UNSCEAR
United Nations Scientific Committee on the Effects of Atomic Radiation

UN environment programme 50 1972-2022

The UNSCEAR 2020/2021 Report, Annex A: Evaluation of Medical Exposure to Ionizing Radiation

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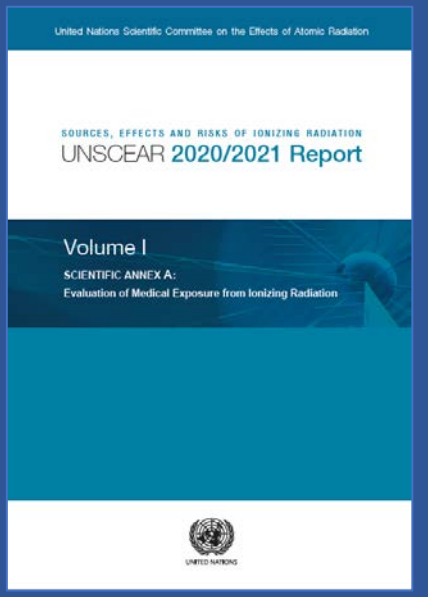

Expert Group

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- H Järvinen (Finland, Lead writer)
- E Samara (Switzerland, Lead writer)
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Questions and answers

Moderation : F Shannoun (UNSCEAR secretariat) and E van Deventer (WHO)

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R Smart (Australia, Lead writer appendix D on nuclear medicine)
G Ibbott (United States, Lead writer appendix E on radiation therapy)

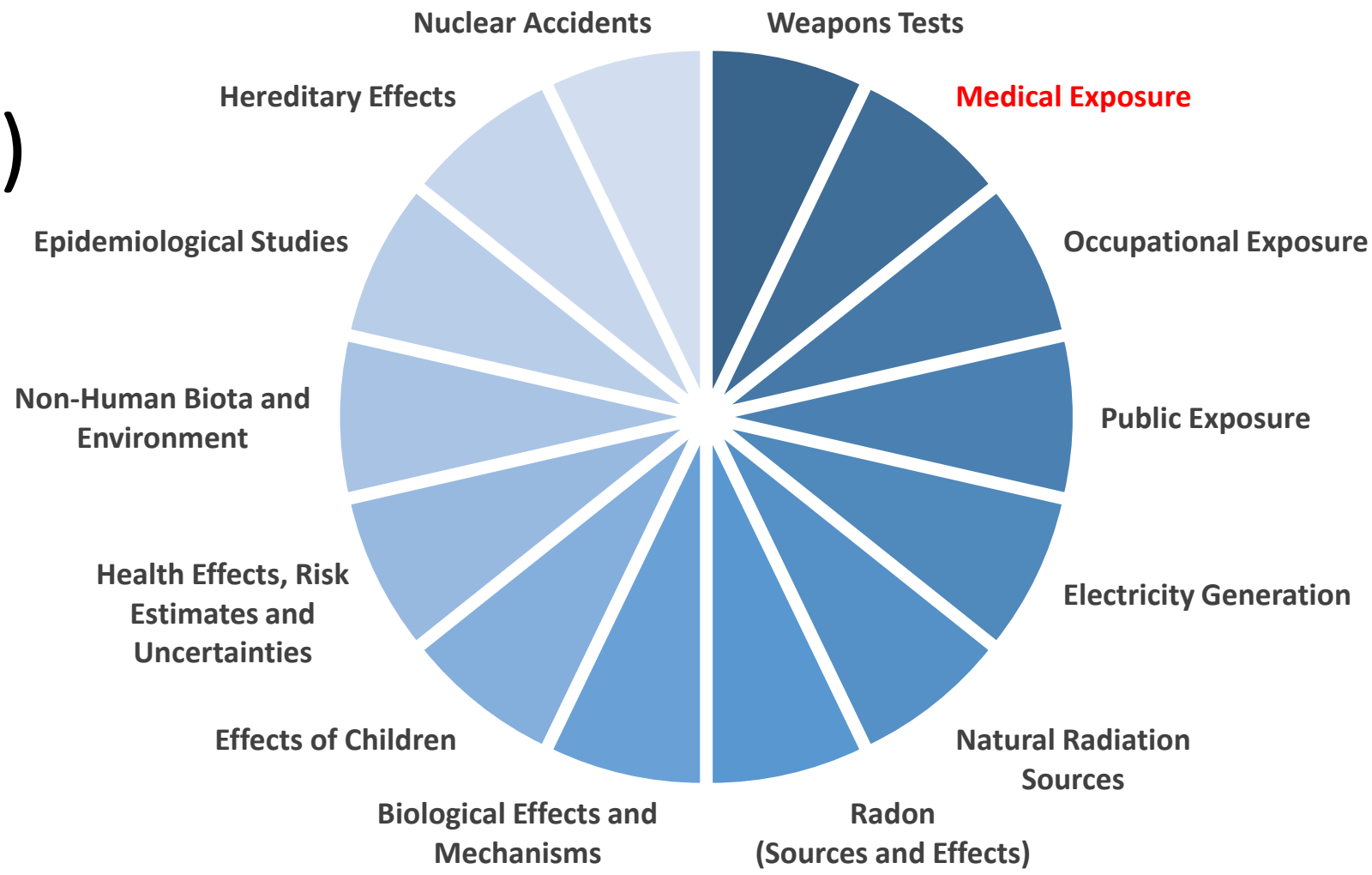
- Established by UN General Assembly (GA) resolution in 1955
- Scientists from 31 UN Member States
- Assess levels, effects & risks of ionizing radiation
  - identify emerging issues
  - improve knowledge
  - identify areas for future research
- Disseminate findings to UN GA, scientific community and public

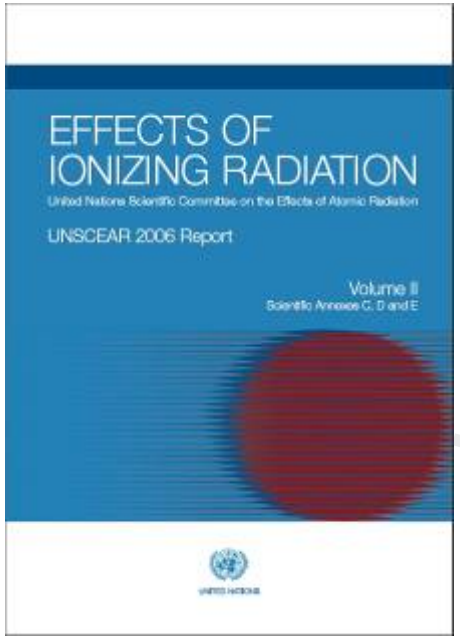
Scientists from 31 UN States Members

- Algeria
- Argentina
- Australia
- Belarus
- Belgium
- Brazil
- Canada
- China
- Egypt
- Finland
- France
- Germany
- India
- Indonesia
- Iran (IR)
- Japan
- Mexico
- Norway
- Pakistan
- Peru
- Poland
- Rep. of Korea
- Russia
- Slovakia
- Spain
- Sudan
- Sweden
- Ukraine
- UAE
- UK
- USA

Input: Other Member States and international organizations provide relevant data and technical input

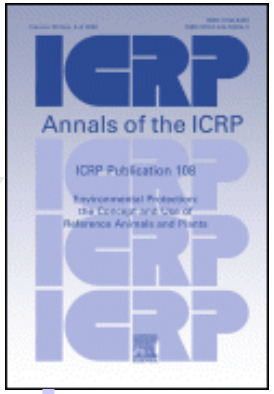
UNSCEAR (key work areas)





UNSCEAR
Scientific basis

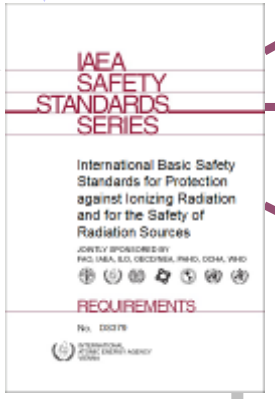
issues
effects
risks



ICRP
Protection philosophy, principles and units

recommendations

issues
levels
trends



ILO convention 115: occupational radiation protection

FAO/WHO Codex Alimentarius Commission (food contamination guides)

UN transport regulations for radioactive material

implemented by UN Member States

SOURCE OF DATA

United Nations Scientific Committee on the Effects of Atomic Radiation
survey.unscear.org

- UNSCEAR Global Survey of Medical Exposure:
  - All UN Member States were invited to provide the UNSCEAR secretariat with relevant data about frequency and doses from various medical radiological examinations;
  - The UNSCEAR secretariat established an online platform and a network of National Contact Persons to collect information from UN Member States through questionnaires.
- Information and data from the literature after a review process by the Expert Group
- Additional supporting data directly from other sources such IAEA[1,2], WHO, OECD/NEA and EC

IAEA International Atomic Energy Agency
World Health Organization
NEA NUCLEAR ENERGY AGENCY
European Commission

[1]NUclear Medicine DAtaBase and [2]DIrectory of RAdiotherapy Centres both run by IAEA

UNSCEAR's medical exposure surveys

- global estimates of level of exposure and frequency, with break-downs by medical procedure, age, sex, health care level, and income
- trends in practice
- related supporting information on equipment and staffing levels

Survey launched in 2014

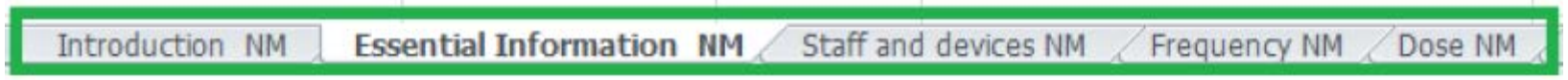
United Nations Scientific Committee on the Effects of Atomic Radiation
survey.unscear.org

- Online database
- Spreadsheet questionnaires

  Diagnostic radiology – including interventional radiology, nuclear medicine and radiation therapy
- Each questionnaire

  Introduction, essential information, staff and devices, frequency, dose
- Doses in relevant “practical” quantities

  (e.g. entrance surface air kerma, kerma-area product, volume computed tomography dose index, administered activity, etc.)



Examinations/Procedures - Radiology

Essential

Information on frequency of radiological examinations (simplified)

* required field

Modality category	Number of examinations	Uncertainty (%)
All radiological examinations*		
Radiography and fluoroscopy (without Dental)		
Dental radiography		
Computed Tomography (CT)		
Image-guided interventional procedures (IGIP)		

Information on staffing (simplified)

* required field

Profession	Number of persons
All physicians*	
Dentists	
Radiologists	

Information on radiology devices (simplified)

* required field

Radiological system	Number of devices
All radiographic systems*	
Dental X-ray systems	
Computed Tomography (CT)*	

Detailed

Information on frequencies of radiological examinations

Modality category	Examination category
Projection radiography (without contrast media)	**Total projection radiography**
	Head (skull & facial bones)
	Head (soft tissue)
	Neck (cervical spine)
	Neck (soft tissue)
	Chest/Thorax (lungs PA & LAT)
	Chest (thoracic spine)
	Chest (shoulder girdle & ribs)
	Mammography
	Mammography (screening)
	Lumbar spine
	Lumbo-sacral joint only
	Abdomen
	Pelvis & hips (bone)
	Pelvis (soft tissue)
	Limbs and joints
	Whole spine (trunk)
	Skeletal survey (head & trunk)
	Dental intraoral
	Dental panoramic

Literature review

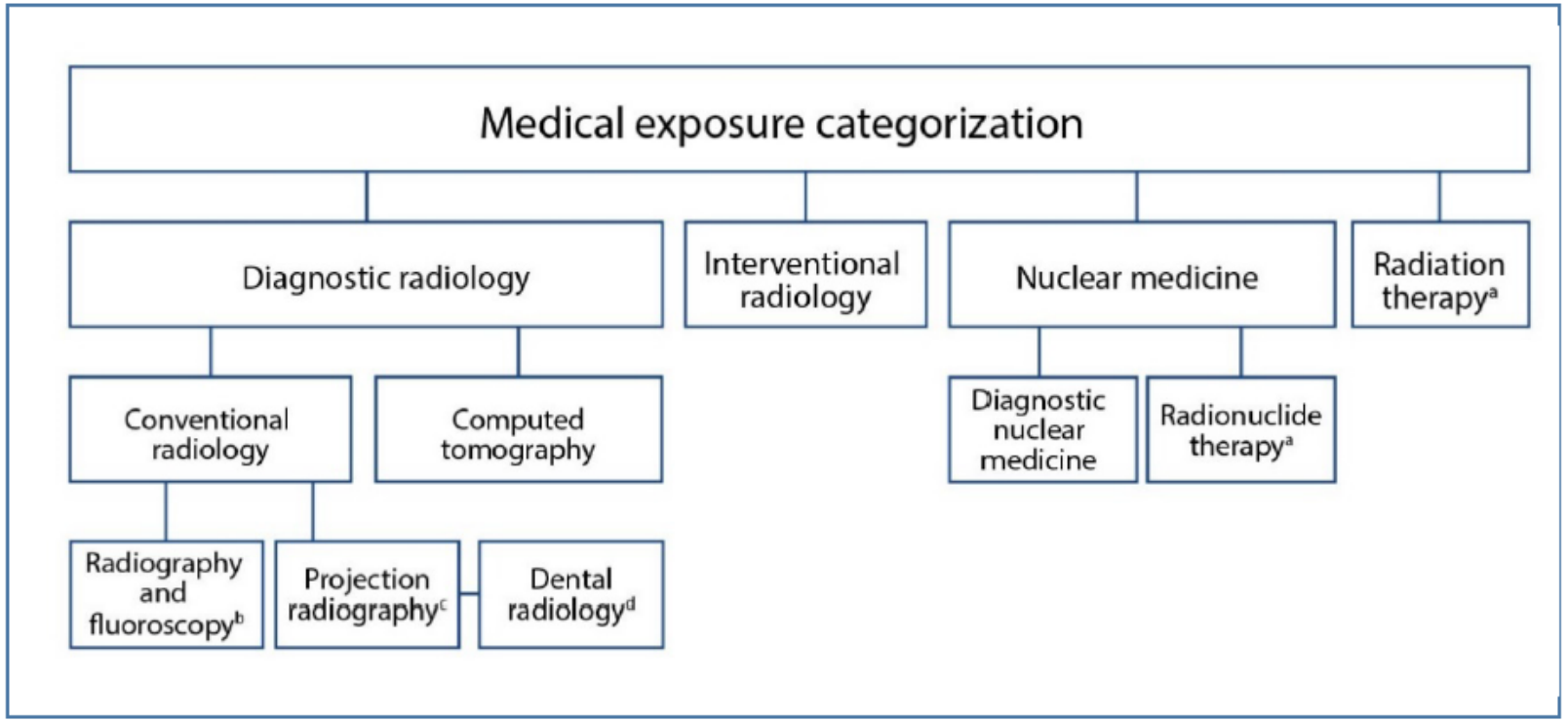
- Comprehensive review of articles published 2005-2018 (inclusive)
- Search terms
  - population dose, collective effective dose (medical), frequencies of examinations, procedures or treatments (radiology, nuclear medicine and radiation therapy), examination codes, patient dose and radiology, automatic dose management.
- Screened to identify publications demonstrating changes and updates in practice since the UNSCEAR 2008 Report
- Some additional recent relevant articles included
- 640 articles identified for review, 373 assessed as meeting the criteria for inclusion in this evaluation
- Literature discussed in details in appendices B-E

Content of the Report

- Main Annex – overall summary
- Appendix A – Methodology
- Appendix B-E – Modalities
  - Introduction
  - Summary of previous UNSCEAR findings
  - Frequencies of examinations
  - Typical effective dose per examination
  - Distributions by age and sex
  - Staff and Devices
  - Trends
  - Summary

+ 6 electronic attachments
(to be published in due course)

Modality categorization used by UNSCEAR



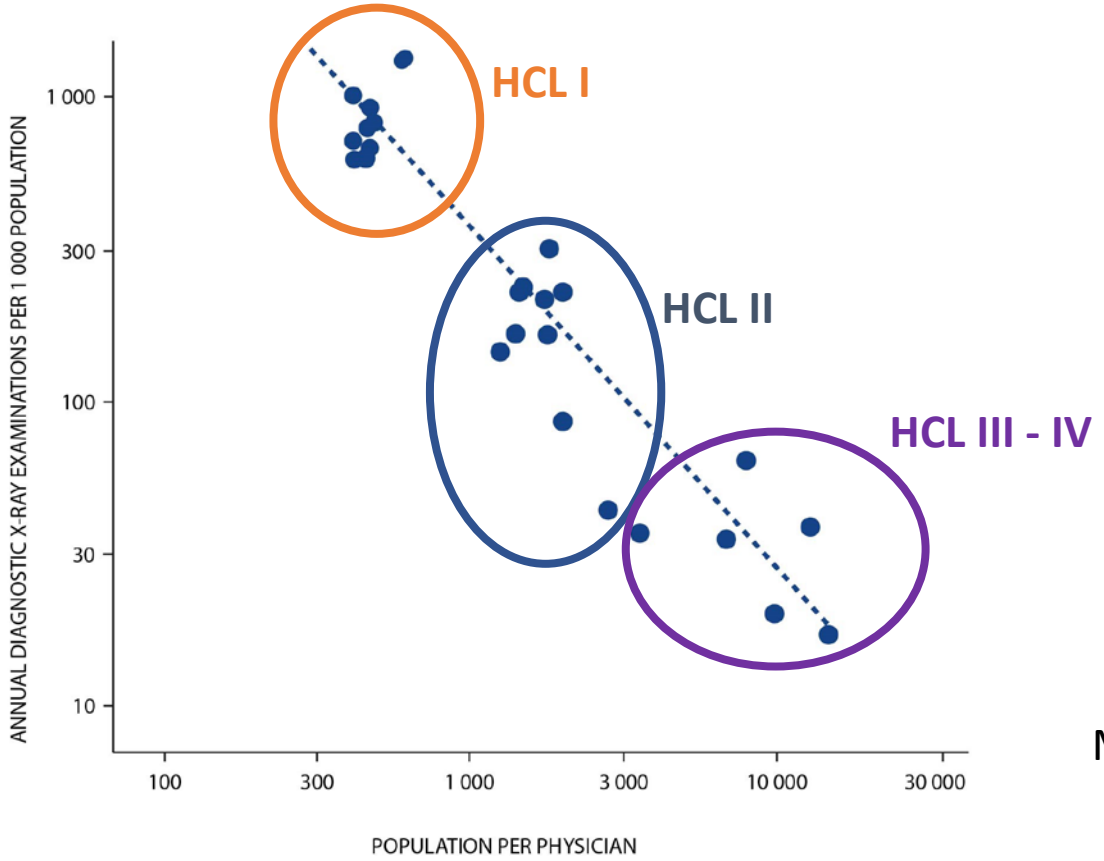
[a] Not part of the collective effective dose assessment because such therapeutic doses are intentionally high enough to cause deterministic effects, however, included in the frequency trend analyses.

[b] Mostly with contrast media.

[c] Without contrast media.

[d] Analysed separately for the global assessment.

Health-care level



Level	Population/physician
HCL I	<1000
HCL II	1000 - <3000
HCL III	3000 - 10,000
HCL IV	>10,000

Mettler et al. Health Phys 52(2): 133-141 (1987)

Categorical extrapolation

Based on data from 65 countries (UNSCEAR Global Survey and additional sources) for the period 2009–2018

Category	*Population-weighted average examinations per 1 000 population*[a]	*Countries included/all countries*[b]	*Proportion of population in assessed data (%)*	*Total population (millions)*	*Extrapolated examinations (millions)*[a]
Extrapolation by health-care level					
I	466	60/105	86	3 908	1 823
II	202	1/31	0.1	2 256	455
III	172	3/31	18	622	107
IV	1.9	1/27	4	526	1
Total	**326**	**65/194**	**48**	**7 312**	**2 386**
Extrapolation by income level					
High	867	43/57	96	1 149	997
Upper middle	267[c]	15/58	80	2 619	700
Lower middle	267[c]	5/45	8	2 882	771
Low	7	2/34	7	662	4.5
Total	**338**	**65/194**	**48**	**7 312**	**2 472**

[a] Values are rounded; however extended precision has been preserved to illustrate differences.

[b] Member States of WHO.

[c] Data for upper middle-income and lower middle-income have been combined. The population-weighted average number of procedures for upper middle-income was 256 per 1,000 population and for lower middle-income was 370 per 1,000 population.

Table A6. Estimates of the global number of conventional radiology (excluding dental) examinations per annum by extrapolation of population-weighted average frequencies to all countries in each category from assessed data by health-care level and by income level

- Categorical extrapolation can be highly dependent on a few data points
- Most data from high income and advanced health care level countries

→ Use a continuous model instead

Continuous models for examination frequencies

Table A13. Predictions of three continuous models tested for estimation of examination/procedure frequencies for the global assessment by modality categories

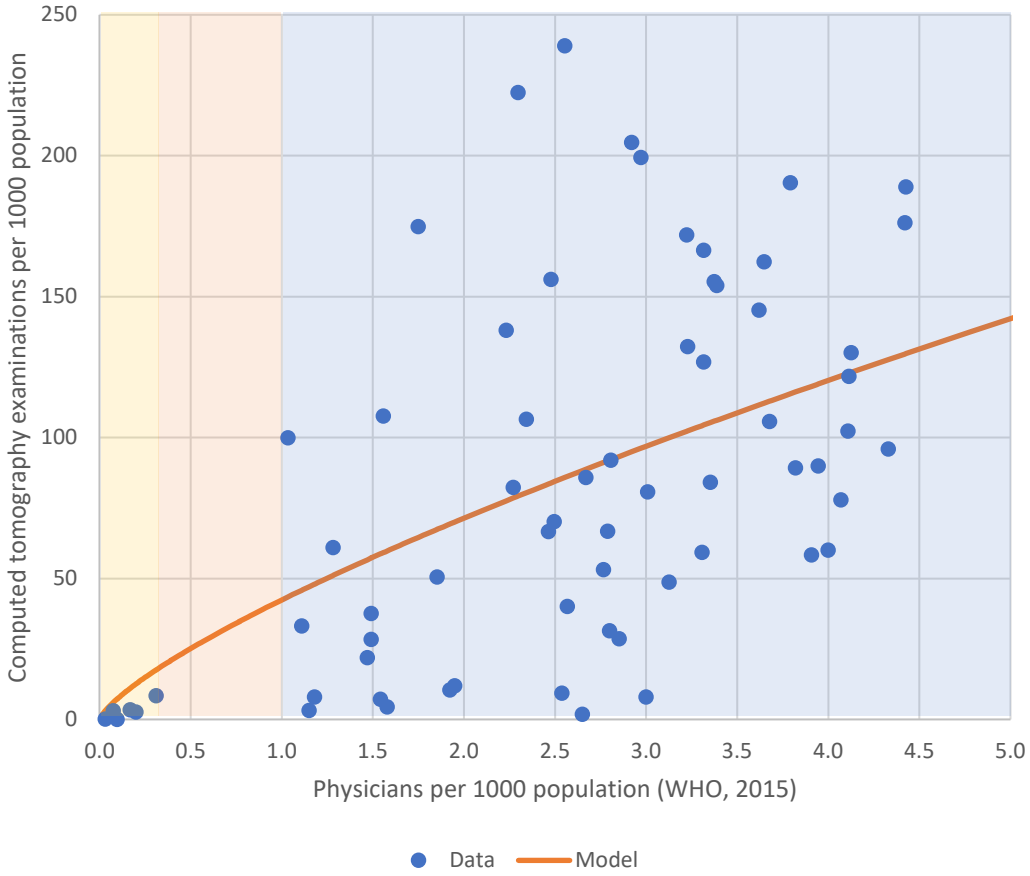
Modelling information	*Model*		
	Power-law *(absolute space)*[a]	Power-law *(log space)*	*Negative binomial regression*[c]
Conventional radiology (excluding dental)			
Mean squared error[b]	111 000	128 000	100 000
Radiography examinations in assessed data (millions)	1 587	1 587	1 587
Additional radiography examinations from model (millions)	1 039	551	843
Total conventional radiology examinations (millions)	2 626	2 138	2 430
Countries with no prediction (missing data)	1	1	14
Proportion of total population included (%)	99.8	99.8	99.3

- Power law as a function of physician density (doctors per 1000 population)
  *Freq = a * (physician density)^b + ε*
- Multivariate negative binomial regression includes other variables

$$ln(N_i) = \beta_0 + \beta_1 \times x_{1,i} + \cdots + \beta_n \times x_{n,i} + \ln(P_i)$$

- Performance and predictions of the 3 models are similar
- Chose power law as a function of physician density due to simplicity and wide availability of data

Continuous models



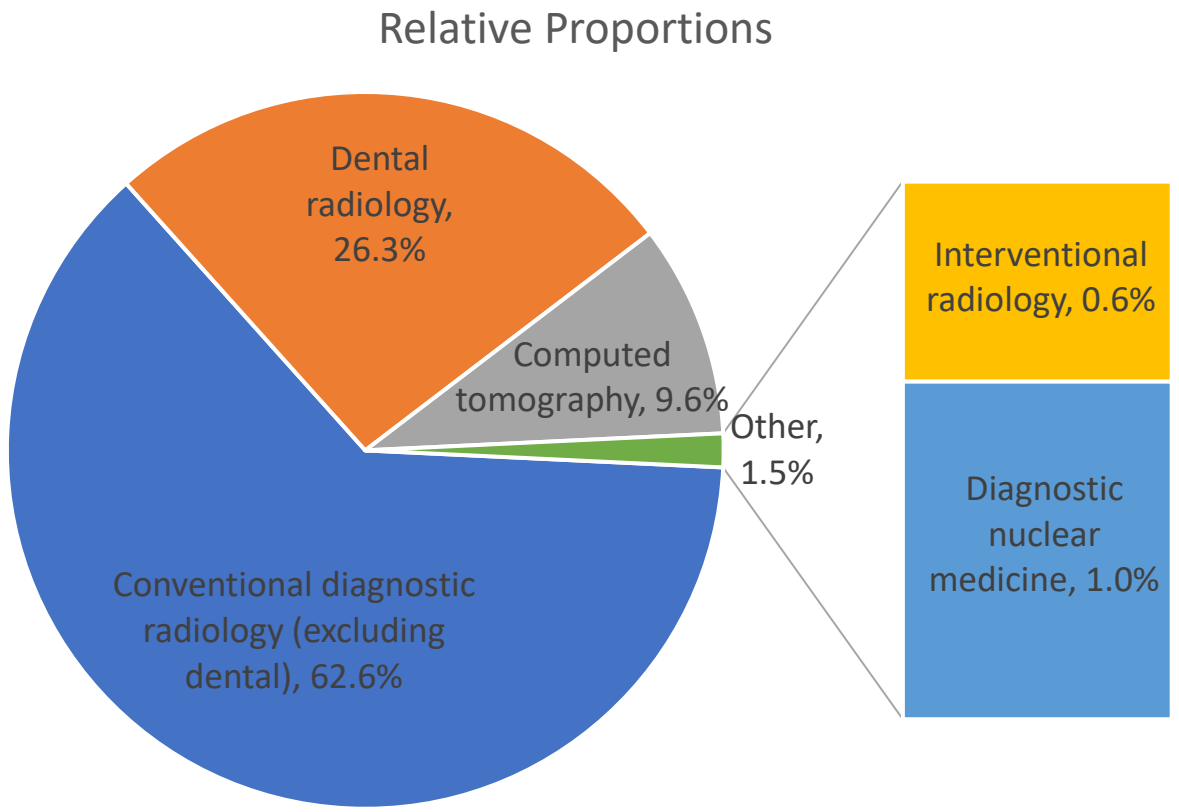
- Separate models for 7 broad modality categories
- Frequency (examinations per 1000 population)
- Power law as a function of physician density (doctors per 1,000 population [WHO, 2015])

$$F = a * (\text{physician density})^{b} + \varepsilon$$

- Used to estimate examination frequency for Member States where no data was available

Examinations / Procedures

Category	Examinations (millions)[a]	Uncertainty (%)
Conventional radiology (excluding dental)	2630	35
Dental radiology	1100	60
Computed tomography	400	40
Interventional radiology	24	80
Diagnostic nuclear medicine	40	70
Radionuclide therapy[b]	1.4	35
Radiation therapy[b]	6.2	25
Total	**4190**	**30**



[a] Values have been rounded
[b] Counts for radionuclide therapy and radiation therapy not included in the total

Dose per examination or procedure

Examination category	Sample size	Mean dose per exam	
		DLP [mGy cm]	Variation [SD]
CT-head (skull & facial bones)			
CT-head (soft tissue & brain)			
CT-neck (cervical spine)			
CT-neck (soft tissue)			
CT-chest (thoracic spine)			
CT-chest (thorax)			
…			
Other (please specify)			

- Standard factors to convert to estimates of effective dose (ICRP 60)
- Combine with average proportions of examinations or procedures within a given modality category
- Frequency-weighted average dose per procedure within each modality category

\+ ***Average relative proportions of each CT examination*** → ***Dose per CT examination***

Average doses and relative frequencies - CT

Examination category	*E* (mSv)	Relative frequency (%)
CT-head (skull and facial bones)	1.5	13.6
CT-head (soft tissue and brain)	1.9	16.4
CT-neck (cervical spine)	3.1	2.9
CT-neck (soft tissue)	2.8	1.2
CT-chest (thoracic spine)	8.0	1.4
CT-chest (thorax)	6.4	15.7
CT-abdomen (lumbar spine)	9.4	4.2
CT-abdomen (abdomen)	11	15.4
CT-abdomen (liver, pancreas, kidneys)	10	3.2
…	…	…
Weighted dose per examination for computed tomography	**6.4**	

Dose per examination or procedure

Category	Frequency-weighted effective dose per examination/procedure (mSv)
Conventional radiology (excluding dental)	0.37 (0.39[a])
Dental radiology	0.01
Computed tomography	6.4
Interventional radiology	15
Diagnostic nuclear medicine	6.8 (5.1[b])
All	**0.99**

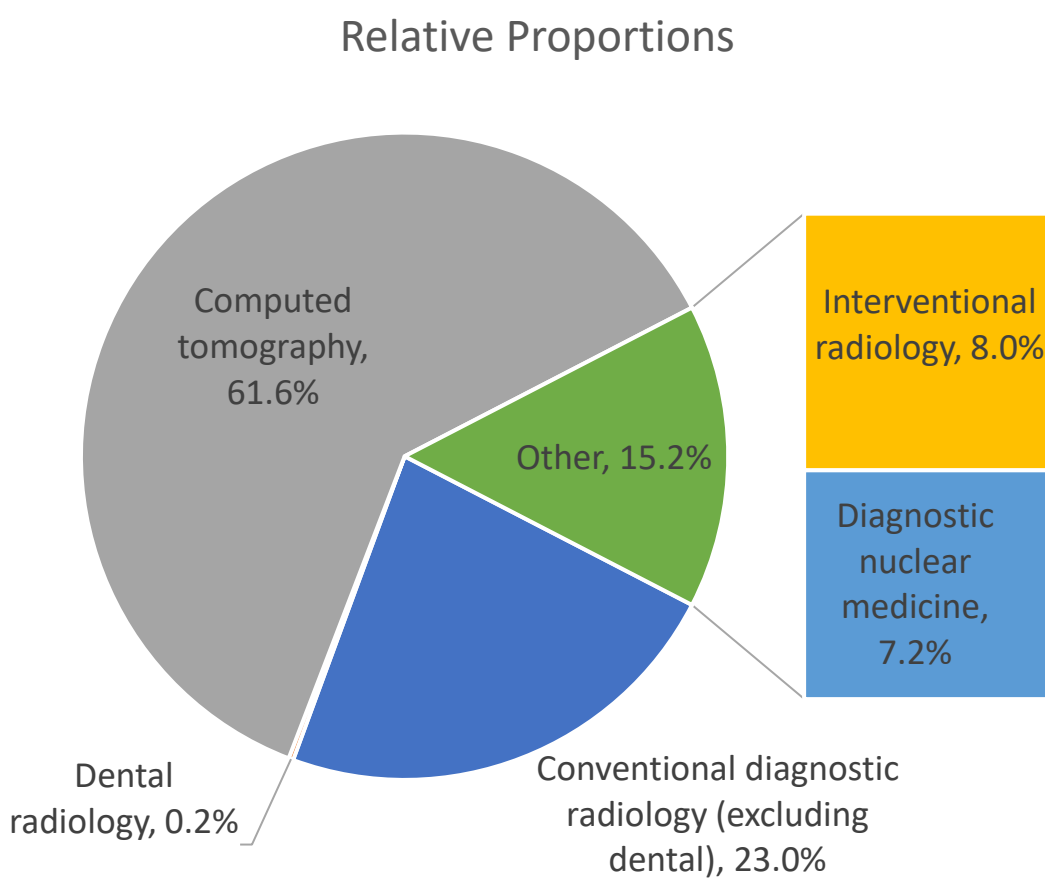
- Survey data used for dose estimates for Member States providing data (~30 countries)
- Practical dose quantities with a conversion factor to estimate effective dose preferred
- Frequency-weighted average dose per procedure from survey data used for Member States not providing data

a Alternative value of 0.39 mSv per examination for Member States in HCL II-IV assumed to have a low level of mammography examinations
b Alternative value of 5.1 mSv per procedure for Member States having no PET equipment and assumed not to be conducting PET procedures

Collective Effective Dose

Category	Collective effective dose (1000 man Sv)[a]	Uncertainty (%)
Conventional radiology (excluding dental)	950	45
Dental radiology	10	70
Computed tomography	2560	45
Interventional radiology	330	90
Diagnostic nuclear medicine	300	75
Total	**4150**	**30**

[a] Values have been rounded



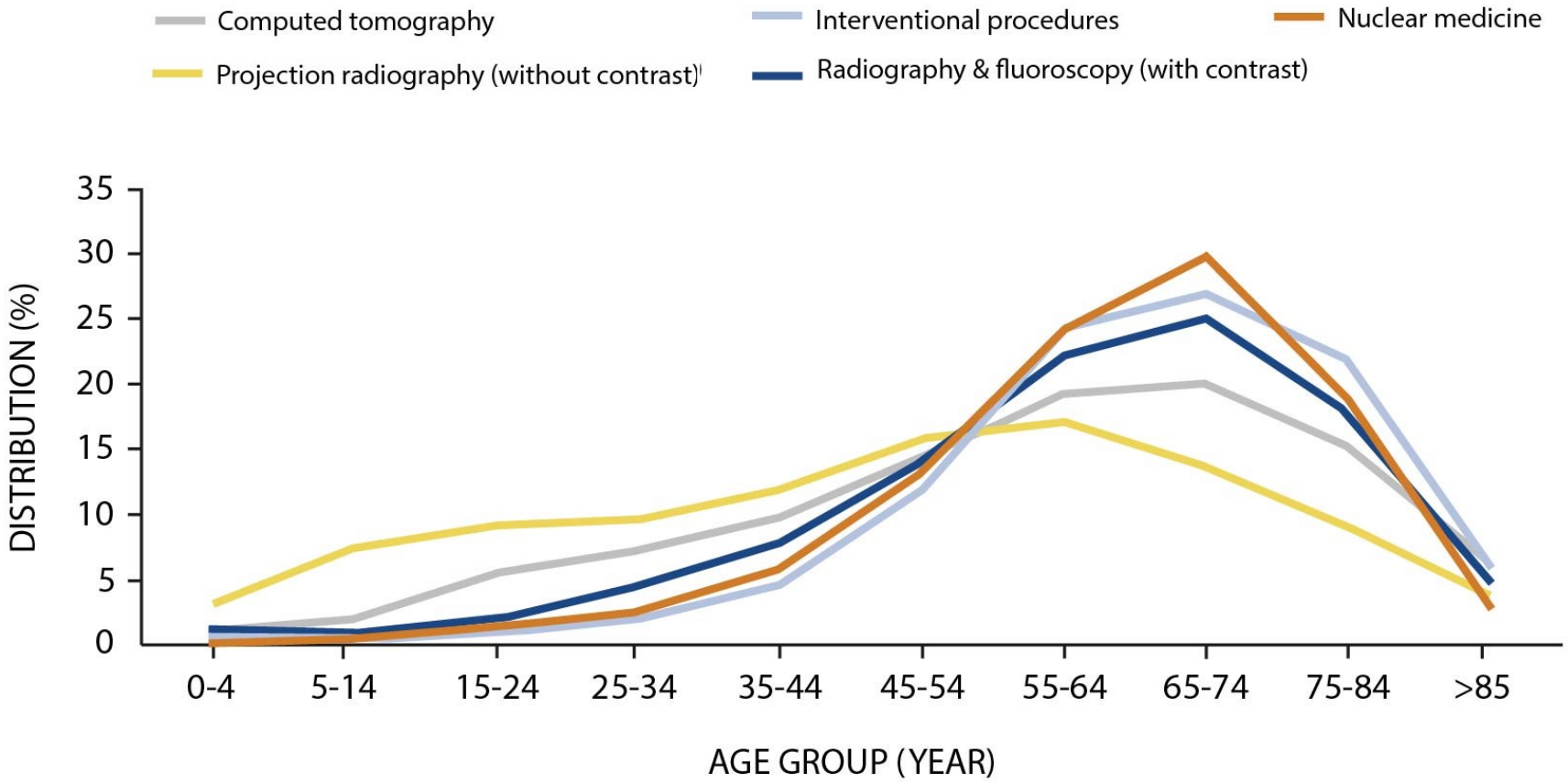
Breakdown by income levels

Categorization by income level

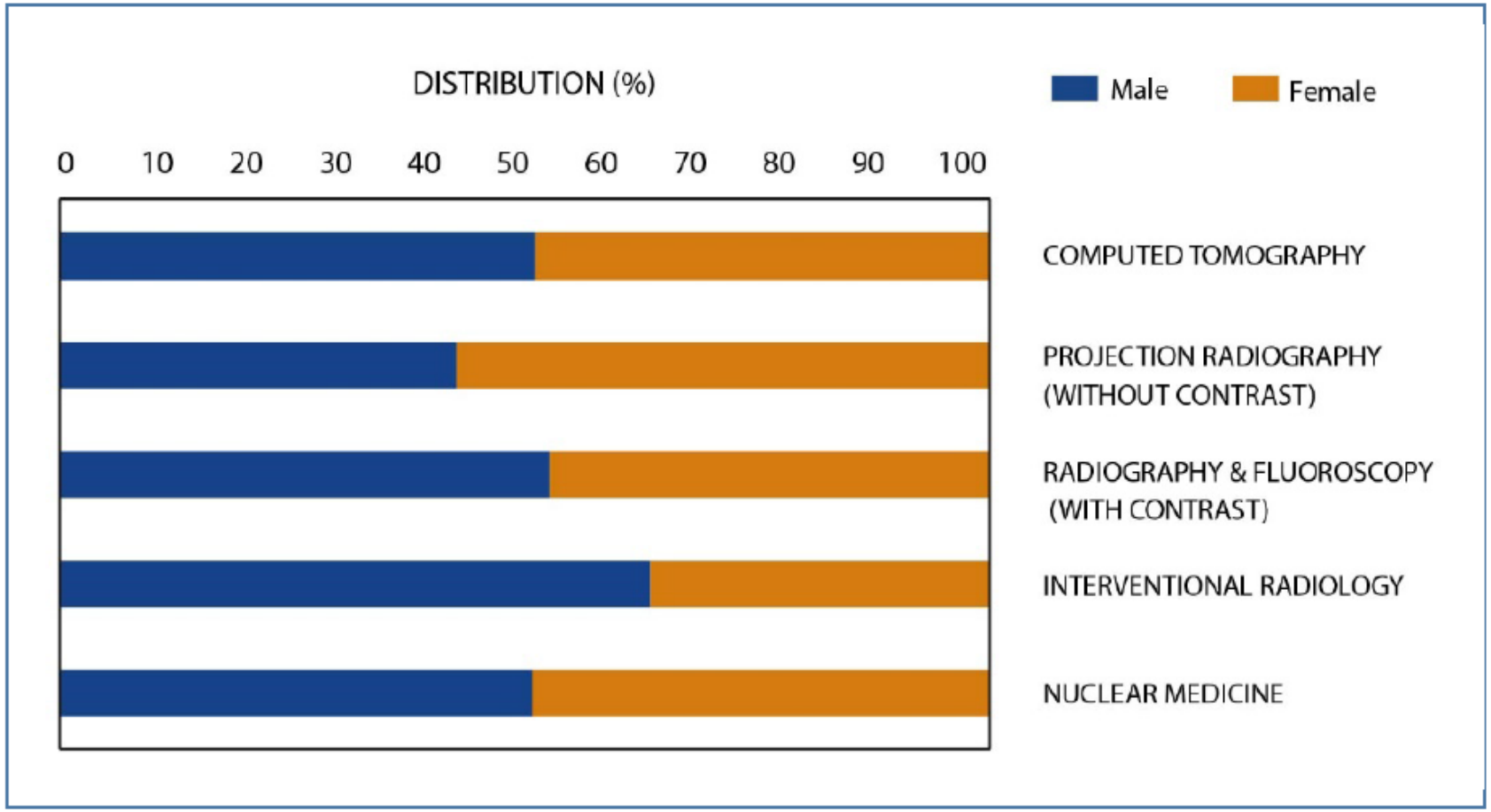
Income level	Population (millions)	Estimated examinations (millions)[a]	Average examinations per 1000[a]	Estimated collective effective dose (1000 man-Sv)[a]	Average annual effective dose per caput (mSv)
High	1149	1850	1610	1970	1.71
Upper middle	2619	1200	460	1190	0.46
Lower middle	2882	1040	360	900	0.31
Low	662	100	150	90	0.13
All	**7312**	**4190**	**570**	**4150**	**0.57**

[a] Values have been rounded

Age distribution of medical exposures by category



Sex distribution of medical exposures by category



Comparison with UNSCEAR 2008 Assessment

UNSCEAR 2008 Assessment

Category	Examinations (millions)	Collective eff. dose (1000 man-Sv)
Conventional radiology (excluding dental)	2900	2350
Dental radiology	480	11
Computed tomography	220	1540
Interventional radiology	3.6	41
Diagnostic nuclear medicine	33	202
All	**3660**	**4210**

UNSCEAR 2020/2021 Assessment

Category	Examinations (millions)	Collective eff. dose (1000 man-Sv)
Conventional radiology (excluding dental)	2630	950
Dental radiology	1100	10
Computed tomography	400	2560
Interventional radiology	24	330
Diagnostic nuclear medicine	40	300
All	**4190**	**4150**

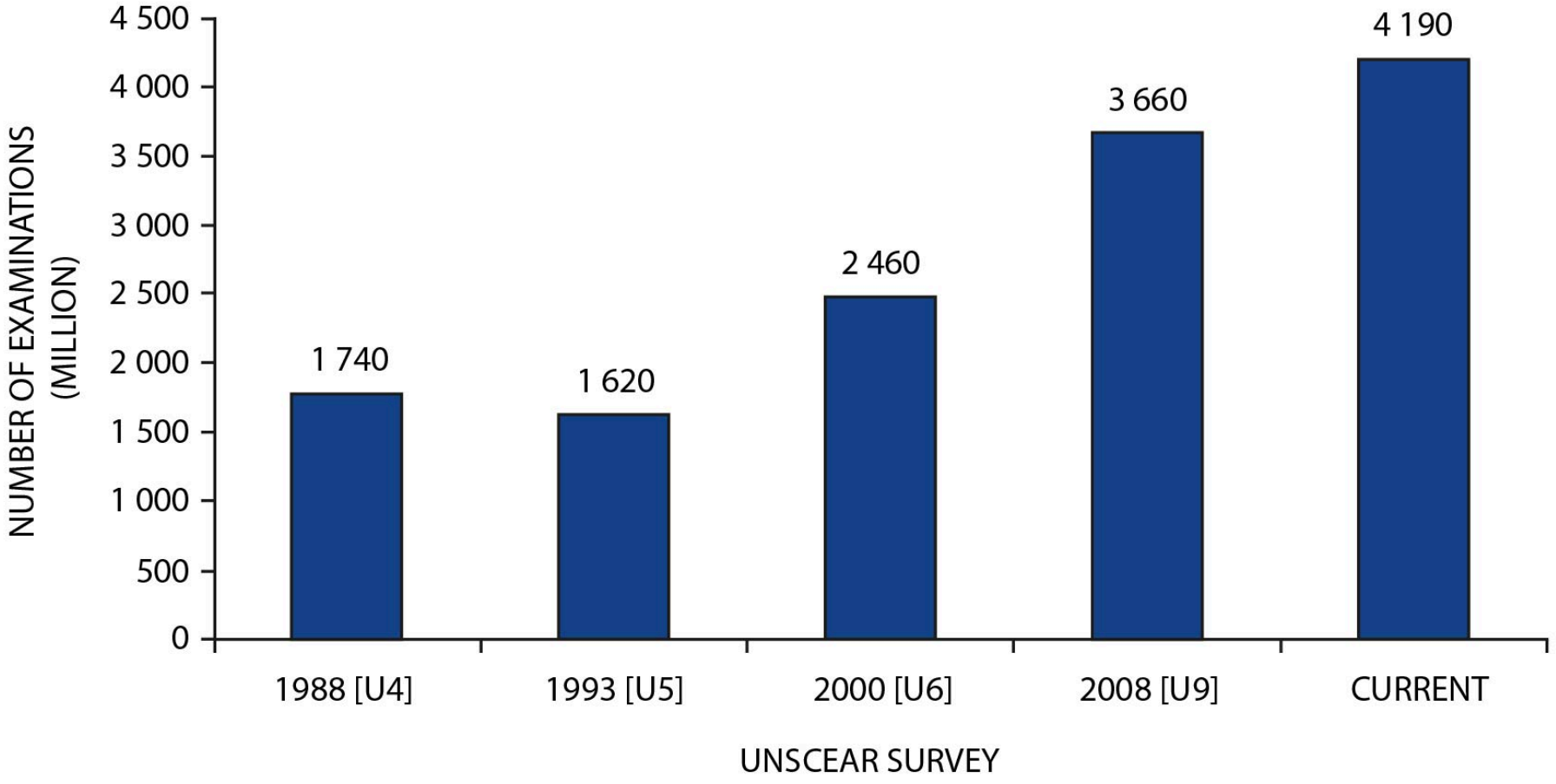
Major changes for radiology

Table 19. Comparison of annual number of examinations/procedures and annual collective dose from medical exposure with UNSCEAR 2008 Report [U9]

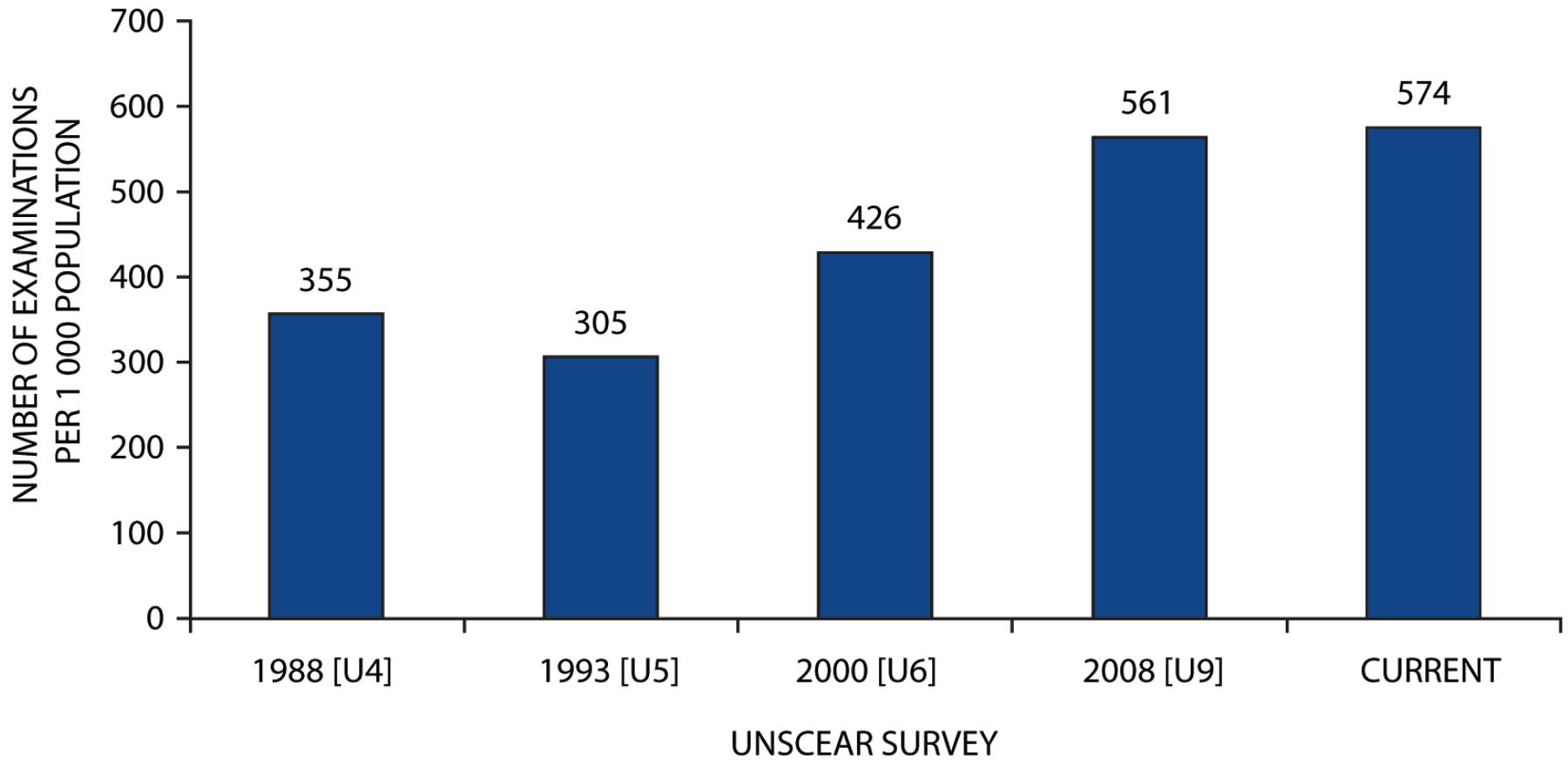
Modality category	*UNSCEAR 2008 Report [U9]*		*Current evaluation*	
	Number of examinations / procedures (millions)[a]	*Collective dose (1 000 man Sv)*[a]	*Number of examinations/ procedures (millions)*[a]	*Collective dose (1 000 man Sv)*[a]
Conventional radiology (excluding dental)	2 900[b]	2 350	2 626	955
Chest (thorax)	930	93	955	97
Chest photofluorography	440	340	64[c]	19[c]
Mammography (clinical)	50	19	120	27
Mammography (screening)	80	22	110	29
Gastrointestinal	135	640	18	65
Biliary system	40	76	2	11
Urography	45	120	8.6	19
Others	240	390	120	140

Major drop for gastrointestinal examinations

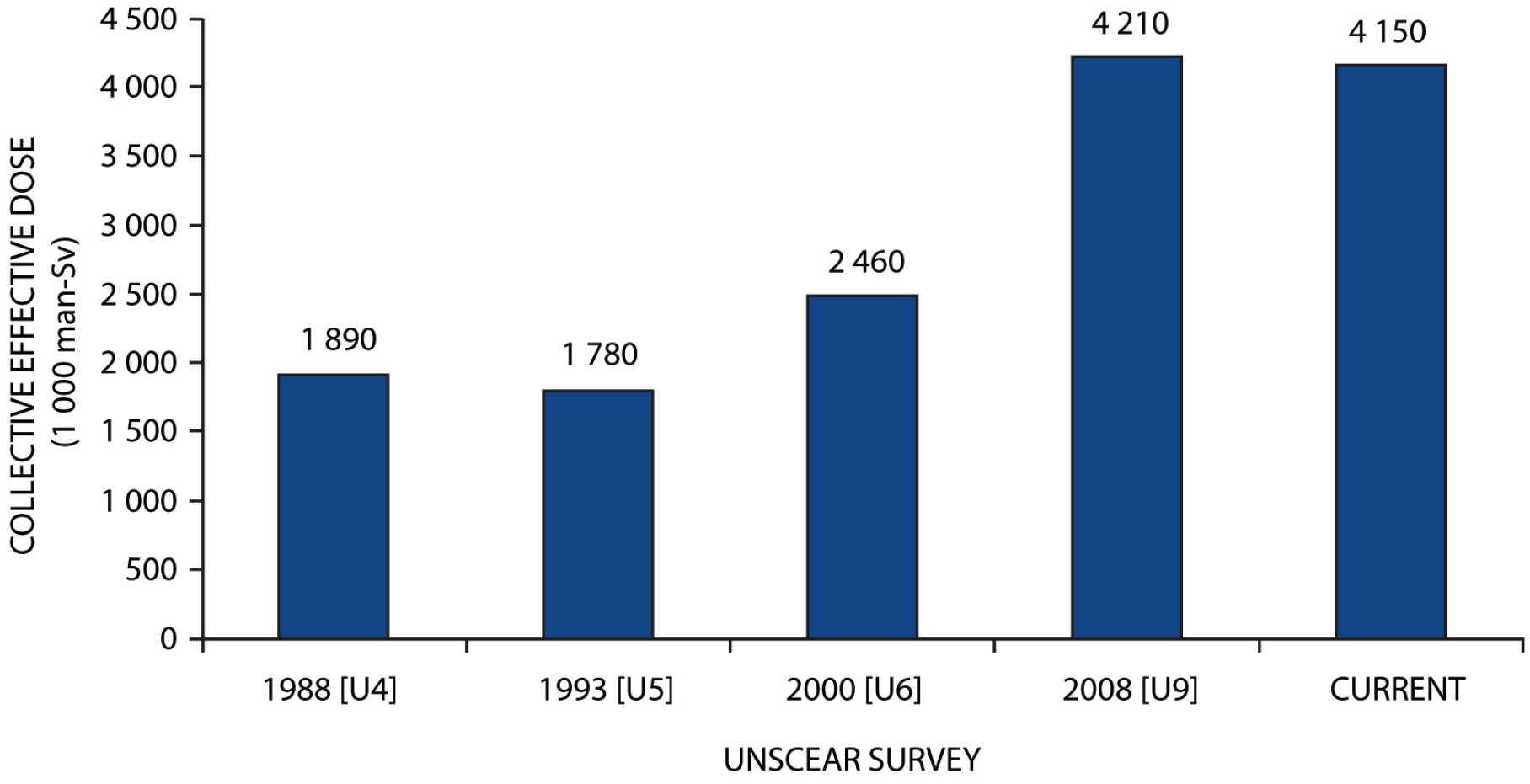
Trend in total examinations/procedures



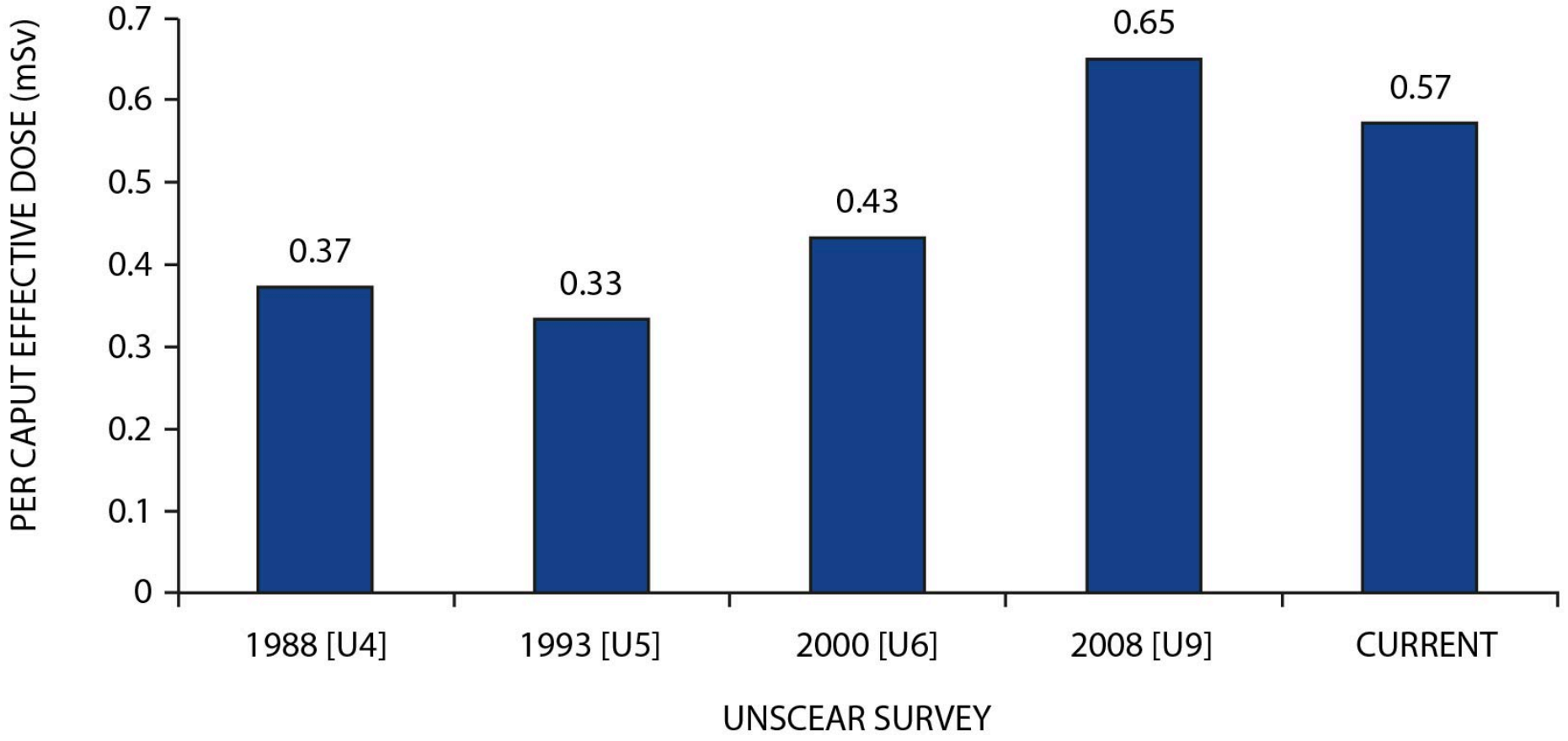
Trend in frequency of examinations/procedures



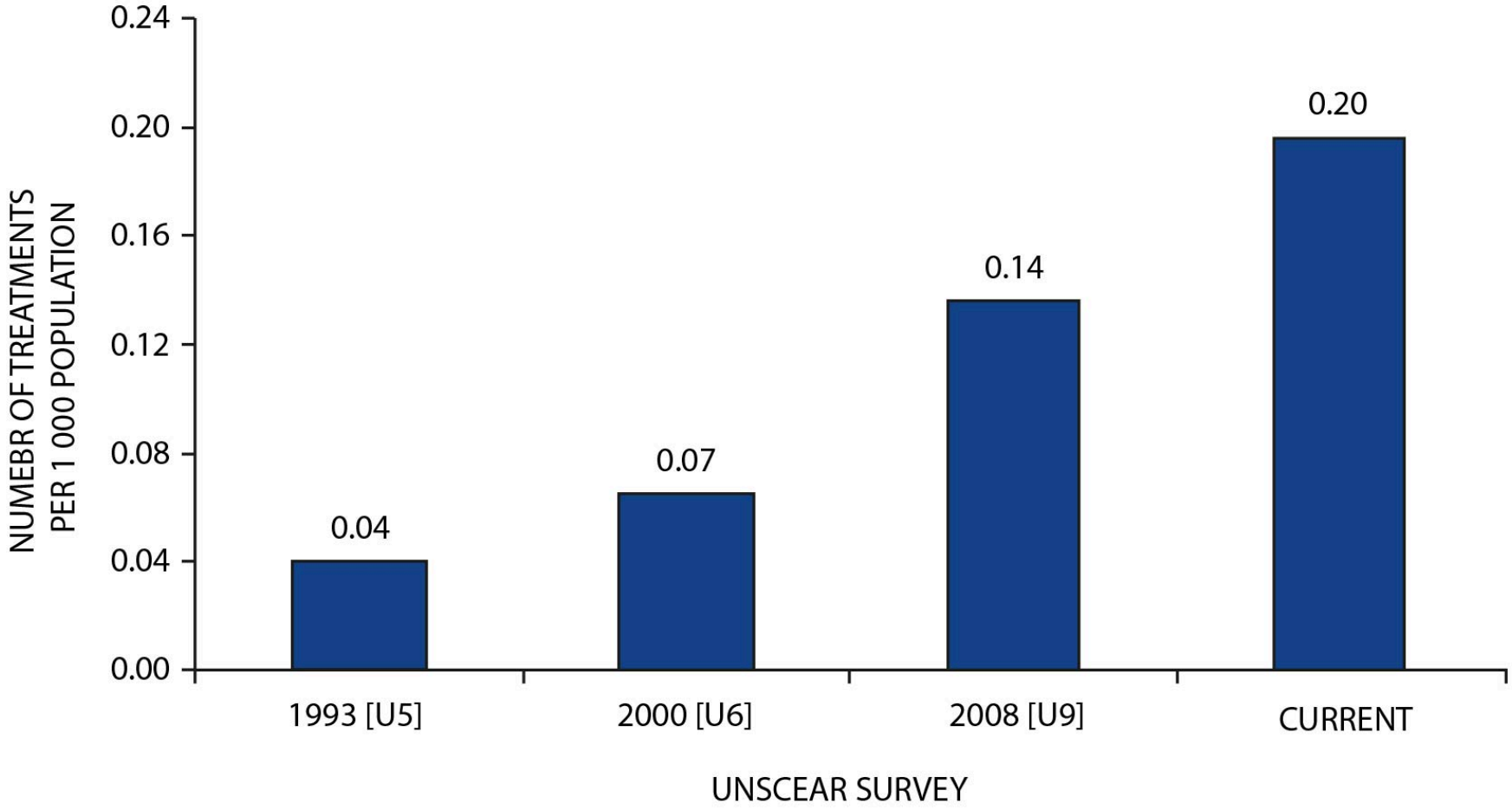
Trend in annual collective effective dose



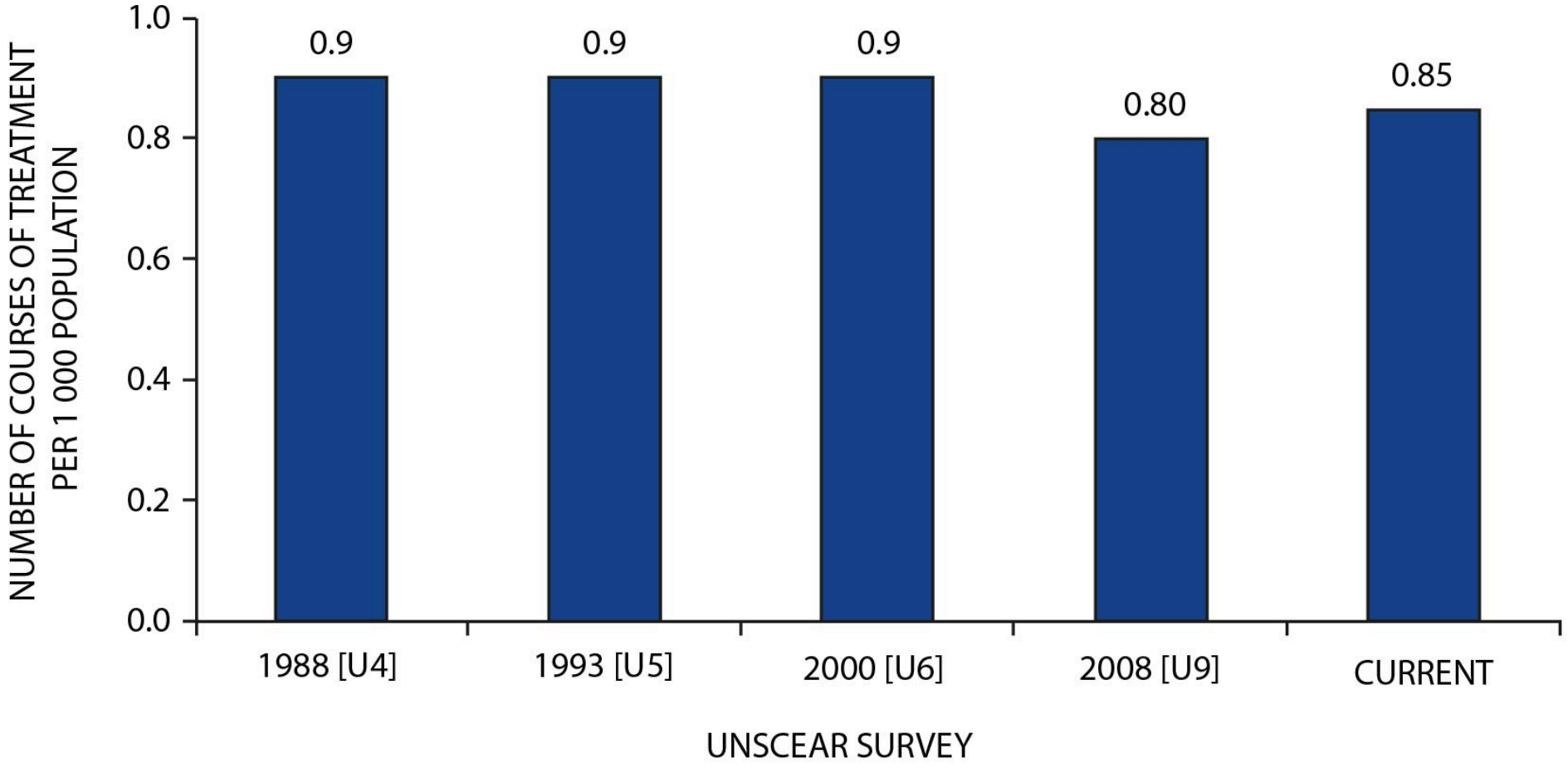
Trend in annual effective dose per caput



Trend in annual radionuclide therapy treatments



Trend in annual courses of radiation therapy treatment

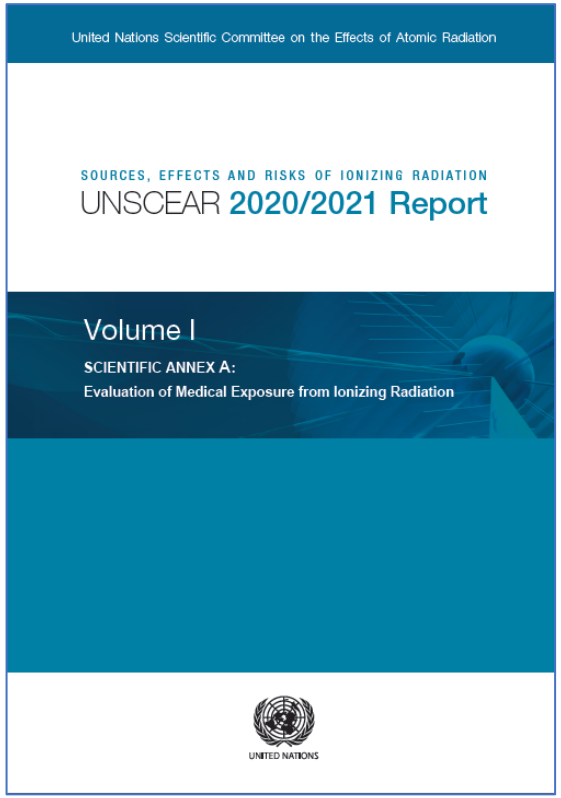


Summary of the 2020/2021 assessment

- Estimated 4.2 billion (±30%) examinations/procedures per year worldwide.
- 1.4 million radionuclide treatments and 6.2 million courses of radiation therapy.
- Estimated annual collective effective dose 4.2 million (±30%) man-Sv.
- Estimated global annual effective dose per caput is 0.57 mSv.
- Estimate derived from a continuous model, not extrapolation of survey data within health-care level categories.
- Computed tomography accounts for 62% of the collective effective dose but only 10% of the total number of examinations/procedures.
- Interventional radiology now estimated to account for 8% of the collective effective dose.

Concluding Remarks

- Medical exposures remain the largest contributor to radiation exposure of the population from artificial sources.
- Timing of a future UNSCEAR medical exposure report will depend on an assessment of the likely amount of data available.
- Encourage countries to use the existing UNSCEAR medical exposure survey template and submit their data to UNSCEAR when they have completed an evaluation.
- International collaboration in collecting information on medical exposures would be ideal to ensure that the data is collected consistently.



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Effect of tissue weighting factors

Table 5. Comparison of estimated annual collective effective dose (2009–2018) by imaging modality using ICRP 60 [I9] and ICRP 103 [I11] tissue weighting factors

Modality category	*Collective dose$_{ICRP60}$ (1 000 man Sv)*[a]	*Collective dose$_{ICRP103}$ (1 000 man Sv)*[a]	*Variation (%)*
Conventional radiology (excluding dental)	955	964	+0.9
Dental radiology	9.7	18.2	+88
Computed tomography	2 556	2 519	–1.5
Interventional radiology	334	332	–0.5
Diagnostic nuclear medicine	297	252	–15
Total	**4 152**	**4 085**	**–1.6**

[a] Values are rounded; however extended precision has been preserved to illustrate differences.

Based on published estimates of E_{103}/E_{60} for each type of examination or procedure