostic practices, respectively.*

UNSCEAR 2008

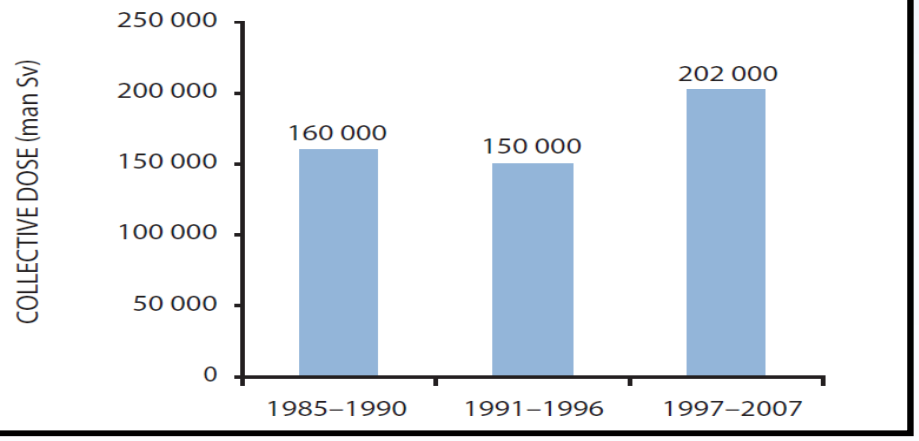
Table 1. Estimated annual per caput dose and annual effective dose to the world population from diagnostic medical and dental radiological examinations (1997–2007)

Health-care level	*Population (millions)*	*Annual per caput dose (mSv)*		*Annual collective effective dose (man Sv)*	
		Medical	*Dental*	*Medical*	*Dental*
I	[illegible]	1.91	0.006 4	2 900 000	9 900

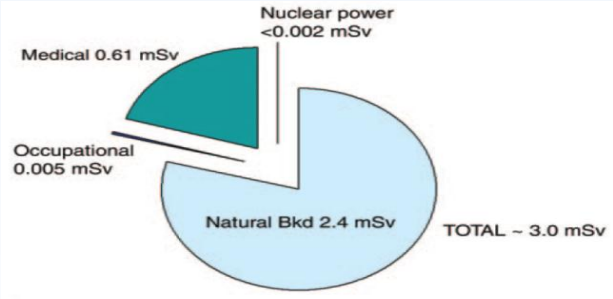
Annual collective effective dose (man Sv)	
Medical	*Dental*
2 900 000	9 900

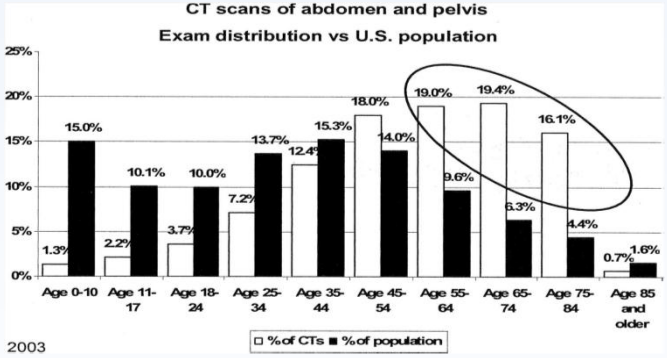
UNSCEAR 2008

Figure VIII. Trend in the annual collective effective dose from diagnostic nuclear medicine examinations



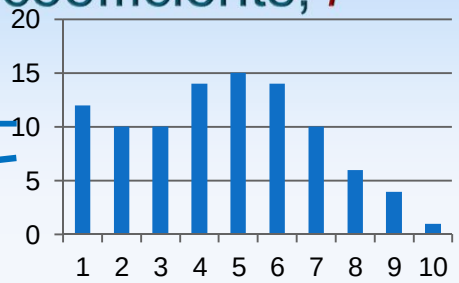
Comparison of collective effective doses are often for different age and sex distributions



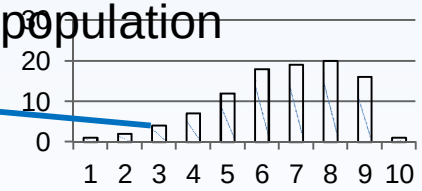


Effective dose involves tissue weighting factors, w_T, and detriment risk coefficients, r

$$E = \sum_T \sum_R w_T w_R D_{T,R}$$



General population



Example of patient population

- Detriment = r E
- Coefficients w_T and r were derived for populations and for the general population

Question (caveat):

- Effective dose is used with some flexibility for populations that are different from those for which w_T and effective dose are derived
- In the context of
  - summarizing uses of radiation in medicine and
  - contribution to the population exposure,
  - not to calculate risk

Effective dose should be expressed with no more than two significant figures

UNSCEAR 2000 Report (page 296-297)

1. "effective dose should not be used directly for estimating detriment from medical exposure (individuals or populations) … by application of the nominal fatality probability coefficients. Such assessments would be inappropriate and serve no purpose in view of the uncertainties arising from potential demographic differences (in terms of health status, age and sex), between particular population of patients and those from general populations for whom ICRP derived the risk coefficients … effective dose could broadly underestimate the detriment from diagnostic exposures of young patients by a factor of 2 and, conversely, could overestimate the detriment from old patients by a factor of at least 5.
2. "The analysis of radiation risk from diagnostic medical exposures requires detailed knowledge of organ doses and the age and sex of patients…."
3. "It is possible…to use effective dose and even collective dose for medical diagnostic exposure as long as this is done only for comparative purposes and for the same or similar patient populations, and it would require additional considerations or significant corrections if we try to use them to compare with other populations."

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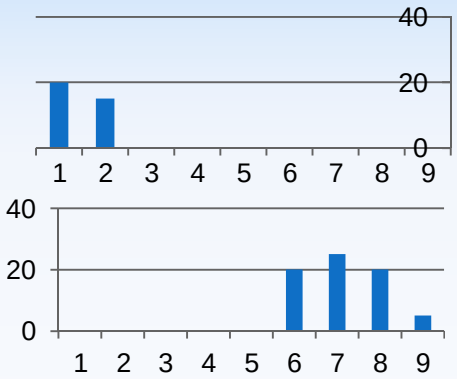
Skewed populations,



Pediatric

Old adults

For comparisons for these different population groups, corrections may be needed

Recap: Effective dose is useful in medical exposure

- For radiation protection:
  - Justification
  - Optimization
  - Dose constraints for comforters and volonteers
- For expressing radiation use and contributions to population exposure
- Buté

But, remembering that

- Collective effective dose is **not i**ntended as a tool for **epidemiological** risk assessment, and it is inappropriate to use it in **risk projections** (ICRP 103).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