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Medical Radiation Exposure

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1. Introduction

There is no doubt that one of the most beneficial applications of ionizing radiation is in medicine. However, this application leads to the largest man-made contribution to the radiation received by the population. The frequency and total use of medical radiations are expected to increase with the largest contribution being from diagnostic radiology.

The basic principle of justification and optimization of ICRP requires that every investigation and treatment using ionizing radiations has to be justified by a clear benefit to the patient and that the technique has to be optimized, to minimize the dose received. The ICRPs recommend that "all radiation doses shall be kept as low as reasonably achievable, taking economic and social factors into account" (also known as ALARA). It means for instance that the X-ray examination shall be conducted in such a way that the required information is obtained at the minimal radiation risk to the patient. The optimization of image quality and patient exposure should be based on adequate knowledge of the health effects of ionizing radiation as well as on knowledge of the technical and methodological factors which influence the quality of radiographic images.

Medical radiation exposure has been evaluated over the years by several international committees, including: The United Nations Scientfic Committee on the Effects of Atomic Radiation (UNSCEAR), the Commission of the European Communities (CEC) and the Nationwide Evaluation of X-ray Trends (NEXT).

There is a need to continue analysing trends and doses because such information permits comparisons and is an essential input material for bodies involved in optimizing procedures and radiation protection.

The fields of application to be considered are:

1) Diagnostic use of X-ray and other external radiation sources.

2) Radioisotopes administered to a patient for diagnostic or therapeutic purposes.

3) Therapeutic use of external and sealed internal radiation sources.

The basic information needed to assess medical radiation exposure is the frequency of each type of diagnostic and therapeutic procedure and the distribution of dose to different parts of the body.

Unfortunately, there are considerable variations in the information from country to country, from hospital to hospital from equipment to equipment. The assessment can only be complete and reliable if data are collected in a

The purpose of undertaking such studies and programmes is not "to replace" the radiologist in the choice of the techniques, but just to provide him/her with additional information on the dose delivered to allow a better choice to be made.

2. Risk-benefit evaluation

In medicine the risk and the benefit associated with ionizing radiation are experienced by same person. At individual levels these risks are usually small compared to the benefit. In the evaluation of risks and benefits the principal characteristics of diagnosis and therapeutic applications may be summarized as:

	Diagnosis	Therapy
-	high percentage of population	-low percentage of population (0.3%)
-	low energy (20-150 Kv)	-high energy (100 Kv 25 MeV)
-	the genetically significant dose is 20 - 50 times higher than in therapy	-"non-stochastic" (deterministic) effects
-	late stochastic effects 0.01%.	-late stochastic effects 10%

3. International Investigations

Several international studies have been carried out to date.

* UNSCEAR has evaluated data received from 37 countries.

* CEC has evaluated six common types of X-ray examination and 24 departments in 10 European countries.

* The NEXT programme in late 1970s' and early 1980s has compared 12 X-ray investigations in the USA and Europe.

All these surveys have drawn attention to unnecessary high doses due to:

. Rx investigations were often requested without adequate evaluations of the patient and alternative techniques
. high repetition rate (not justified)
. incorrect radiographic techniques
. inappropriate or poorly functioning equipment
. poorly trained personnel

Four levels of health care have been identified by WHO.

Level I	more than 1 MD per 1000 population
Level II	1 MD per 1000 - 3000 population
Level III	1 MD per 3000 - 10000 population
Level IV	1 MD per more than 10000 population.

4. X-ray Diagnosis

- o X-ray diagnosis has the greatest radiological impact on population. 85% of the imaging diagnostic investigations made in 1985 in the USA, were X-ray procedures.
- o The frequency of use has been shown to be related to availability of equipment.
- o Clear correlation has been shown between the number of X-ray investigations and the number of physicians (level of health care).

For example, one of the key findings of the NEXT programme has been the frequent use of X-ray fields much larger than needed for the investigation, leading to much higher doses than necessary.

However, although it is easy to find out the "erroneous techniques" by comparing the gonad equivalent dose, it is less easy to indicate the specific parameter responsible for it; as sometimes other parameters compensate.

The skin dose is considered a good index for quality control, but it is clearly not enough to evaluate the technique. Here are some examples:

A) Chest P/A - with approximately the same skin entrance exposure.

1. tension =72 KV, current.t = 24 mA.s; HVL=20 mmAl, field area= 76x74 cm^2
2. tension =65KV, current .t = 40 mA.s, HVL 2.3 mm Al, field area 40x47 cm^2.

gonad equivalent dose 1 = 0.18 mSv rad; (2)= 1 mrad

gonad equivalent dose 2 = 0.01 mSv

B) Abdomen A/P with again the same skin entrance "exposure".

1. tension = 82 KV, current .t = 60 mA.s, HVL=1 7 mm Al, field area= 72x70 cm^2

2. tension 94KV, current.t = 60mA.s, HVL=3.6 mmAl field area 34.39 cm^2.

gonad equivalent dose 1 = 4.41 mSv

gonad equivalent dose 2 = 0.01 mSvd

C) Abdomen A/P with again the same skin entrance "exposure".

1. tension = 77 Kv, current .t = 100 mA.s, HVL=3.5mm Al, field area = 58x76cm^2

2. tension = 70 Kv, current .t = 150 mA.s, HVL = 3 mm Al, field area = 38x42 cm^2.

gonad equivalent dose 1. = 10.96 mSv;

gonad equivalent dose 2. = 0.07 mSv

For an assessment of the radiological impact to the population as a whole, two groups of investigations are particularly important:

- Those giving high individual doses, as for example fluoroscopy (in particular angiography) computer tomography, etc.

- Procedures frequently performed as for example dental examinations or mass screenings (chest, mammography).

4.1. Fluoroscopy

In fluoroscopy the X-ray are projected onto a fluorescent screen which can be connected to an image intensifier.

In photofluorography an image on a fluorescent screen is permanently recorded by photograph or video recording (also in digital).

Fluoroscopy gives very high doses to the patient and to the radiological staff. The recent improvement in image intensifying techniques can reduce the dose by about 50%.

The variation of the doses quoted in national and international studies is very wide also for the same kind of examination depending on patient, equipment, radiologist etc.

High skin doses are recorded in cardiac angiography (1 Gy), and in coronory angioplasty (5 Gy).

In these investigations the use of films (rather than fluroscopy) and digital techniques is recommended.

Cardiac investigations cause high individual dose to the population, but collective dose is more influenced by much more frequent examinations of the upper gastrointestinal tract and with barium enemas. Mean effective dose of 2.4-4.1 mSv respectively are quoted in the USA. Because of their frequent use they represent more than 40% (USA, Japan) of the collective doses received for X-ray diagnosis.

4.2 Chest Examinations

Although the dose from chest X-rays is generally low, it leads in the USA to over 5% of collective effective dose, being the most frequent investigation apart from dental. The frequency varies from 240 investigations per 1000 population (countries of health care level I) to 54 investigations per 1000 population (countries of health care level II)

The recorded doses from 3 industrialized countries are reported as follows:

	Canada	Sweden	USA
average skin dose for P/A chest	0.12 mGy	0.21 mGy	0.19 mGy

These figures hide considerable variations around the means, (Sweden: 26-fold difference; USA:175 fold))

In general, investigations made in private practices give higher exposure because scatter suppression grids are seldom used and films tend to be underprocessed.

4.3 Mammography

This concerns the investigation for suspected cancer and involves symptomatic and asymptomatic women.

Several countries have introduced or are considering this type of mass screening. In Sweden, absorbed dose per view = about 1mGy. Enormous variation from country to country are quoted.

From the point of view of the equipment the combination giving best ratio of information-content to dose is with molybodenum target plus receptor of rare-earth screen and simple coated film.

4.4 Dental Radiology

Dental X-rays vary from 250 investigations per 1000 population in countries health care level I to 4 investigations per 1000 in countries at health care level II.
The effective dose to the patient x 2 dental film exposure = 0.03 mSv (4-35 fold variations are reported).

4.6. General Considerations

It is clear that justification and optimization of medical exposures are not dealt with in the same way even in countries which are geographically close and economically similar, because of different health care structures and different medical approaches.

In general, the number of examinations is increasing (not to the extent it was 10 years ago, however), while the doses per examinations are decreasing.

Alternative imaging procedures have been introduced, such as: Ultrasound, Nuclear Magnetic Resonance, etc.

Rare earth screens and image intensifying screens are one of the most important technical development to reduce the dose.

National recommendations could in principle, reduce the collective dose (a UK report states that 50% of the current collective dose could be avoided).

Quality assurance programmes have demonstrated to decrease dose variation and reduce unnecessary exposure, the most critical point still being the procedure.

5. Nuclear Medicine

The main points regarding the contribution of nuclear medicine can be sumarized as follows:

- Tc 99m (Tc-99m labelled compounds) and I 131 are the two most important radioisotopes used in diagnostic nuclear medicine.

- the use of I 131 is diminishing drastically, reducing the contribution to the collective dose.

- thyroid examinations still contribute to about 50% of collective dose.

- Tomographic investigations (SPECT) require, on average, higher activities than the similar plan examinations

- most examinations are performed on adult patients, (in the USA 98% over 15 years; 91% over 30 years).

- age dependent doses per unit activity administered are given in ICRP publication 53

- Because of different methods and assumptions in the data available it is difficult to estimate the doses (in industrialized countries effective dose per examination is a few mSv).

- there are enormous differences even between countries culturally and economically similar.

- The number of N.M. investigations made in industrialized countries increased though the 1970s but has been almost constant in the 1980s.

- The kind of examination made in industrialized countries has changed, becoming more and more complex (PET, etc.).

- In developing countries "in-vitro" techniques are expected to increase more rapidly than "in-vivo" ones.

- in-vivo therapy with radioisotopes deserve particular consideration because of high doses and the problem of waste management.

6. Radiotherapy

The main points regarding Radiotherapy can be summarized as follows:

* The objective is the accurate delivering of a calculated dose to a target organ
* The genetic effects are usually not very relevant

* The absorbed dose to organs other than the target, is used to assess the risk of the patient.
* Radiotherapy will become more frequent in most countries because of:
  - increasing life span (higher cancer incidence)
  - increased awareness of early symptoms and early stage diagnosis.

6.1. Actual situation

In industrialized countries the cancer incidence is about 3500 cases per million population (50% of these have radiotherapy), and one person every 2000 is subject to some form of radiotherapy with external sources (not only for cancer). In developing countries only 0.1 per 2000 persons, are subject to radiotherapy because of lack of facilities.

In Europe the results from radiation treatment of cancer (5 years survival) have improved during the last 20 years by almost a factor or two (the actual value is about 50%); this is due to:

. technical development of equipment (linear accelerators, etc.)
. better dosimetry and treatment planning (computer)
. better knowledge of radiobiology
. earlier diagnosis.

6.2 Dosimetry accuracy

Accuracy in dosimetry is continually improving. In 1925 Sievert carried out an "astonishing" investigation in Radiotherapy depts. in Scandinavian countries. He said: "It had been thought that the same dose was being given in all the roentgen therapy depts but variations between 320 R and 1400 R were found".

In 1982-86 a comparison of scandinavian centres (Svensson, Johansson) still found that 5 out of 23 centres had variations of the absorbed dose higher than 10%.

An international code of practice for "absorbed dose determination" was published by the IAEA (1987).

One of the "good criteria" for "acceptable practice" is (EORTC):

± 3% for the calibration of therapy units

± 5% for the delivery of the prescribed dose (depth dose, wedge factor, etc.).

- National and international surveys are very important for the standardization of doses.

- Quality control programmes and accurate dosimetry are essential for Radiotherapy.
- The presence of medical Physics is mandatory in Radiotherapy departments

Exposure of the General Public

The situations for the general public to be exposed are:

X-ray

- Mobile equipment can cause exposure to other people.
- Assistance to patients (children etc).
- X-ray screening of children (schools) or prerequisites for employment, the value is doubtful and they are not advisable (FDA-1981).

Radioisotopes

- Family members of patients (problem of irradiation and radioactive waste) but doses rarely exceed 1 mS in diagnostic practice.
- The waiting rooms (hot and cold) are sometimes not separated in the nuclear medicine departments, about 30 uSv have been estimated for the accompaning person.

Radiotherapy

- Therapy with I^{131} is critical if the patient is at home (not advisable), high exposures are around the bed.
- the problems of parents visiting patients under brachytherapy has to be considered; the time limited and the "geometry" of the room well studied.

Country	Year	Diagnostic examinations (thousands)			Therapeutic treatments (thousands)			
		Medical x rays	Dental x rays	Radio-isotopes	X-ray therapy	Tele-therapy	Brachy-therapy	Radio-isotopes
Sweden	1970-1974	4800	3600	77.0	6.8	9.2	2.0	2.7
	1980-1984	4700	7000	128	2.2	11.4	1.6	3.3
	1985-1989	4400 [d]	7000	122	1.6	13.3	1.5	3.6
Switzerland [M29]	1971	8555						
	1978	8704						
United Kingdom	1980-1984	27000	9000	380	150			
United States	1985-1989	200000	100000	6783				
Yugoslavia	1985-1989	3350 [r]	83000	140	15.1 [e]	50.2 [e]	2.0 [e]	2.4 [e]
HEALTH CARE LEVEL II								
Barbados	1980-1984			0.2	0.1	0.3	0.04	0.02
	1985-1989			0.3	0.1	0.3	0.05	0.04
Ecuador	1970-1974	167	10.0	3.1	0.3	0.2	0.04	0.05
	1980-1984	385 [r]	35.7	7.4	0.5	0.5	0.09	0.05
	1985-1989	530 [m]	65.4	8.5	0.5	0.9	0.2	0.07
Peru	1985-1989	21 7		4.8	0.3	2.7	0.9	0.3
HEALTH CARE LEVEL III								
Myanmar	1985-1989	53.5						
Tunisia	1985-1989		100	7.0		6.5	3.0	0.3
Vanuatu	1985-1989	11.1		0	0	0	0	0
HEALTH CARE LEVEL IV								
Rwanda	1970-1974	28.0						
	1988-1989	61.1						

[a] Number of procedures, not patients.
[b] Number of treatments, not patients.
[c] Including 7 interventional radiology.
[d] Including 400 pantomographic.
[e] Primary stage radiotherapy only.
[f] Including 1650 pantomographic.
[g] Including 9640 pantomographic.
[h] Including 11229 pantomographic.
[i] Including 3 interventional radiology.
[j] Including 0.15 interventional radiology.
[k] Including 180 interventional radiology.
[l] Including 359 mass miniature chest, 30 chiropractic.
[m] Including 129 mass miniature chest, 41 chiropractic.
[n] Including 67 mass miniature chest (abolished 1990), 47 chiropractic.
[o] One hospital only, to indicate trend.
[p] Excluding military, legal and pre-employment.
[q] Including 6 interventoinal radiology.
[r] Including 1.7 interventional radiology.
[s] Bosnia, Herzegovina, Croatia and Slovenia only.
[t] Including 19 intervantional radiology.
[u] Including 27 interventional radiology.

Table 3, continued

Country	Year	Chest examinations			Extremities	Skull	Lumbosacral	Pelvis / hips	Abdomen	G.I. tract		Cholecystography	Urography	Angiography	Mammography	Computer tomography
		Radiography	Mass miniature	Photofluoroscopy						Upper	Lower					
Sweden	1970-1974	116		111	65	44	22 [h]	35	12	30	16	18	23	1.2 [i]	3.1	
	1985-1989	121			55	15	21 [h]	43	7.7	12	13	5.0	14	0.2 [i]	46 [j]	11
HEALTH CARE LEVEL II																
Barbados	1985-1989				86				23	4.4	2.0	0.3	7.7	0.1	1.2	1.4
China (Beijing area)	1970-1974	3.4			4.3	1.1	1.4	0.9	1.1	0.8	0.1	0.4	0.2	0.1		
	1985-1989	14			4.9	3.2	1.9	1.0	2.2	2.2	0.7	0.6	0.4	0.4	0.1	0.3
Ecuador	1970-1974	5.9	3.2	1.5	3.3	2.3	1.7	2.6	4.1	0.6	0.3	0.1	0.2	0	0.1	0
	1985-1989	15	0	3.6	5.6	3.9	2.9	4.6	7.1	2.2	1.2	0.8	1.3	2.5	0.6	2.2
HEALTH CARE LEVEL III																
Cape Verde	1985-1989	69														
Philippines	1985-1989	67	1.2	10	11	6.3	3.0	3.6	5.5	1.5	1.4	1.6	1.9	0.2	0.1	
Vanuatu	1985-1989			44	40	4.2	2.5	2.8	4.7 [k]	0.4	0.2		0.6	0	0	0
HEALTH CARE LEVEL IV																
Rwanda [l]	1987-1989	4.2			2.4	1.5			0.2				0.03			

[a] Including 1.0 screening.
[b] Including 3.1 screening.
[c] Excluding all fluoroscopy.
[d] Excluding pelvis.
[e] Fluoroscopy only.
[f] Screening.
[g] All spine.
[h] Including lumbar spine.
[i] Cerebral.
[j] Including 30 screening.
[k] Including cholecystography.
[l] Estimated from figures from Kigali Hospital.

Organ/ procedure	Health care level	Country	Age distribution (%)			Sex distribution (%)	
			0-15 years	16-40 years	> 40 years	Male	Female
Lumbosacral	I	Australia	3.3	36	61	44	56
		Czechoslovakia	3.9	31	65	50	50
		Japan	1.2	35	64	56	44
		Kuwait	8.4	44	47	44	56
		Netherlands	5.9	40	54	49	51
		New Zealand	5.4	40	55	51	49
		Norway	1.5	39	59	47	53
		Poland				50	50
		Sweden [a]	3.2	30	67	43	57
		Yugoslavia	13	25	63	40	60
	II	China [b]	2.6	50	48	61	39
		Djibouti [c]	12	38	50	44	56
		Ecuador	4.0	56	40	64	36
	III	Myanmar [c]	14	44	42	53	47
		Philippines	15	42	43	62	38
		Vanuatu	7.4	52	41	59	41
Pelvis / hips	I	Australia	12	19	69	38	62
		Czechoslovakia	76	7.7	16	45	55
		Japan	18	22	60	44	56
		Kuwait	15	29	56	41	59
		Netherlands	17	17	66	38	62
		New Zealand	18	17	64	44	56
		Sweden [a]	13	7.6	80	35	65
		Yugoslavia	3.5	37	59	22	78
	II	China [b]	23	39	38	48	52
		Djibouti [c g]	30	45	25	51	49
		Ecuador	15	60	26	42	58
	III	Myanmar [c]	9.1	43	48	51	49
		Philippines	18	46	37	61	39
		Vanuatu	25	52	22	62	38
Abdomen	I	Australia	10	24	66	53	47
		Czechoslovakia	8.6	27	64	53	47
		Japan	8.2	24	68	54	46
		Kuwait	11	38	51	43	57
		Netherlands	6.1	23	71	53	47
		New Zealand	13	28	59	49	51
		Norway	17	31	53	47	53
		Poland				54	46
		Spain	11	39	51	52	48
		Sweden [a]	11	17	72	47	53
		Yugoslavia	5.9	35	59	50	50
	II	China [b]	5.1	61	34	60	40
		Djibouti [c]	25	40	35	42	58
		Ecuador	4.9	39	56	55	45
		Jamaica [d]				48	52
	III	Myanmar [c]	15	41	44	50	50
		Philippines	19	45	36	50	50
		Vanuatu [h]	10	66	23	35	65
Upper GI tract		Australia	1.4	20	79	40	60
		Czechoslovakia	1.2	35	64	52	48
		Japan	0.7	24	76	53	47
		Kuwait	1.6	43	56	49	51
		Netherlands	3.0	29	69	51	49
		New Zealand	5.1	30	66	50	50
		Norway	0.5	33	66	45	55
		Poland				47	53
		Spain	5.0	28	67	51	49

Organ/ procedure	Health care level	Country	Age distribution (%)			Sex distribution (%)	
			0-15 years	16-40 years	> 40 years	Male	Female
Urography, continued	III contd.	Philippines	13	39	48	64	36
		Vanuatu	5.9	59	35	65	35
Angiography	I	Australia	1.7	8.9	89	58	42
		Czechoslovakia	1.6	18	81	58	42
		Japan	0.2	27	73	47	53
		Kuwait	1.9	36	62	53	47
		Netherlands	0	5.9	94	63	37
		New Zealand	0	21	79	54	46
		Poland				48	52
		Sweden [a]	2.9	20	77	49	51
	II	China [b]	1.5	56	43	55	45
		Ecuador	15	50	35	72	28
	III	Myanmar [c]	11	45	44	59	41
		Philippines	21	34	45	68	32
Mammography	I	Australia	0.1	30	70		
		Czechoslovakia	0	35	65	0	100
		Japan	0	51	49	0	100
		Kuwait	0	44	56	0	100
		Netherlands	0	28	72	1	99
		New Zealand	0	25	75	0	100
		Norway	0	25	75	0.3	99.7
		Spain	1.2	37	62	0.6	99.4
		Sweden [a]	0	8.9	91	0.2	99.8
		Yugoslavia	0	44	56	0	100
	II	China [b]	0	51	49	1	99
		Ecuador	0	90	9.9	0	100
	III	Philippines	0	11	89	0.5	99.5
Computer tomography	I	Australia	4.5	30	66	46	54
		Czechoslovakia	8.9	33	58	52	48
		Japan	5.0	15	80	55	45
		Kuwait	5.4	45	49	51	49
		Netherlands	5.8	25	69	53	47
		New Zealand	12	26	62	53	47
		Norway	6.1	27	67	53	47
		Poland				56	44
		Sweden [a]	6.8	21	73	53	47
		Yugoslavia	10	30	60	40	60
	II	China [b]	6.5	30	64	60	40
		Ecuador	4.4	58	37	55	45

[a] Age distribution: 0-14 years, 15- 39 years, > 40 years; Stockholm county statistics only (about 20% of population).
[b] Beijing area only (about 3% of population).
[c] Statistics from Institute P. Pascal only.
[d] Statistics from Kingston Hospital only.
[e] Statistics from Gyangon General Hospital only.
[f] All bone examinations.
[g] Hip and femur only.
[h] Including cholecystography.

Table 5, continued

Country	Year	Chest examinations			Extremities	Skull	Lumbo-sacral	Pelvis / hips	Abdomen	G.I. tract		Cholecystography	Urography	Angiography	Mammography	Computer tomography
		Radiography	Mass miniature	Photofluoroscopy						Upper	Lower					
Sweden [a]	1970-1974 Range	21 13-28		73 36-220	20	68	410 [e] 210-740	87 / 120 40-140	200	310 90-460	600 370-900	90 40-100	510 360-510	680 [p]	/ 7 [q] / 1-20	
	1985-1989 Range	10 1-70			5.7 1.8-14	13 12-15	170 [e] 27-450	45 / 60 14-300	125 33-275	325 60-1200	430 70-1900	60 18-150	250 15-1000		5 / 10 3-10[r]	
United States	1984-1989 Range	0.18 [e] 0.01-0.94					4.9 [e] 0.70-25		4.2 [e] 0.58-19						1.8 [e] 0.4-12	330-630 [t]
HEALTH CARE LEVEL II																
China [t]	1985-1989 Range		1.2 0.08-17				27 0.15-286			30 0.01-508	37 0.26-680	25 0.58-426				
Ecuador	1985-1989 Range	0.81 [u] 0.77-0.89			0.77 0.66-0.88	2.5 2.4-2.6	9.8 9.5-10	2.1 / 1.0 0.9-2.6	4.6 2.5-6.7	3.3 0.82-5.7	2.6 1.2-3.9	2.6 1.7-3.6	3.7 3.2-4.2	1.2 0.4-8.2	7.9 7.0-8.7	14 13.5-14.4
Jamaica	1985-1989 Range		0.25 0.2-0.3		1.2 1.2-1.3				1.2 1.2-1.3			1.2	1.7 1.6-1.8			
HEALTH CARE LEVEL III																
Myanmar	1970-1974	0.75			0.26	3.9	4.9	3.9 / 3.9	5.1	3.4	4.5	3.3	4.1	4.1		
	1985-1989	0.80			0.45	2.3	4.0	3.3 / 2.3	2.6	2.6	4.2	3.2	3.9	4.1	0.63	
Thailand	1985-1989 Range		0.09 0.08-0.09	6.5 3.4-9.5	0.07 0.04-0.1	2.4 2.2-2.5	2.8 2.4-3.1	3.2 / 2.5 2.3-3.5	2.6 2.5-2.6	3.4 3.1-3.6		3.1 2.7-3.5	2.9 2.8-3.0	2.6 2.2-2.9		

[a] One slice.
[b] Skull.
[c] One Ottawa hospital.
[d] On the axis.
[e] Converted from ESE assuming that 1 mR = 0.0087/0.75 mGy ESD.
In the case of United States, applies also for range.
[f] Coronary catheterization.
[g] Multiple average dose to head for average years 1983-1984, to body for range.
[h] Dose quantity: effective dose equivalent (mSv).
[i] Barium/double contrast.
[j] Fluoroscopy.
[k] All spine.
[l] Air kerma x area (mGy cm^2). Applies also for range.
[m] For skull. Values for thorax, abdomen and pelvis are 21, 35 and 36, respectively.
[n] Dose quantity: energy imparted given in mJ.
[o] Including lumbar spine.
[p] Cerebral.
[q] ESD, not energy imparted: screening/clinical. Applies also to range.
[r] Mostly screening.
[s] Multiple scan absorbed doses in a sample not considered statistically representative.
[t] Beijing area.
[u] Including fluoroscopy (20% of examinations).

Table 7
Average organ doses in common examinations of women by computer tomography and conventional x-ray diagnosis
[P10]

Examination	Organ receiving dose	Dose from computer tomography [a] (mGy)	Dose from conventional x-ray diagnosis (mGy)
Skull (top)	Brain	24.3-32.2	0.67 [b]
	Bone marrow	3.1- 4.1	0.16 [b]
	Thyroid	0.96- 1.4	0.42 [b]
Thorax	Breast	23.5-27.1	0.09 [c]
	Lungs	20.0-25.5	0.15 [c]
	Bone marrow	4.3- 5.8	0.04 [c]
	Thyroid	2.3- 3.1	0.02 [c]
Abdomen	Upper large intestine	20.0-26.7	2.3 [b]
	Lower large intestine	10.1-13.5	1.1 [b]
	Uterus	14.7-20.1	2.9 [b]
	Bone marrow	6.9- 9.7	0.4 [b]
Pelvis	Uterus	16.1-21.9	1.7 [b]
	Upper large intestine	7.5-10.3	2.0 [b]
	Lower large intestine	14.6-19.8	1.6 [b]
	Bone marrow	5.6- 7.9	0.18 [b]

[a] Range for various kV and filtrations.
[b] AP projection.
[c] PA projection.

Table 9
Annual per caput and collective effective dose equivalent from diagnostic x-ray examinations

Country	Year	Reference	Effective dose equivalent per caput (mSv)	Collective effective dose equivalent (man Sv)
HEALTH CARE LEVEL I				
Czechoslovakia	1980	[K17]	0.6 [a]	8600
Finland	1987	[R16, S21]	0.7	3500
France	1980s	[S17, S21]	1.6	89000
Germany	1983 1988	[B7, S21] [S17, S21]	1.5 1.0	90000 61000
Netherlands	1980 1987	[B6, S21] [B6, S21]	0.34 0.31 [b]	4800 4500
Norway	1988	[S22]	0.6	2500
Spain	1985-1986	[V5] [S17]	0.8 1.2	31100 46600
Sweden	1985	[V4]	0.6	4600
United Kingdom	1983	[S17]	0.3	17000
United States	1980	[N1]	0.4	92000
USSR	1987	[S18] [N4]	1.1 1.2	311400 339700
HEALTH CARE LEVEL II				
China (Beijing area)	1983	[Z1]	0.4	3600

[a] Effective dose equivalent per examined patient is 0.9 mSv.
[b] Effective dose equivalent per examined patient is 0.56 mSv.

Table 12
Existence of regulations or recommendations on quality assurance
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

	X-ray diagnostics			Radiation therapy			Nuclear medicine		
	Legal regulations	Recommendations	No QA rules	Legal regulations	Recommendations	No QA rules	Legal regulations	Recommendations	No QA rules
HEALTH CARE LEVEL I									
Argentina		*			*			*	
Australia	*			*			*		
Canada [a]	*	*				*		*	
Czechoslovakia		*				*		*	
Denmark	*			*			*		
Japan [b]			*			*			*
Kuwait	*			*			*		
Luxembourg	*			*			*		
Malta		*				*			*
New Zealand			*	*				*	
Norway			*			*			*
Poland		*			*			*	
Romania		*			*			*	
Singapore		*						*	
Spain			*						
Sweden	*			*			*		
United Kingdom		*			*			*	
United States [c]	*	*			*			*	
Yugoslavia	*			*			*		
Total [d]	6	9	4	7	5	5	6	9	3
HEALTH CARE LEVEL II									
Barbados	*				*			*	
China		*				*			*
Djibouti			*			*			*
Ecuador	*				*			*	

Table 13
Annual average frequency of diagnostic nuclear medicine examinations (Number per 1000 population)
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

Country	Year	Bone	Brain	Cardiovascular	Liver/spleen	Lung		Renal	Thyroid		Other	Total
						Ventilation	Perfusion		Scan	Uptake		
HEALTH CARE LEVEL I												
Argentina	1985-1989	2.8	0.4	2.4		1.6 [a]		0.8	4.5			12.5
Australia	1970	0.05	1.0		0.6	< 0.01	0.5	0.1	1.5			3.8
	1980	1.9	1.0	0.1 [b]	1.4	0.3	0.9	0.6	0.8			7.0
	1989	5.3	0.1	2.8 [b]	0.9	2.0 [c]		1.2	2.2			14.6
Canada [d]	1985-1989	16.8	15.3	4.4	3.9	0.7	2.0	1.8	4.4	3.9	2.7 [e]	55.9
Czechoslovakia	1970-1974	0.09	1.3	0.02	3.6	0.05	0.1	6.1	1.7	1.0		14.0
	1985-1989	1.6	1.7	0.5	4.9	0.3	1.3	9.7	2.1	0.6		22.7
Italy	1974	0.06	0.6	0.09	1.2 [f]	0.06	0.04	0.7	0.2	3.0	1.9 [g]	7.8
	1985	2.0	0.3	0.3	1.5	0.02	0.3	0.3	2.0	0.7	0.08 [g]	7.3
Japan	1985-1989	2.1	0.3	0.9	0.9	0.3		1.8	0.4	0.4	1.4 [h]	8.4
Kuwait	1985-1989	1.7	0.2	1.9	1.1	0.4	0.8	3.9	3.2	0.03		13.1
Luxembourg	1988							0.3		1.0		23.5
Netherlands	1985-1989	3.6	1.2	1.5	1.5	0.4	0.7	0.8	1.1	0.3	0.4	11.5
New Zealand	1970-1974	0.3	1.2	0.3	0.7		0.3	0.06	0.4	1.2	0.2 [i]	4.6
	1985-1989	2.8	1.0	0.4	0.6	0.4	0.6	0.8	0.7	0.3		7.5
Norway	1970-1974	0.2	0.7		0.8	0.01	0.1	0.5	0.7	0.8	0.2 [j]	3.9
	1985-1989	3.4	0.2	1.5	0.5	0.2	0.6	1.0	1.1	0.6	0.3 [j]	9.3
Romania	1985-1989	0.05	0.2	0.03	1.1	0.06		0.3	0.7	0.7	0.4	3.5
Sweden	1974	0.5	1.5	< 0.01	1.3	0.3 [l]	0.3	2.7 [n]	1.7 [p]	1.8		10.1
	1985-1987	4.2	0.4	0.7 [k]	0.7	0.2 [m]	1.2	3.0 [o]	1.6 [q]	0.5		12.6
United States	1985-1989	8.3	0.4	5.4	1.9	2.3	3.0	1.2	1.6	0.7	0.8	25.7
Yugoslavia	1985-1989	0.7	0.3	0.2	0.7	< 0.01	0.1	2.5	1.3	0.2	0.1	6.1

Table 14
Age- and sex-distribution of patients in diagnostic nuclear medicine examinations, 1985-1989
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

Organ/ procedure	Health care level	Country	Age distribution (%)			Sex distribution (%)	
			0-15 years	16-40 years	> 40 years	Male	Female
Bone	I	Australia	6.7	22	71	43	57
		Canada [a]	3.4	10	87	36	64
		Czechoslovakia	1.9	49	49	48	52
		Italy	0.8	8.2	91	34	66
		Kuwait	45	30	25	60	40
		Netherlands	3.9	24	72	53	47
		New Zealand	5.8	13	81	44	56
		Norway	2.6	11	86	52	48
		Sweden [b]	2.7	13	85	46	54
		Yugoslavia [c]	3.4	30	67	41	59
	II	China [d]	21	35	44	63	37
		Ecuador	5.1	25	70	63	37
		Iraq				30	70
		Peru [e]	20	41	40	40	60
	III	Thailand [f]	0.3	33	67	17	83
Brain	I	Australia	21	22	58	52	48
		Canada [a]	2.6	25	72	49	51
		Czechoslovakia	0	18	82	54	46
		Italy	0	10	90	53	47
		Kuwait	4.7	76	20	90	10
		Netherlands	3.6	17	80	58	42
		New Zealand	4.5	30	66	53	47
		Norway	1.6	19	80	46	54
		Sweden [b]	0.1	26	74	50	50
		Yugoslavia [c]	0	30	70	45	55
	II	China [d]	17	24	59	60	40
		Ecuador	0	14	86	10	90
		Iraq				48	52
		Peru [e]	48	26	26	40	60
	III	Thailand [f]	1.4	26	73	45	55
	IV	Ethiopia	12	64	24	58	42
Cardiovascular	I	Australia					
		- Tellurium-201	0.1	7.0	93	62	38
		- Technetium-99m	0.2	1.0	99	64	36
		Canada [a]	6.0	9.5	85	62	38
		Czechoslovakia	3.8	52	45	64	36
		Italy	0	11	89	76	24
		Kuwait	0.8	29	70	55	45
		Netherlands	0.6	9.1	90	66	34
		New Zealand	0.7	13	86	66	34
		Norway	0.1	23	77	58	42
		Sweden [b]					
		- Blood pool	0	46	54	66	34
		- Myocardial	0	1.4	99	64	36
		Yugoslavia [c]	2.0	25	73	75	25
	II	China [d]				33	67
		Ecuador	0	10	90	75	25

Organ/ procedure	Health care level	Country	Age distribution (%)			Sex distribution (%)	
			0-15 years	16-40 years	> 40 years	Male	Female
Thyroid scan	I	Canada [a]	0.8	48	51	14	86
		Czechoslovakia	3.3	64	33	18	82
		Kuwait	5.0	75	20	20	80
		Netherlands	0.7	31	69	31	69
		New Zealand	1.7	29	69	16	84
		Norway	2.4	29	69	16	84
		Sweden [b]	0.9	24	75	19	81
		Yugoslavia [c]	0.5	30	70	28	72
	II	China [d]	2.9	38	59	18	82
		Ecuador	9.0	22	69	14	86
		Peru [e]	9.8	39	51	20	80
	III	Thailand [f]	1.9	52	46	11	89
	IV	Ethiopia	0.7	80	20		
Thyroid uptake	I	Australia	2.2	36	61	15	85
		Canada [a]	0	42	58	14	86
		Czechoslovakia	0	56	44	24	76
		Italy	1.0	37	62	16	84
		Kuwait	0	90	10	30	70
		Netherlands	0.4	37	63	40	60
		New Zealand	0	20	80	20	80
		Norway	1.5	22	77	17	83
		Yugoslavia [c]	0	45	55	18	82
	II	China [d]	3.4	58	38	18	82
		Ecuador	9.1	22	69	14	86
		Iraq				24	76
		Peru [e]	12	47	41	20	80
	III	Thailand [f]	1.8	52	46	12	88
	IV	Ethiopia	0.7	80	20	40	60
Other	I	Canada [a]					
		- Ga-67	2.1	33	65	50	50
		- In-111	0	12	88	57	43
		Italy					
		- Oncology Ga-67	0	26	74	50	50
		Netherlands	4.4	31	64	49	51
		Yugoslavia [c]	0	50	50	50	50
	II	China [d]					
		- Gallbladder	2.0	27	71	64	36

[a] Nova Scotia Province only (about 3.5% of the population).
[b] Age distribution: 0-14 years, 15- 39 years, > 40 years; Stockholm county statistics only (about 20% of population).
[c] Statistics from Serbia only (about 40% of the population).
[d] Beijing area only (about 3% of population).
[e] Statistics from Instituto Peruano de Energía Nuclear only (about 60% of examinations).
[f] Statistics from National Cancer Institute plus Rajavithi Hospital only.

Country	Year	Population (thousands)	Number of radiologists	Diagnostic x-ray units		Teletherapy units			Nuclear medicine clinics
				Medical	Dental	X-ray	^{60}Co, ^{137}Cs	Accelerators	
Sweden [k]	1970-1974	8129	542 [l]	2700	5500	31 [m]	23	12	
	1980-1984	8327	645 [n]	2400	12500	24 [m]	17	27	125
	1985-1989	8414	920 [o]	2000	12900	22 [m]	14	33	120
United Kingdom	1980-1984	54600	1600						288
United States	1970-1974	213669	12216	97788	110974	3441			
	1980-1984	234238	12595	129695	187772	3299			
	1985-1989	248630	12381	108903	142699	1324			
Yugoslavia	1970-1974 [p]	2816		318	99	7	2		5
	1980-1984 [q]	4181		568	239	6	6	1	22
	1985-1989 [q]	23207		1624	741	27	14	10	36
Average per 1000 population	1970-1974		0.063	0.45	0.44	0.014	0.003	0.0004	0.005
	1985-1989		0.076	0.39	0.46	0.005	0.003	0.0022	0.008
HEALTH CARE LEVEL II									
Barbados	1980-1984	250				2	1	0	1
	1985-1989	250				2	1	0	1
China (Beijing area)	1970-1974	27056	734	630		4	1	0	4
	1980-1984	32721	1537	1149		4	4	0	11
	1985-1989	34673	2192	1550		2	3	1	13
Ecuador	1970-1974	6522	30	155	97	2	3	0	5
	1980-1984	8129	83	305	350	6	7	0	10
	1985-1989	10500	128	430	640	6	8	0	13
Peru	1980-1984	18000		1390	1654	20	8	1	20
	1985-1989	20000	150	2400	1836	20	11	1	30
Average per 1000 population	1970-1974		0.023	0.026		0.0002	0.0001	0	0.0003
	1985-1989		0.038	0.11		0.0005	0.0004	0.00003	0.0009
HEALTH CARE LEVEL III									
Cape Verde	1985-1989	330	1	1	1	0	0	0	0
Myanmar	1980-1984	35000	12						
	1985-1989	39000	28						
Philippines	1985-1989	54000	441	1538	25				
Tunisia [r]	1986	6966	88 [r]	740	451	0	3	1 [s]	3
Vanuatu	1985-1989	137	0	6	3	0	0	0	0
Average per 1000 population	1985-1989		0.009	0.037	0.008	0	0.0004	0.0001	0.0004

Table 2
Patients examined or treated by medical radiation
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures, unless otherwise indicated

Country	Year	Diagnostic examinations (thousands)			Therapeutic treatments (thousands)			
		Medical x rays	Dental x rays	Radio-isotopes	X-ray therapy	Tele-therapy	Brachy-therapy	Radio-isotopes
HEALTH CARE LEVEL I								
Argentina	1985-1989			415		29.0	6.0	5.3
Australia	1970-1974	4634	10.0	52	49.9			
	1985-1989	9149		112	5.4	4.4	17.5	2.4
Canada	1970-1974	18880 [a]			432 [b]			
	1985-1986	26563 [a]			519 [b]			
Czechoslovakia	1970-1974	6038	720	145	8.4	10.2	2.2	0.5
	1980-1984	9851	1194					1.3
	1985-1989	8750	884	241	5.1	11.4	1.5	1.9
Denmark	1985-1989	2600 [c]	2400	72	7.0	7.0	0.6	0.1
Finland [R16]	1977	5100						
	1984	4600						
	1986-1987	4300	1100 [d]	100	3.2 [e]			
Japan	1970-1974	73064	91500 [f]	168	132 [b]	1656 [b]	15.5	4.4
	1980-1984	96300	99040 [g]	541	13 [b]	1762 [b]	13.6	3.0
	1985-1989	141500	95768 [h]	989				
Kuwait	1985-1989	1137 [i]	190	24.3	0.3	0.9	0.02	0.03
Luxembourg	1988	294	69.1	9.2	3.4 [b]	4.0 [b]	0.03	0.07
Malta	1970-1974	33.2	0.9		0.1	0.2	0.01	
	1980-1984	84.7	2.3		0.1	0.4	0.01	
	1985-1989	110 [j]	3.2		0.1	0.5	0.01	0.03
Netherlands	1980-1984	7900 [k]	5700		2.5	24.1	1.5	
New Zealand	1970-1974	7900 [l]	~ 1000	18.9	3.9	3.2	0.3	0.5
	1980-1984	2263 [m]		25.9	1.5	6.0	0.3	0.6
	1985-1989	2114 [n]	913	24.5	1.1	8.6	0.2	0.5
Norway	1970-1974	1600	2500	16.0	1.0 [o]			0.08
	1980-1984	2200	3300	36.0				0.3
	1985-1989	2200	3500	39.0	0.04 [o]			0.6
Poland	1985-1989	24949	2300					
Romania	1985-1989				9.1	4.8	1.5	1.2
Spain	1985-1989	19012 [p]						

Table 15, continued

Country	Year	Average activity administered (MBq) *(Range in parentheses)*							
		Bone		Brain			Cardiovascular		
		Tc-99m phosphate	Other/unknown	Tc-99m pertechnetate	Tc-99m gluconate	Other/unknown	Tc-99m erythrocytes	Tl-201 chloride	Other/unknown
Norway	1970-1974 1985-1989	507 (± 121 SD) 574 (± 91 SD)		523 (± 130 SD) 615 (± 139 SD)			764 (± 145 SD)	96 (± 56 SD)	
Romania	1985-1989					370			
Sweden	1974 1985-1989	330 420 (160-600)		400 530 (350-700)			370 650 (50-900)	55 72 (50-120)	
Yugoslavia [b]	1985-1989	555 (350-740)				555 (370-740)	555 (100-740)		
HEALTH CARE LEVEL II									
China [c]	1985-1989	740 (55-925)		370 (296-555)					370 (222-518)
Ecuador	1970-1974 1985-1989	740 (-925)				7.4 (-9.3) 555 (-740)	555 (-740)		
Iraq	1985-1989	(650-750)				(650-750)			
Jamaica	1970-1974 1985-1989	182 (-740)				370 (-740) 182 (-740)	370 (-740)		
Peru	1985-1989	740 (555-925)				740 (555-925)			
HEALTH CARE LEVEL III									
Thailand [d]	1977-1981 1985-1989	740 (740-935) 740 (740-925)		740 (740-925) 740 (740-925)	740 (740-925) 740 (740-925)				

Table 15, continued

Country	Year	Average activity administered (MBq) *(Range in parentheses)*							
		Liver / spleen			Lung			Renal	
		Tc-99m colloid	Tc-99m HIDA	Other/unknown	Tc-99m MAA	Tc-99m microspheres	Other/unknown	I-131 hippurate	I-123 hippurate
HEALTH CARE LEVEL I, continued									
Italy	1985-1989			140 (55-448)			116/191 (55-925)		
Japan	1985-1989	196			230				
Kuwait	1985-1989	92 (55-129)	92 (55-129)		155 (118-192)	1042 (908-1176)			
Netherlands	1985-1989	75 (75-110)			75 (75-150)				20 (2-20)
New Zealand	1970-1974 1985-1989	101 (26-259) 162 (37-370)			146 (33-370) 151 (30-750)				
Norway	1970-1974 1985-1989	118 (± 47 SD) 125 (± 40 SD)			95 (± 39 SD) 98 (± 29 SD)			4.2 (± 3 SD) 4.9 (± 1.1 SD)	
Romania	1985-1989			74					
Sweden	1974 1985-1989	70 125 (70-400)			66 87 (35-120)	440 (30-1900)	5.1 420 (10-800)	0.9 0.9 (0.1-4.5)	
Yugoslavia [b]	1970-1974 1985-1989			10 (8-12) 74 (60-150)			3.7 (3-5) 74 (60-150)	6 (5-8) 6 (5-8)	
HEALTH CARE LEVEL II									
China [c]	1970-1974 1985-1989	 222 (185-370)		74 (37-100)				0.37 (0.26-0.56)	

Table 15, continued

PART III

Country	Year	Average activity administered (MBq) *(Range in parentheses)*							
		Renal			Thyroid				
		Tc-99m gluconate	Tc-99m other	Other/unknown	Tc-99m pertechnetate	I-131 uptake	I-131 scan	I-123 uptake	I-123 scan
HEALTH CARE LEVEL I									
Argentina	1985-1989		555						
Australia	1970 1980 1989	109 579 573	 490 427		61 145 156	1.4 0.5 0.7			
Canada [a]	1970-1974 1985-1989		 296 (74-370)	11.1	 260 (185-370)	0.6 0.6 (0.4-0.6)	0.9		
Czechoslovakia	1970-1974 1985-1989		80 (60-120) 80 (60-120)		60 (40-160) 80 (60-300)	1.5 (1-2) 1.5 (1-2)			
Italy	1985-1989		78			1			
Japan	1985-1989		320		360 (males) 450 (females)		6		
Kuwait	1985-1989		259 (148-370)		185 (148-222)	0.3 (-0.7)			
Netherlands	1985-1989				50	0.2 (0.2-7)		2 (2-20)	30
New Zealand	1970-1974 1985-1989	210 (81-592) (74-1110)	 116,340 (20-623)		140 (22-460) 144 (9-746)	0.7 (0.11-3.9) 9.5 (0.7-33)			
Norway	1970-1974 1985-1989		150 113 (± 91 SD)		71 (± 39 SD) 69 (± 40 SD)	1.1 (± 0.5 SD) 1.2 (± 0.7 SD)	1.2 (± 0.3 SD) 1.5 (± 0.4 SD)		

Table 15, continued

Country	Year	Average activity administered (MBq) *(Range in parentheses)*							
		Renal			Thyroid				
		Tc-99m gluconate	Tc-99m other	Other/unknown	Tc-99m pertechnetate	I-131 uptake	I-131 scan	I-123 uptake	I-123 scan
HEALTH CARE LEVEL III									
Thailand [d]	1977-1981				74 (74-83)	2.2 (2.2-2.4)			
	1985-1989				74 (74-83)	2.2 (2.2-2.4)			
Tunisia	1970-1974		185		111	3.7			
	1985-1989		111		111	1.9			
HEALTH CARE LEVEL IV									
Ethiopia	1970-1974					1.7 (1.7-2.2)			
	1985-1989		74 (37-74)			1.7 (1.7-2.2)			

[a] Nova Scotia Province only (about 3.5% of the population).
[b] Serbia and Macedonia only (about 50% of the population).
[c] Beijing area only (about 3% of the population).
[d] Statistics from Rajavithi Hospital only.

Table 17
Annual per caput and collective effective dose equivalent from diagnostic nuclear medicine examinations

Country	Year	Ref.	Effective dose equivalent (mSv)		Collective effective dose equivalent (man Sv)
			Per caput	Per examined patient	
HEALTH CARE LEVEL I					
Canada	1984	[L7]	0.17	3.8	4200
Manitoba	1985	[H17]	0.13	5.2	127
Above estimate extrapolated to entire country			0.13	5.2	3200
Germany, Bavaria and West Berlin	1985-1986	[K10]	0.11-0.12	2.7-3.2	
Above estimate extrapolated to entire country			0.11-0.12	2.7-3.2	7000
Japan	1982	[M10,M11,M12]	0.035		4240 [a]
Netherlands	1984	[B3]	0.037	2.7	540
Reinterpretation with ICRP 53 dose coefficients and new examination frequency data		[B20]	0.034	2.9	480 [b]
Same estimate, taking account of age distribution of patients		[B20]	0.031	2.7	450 [b]
Sweden	1986	[V4]	0.05	3.5	420
United Kingdom	1982	[H10]	0.02		1000
United States	1982	[N1]	0.14		32100

[a] Collective dose component to women is 1910 man Sv.
[b] The collective dose due to the somatic part of the effective dose equivalent is reported to be 575 man Sv [B20].

Table 18
Regional differences in diagnostic nuclear medicine examinations

Region	Country	Year	Ref.	Examinations with Tc-99m (%)	Examination performed (%)			
					Brain	Bone	Cardio-vascular	Other
North America	Canada (Manitoba)	1985	[H17	86	19	27	9	45
	United States	1982	[H17, N1]	82	11	24	13	52
Europe	Germany	1986	[K10]	79-86	1-2	24-27	7	65-67
	Sweden	1987	[H18, H19]	64	2	30	6	62

Table 20
Annual average frequency of brachytherapy treatments (Number of patients per 1000 population)
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

Country	Year	Breast tumour	Prostate tumour	Gynaecological		Brain tumour	Other tumours	Benign disease
				Radium	Afterloading			
HEALTH CARE LEVEL I								
Australia	1970-1974 1985-1989	0 0.016	0.001 0	0.068 [a] 0.019 [a]	 0.034	0	0.18 0.076	0.52
Czechoslovakia	1970-1974 1985-1989			0.064 0.023	0.16 0.12			
Japan	1970-1974	0.01		0.082			0.024	
Kuwait	1985-1989	0	0	0	0.006	0	0	0.054
Luxembourg	1988	0.067						
Malta	1985-1989				0.032			
New Zealand	1985-1989				0.066			
Norway [b]	1970-1974 1985-1989	0.001 0	0 0.0005	0.13 0.043	0 0.049	0 0.0002	0.010 0.005	
Sweden	1970-1974 1985-1989		0.0004 0.0006	0.037 [c] 0.010 [c]	0.006 0.045			0.001 0.001
Yugoslavia	1985-1989	0.049 [d]	0.026 [d]	0.061 [e]	0.26 [e]	0.036 [d]	0.012 [f]	
HEALTH CARE LEVEL II								
Barbados	1985-1989			0.24 [g]				
Ecuador	1970-1974 1985-1989	0 0	0 0	0.006 0.015	0 0.002	0 0	0 0	0 0
Iraq [h]	1985-1989			0.009 [g]				
Jamaica [i]	1985-1989	0		0.061				0.012
Peru	1970-1974 1985-1989			0.031 0.044			0.001 0.0004	

[a] Iridium, not radium.
[b] Including palliative treatments; doses for curative treatments only are about 10% higher.
[c] Radium and caesium.
[d] Croatia only (about 20% of the population).
[e] Excluding Montenegro, Vojvodina and Kosovo (i.e., based on about 80% of the population).
[f] Data partly from Serbia (about 40% of the population), partly from Slovania (about 10% of the population.
[g] Manual administration of caesium-137.
[h] Statistics from Institute of Radiology and Nuclear Medicine, Baghdad.
[i] Statistics from Kingston Hospital only.

Organ/ procedure	Health care level	Country	Age distribution (%)			Sex distribution (%)	
			0-15 years	16-40 years	> 40 years	Male	Female
Gynaecological tumours, continued	I contd.	Sweden	0	5.9	94	0	100
		Yugoslavia [a]	0	14	86	0	100
	II	Ecuador	1.4	14	84	0	100
		Iraq	1.6	41	58	0	100
	III	Myanmar [b]	0.6	6.4	93	0	100
		Thailand [c]	0.1	30	70	0	100
Wilm's tumour	I	Kuwait [d]	100	0	0	67	33
		New Zealand [e]	100	0	0	50	50
		Norway [f]	100	0	0	100	0
		Sweden [c]	100	0	0	80	20
		Yugoslavia [c]	100	0	0	50	50
	II	Ecuador [f]	100	0	0	100	0
		Iraq	100	0	0	50	50
	III	Myanmar [b, d]	100	0	0	33	67
		Thailand [c]	100	0	0	44	56
Neuroblastoma	I	Kuwait [g]	75	25	0	50	50
		New Zealand [h]	100	0	0	50	50
		Norway [h]	16	33	50	71	29
		Sweden [c]	100	0	0	80	20
		Yugoslavia [c]	30	40	30	50	50
	II	Ecuador	50	50	0	50	50
		Iraq	100	0	0	67	33
	III	Myanmar [b, f]	100	0	0	0	100
		Thailand [c]	100	0	0	63	36
Benign diseases	I	Czechoslovakia	0	1.4	99	26	64
		Kuwait				50	50
		New Zealand	4.0	44	52	55	45
		Sweden	1.6	60	39	42	58
	II	Ecuador	0	8.3	92	98	2.5
	III						
All malignant tumours	I	Romania	1.3	14	85	37	63

[a] Statistics from Serbia only (about 40% of the population).
[b] Statistics from Yangon General Hospital only.
[c] Statistics from Department of Radiology, National Cancer Institute only.
[d] 3 patients.
[e] 5 patients.
[f] 1 patient.
[g] 4 patients.
[h] 6 patients.

Table 23
Target organ and entrance surface absorbed doses to patients in radiation teletherapy, 1985-1989
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

Country	Dose region	Absorbed dose (Gy) *(Range in parentheses)*							
		Leukaemia	Lymphoma	Breast tumour	Lung/ thorax tumour	Gynaeco-logical tumour	Wilm's tumour	Neuro-blastoma	Benign disease
HEALTH CARE LEVEL I									
Australia	Target	20 (8-25)	40 (35-45)	50 (30-60)	60 (20-60)	50 (30-55)	(10-25)	(10-40)	
Czechoslovakia	Target Surface	15.5 (2-36) 13.4 (1-43)	35 (9.6-46.8) 40.2 (10.5-50)	49 (8-56) 55.4 (7.2-60)	51 (20-60) 35 (25-40)	53.4 (8-70) 40 (14-60)			6 (1.5-6)
Kuwait	Target Surface	18 (15-24) 12	36 (30-40) 24	45 (45-50) 37 (26-30)	40 (40-50) 24 (24-30)	40 (40-50) 24 (24-30)	45 (30-45)	45	(30-45) (4-25)
Malta	Target		35 (30-40)	50 (45-60)	45 (30-50)	45 (35-50)	25 (20-35)	30 (12-45)	
New Zealand	Target secondary	19 (18-24)	38 (35-40)	55 30	55 30	42 (33-45)	24 (15-25)	30 (6-35)	12-48 (-50)
Norway	Target Surface	35 (20-40) 21	35 (30-45) 50 (43-60)	32 (20-60) 46 (29-86)	33 (20-50) 47 (29-71)	35 (30-50) 50 (43-71)	11	54 (30-61)	
Sweden	Target Surface	(20-30)	(20-50) (20-35)	(47-70) (30-45)	(20-60)	(30-60) (28-45)			(7-40)
Yugoslavia [a]	Target	20 (20-30)	30 (20-50)	50 (50-70)	45 (43-60)	20 (20-60)	20 (20-40)	20 (20-40)	10 (10-20)
HEALTH CARE LEVEL II									
Barbados	Target			45 (30-50)	35 (20-45)	35 (20-45)			
China	Target Surface	50 (46-55) 60 (56-65)	40 (36-55) 50 (46-60)	40 (36-45) 50 (46-56)	40 (36-70) 50 (46-87)	50 (46-80) 60 (56-100)	40 (36-41) 50 (46-51)	40 (36-42) 50 (46-52)	30-60 (12-65) 17-70 (14-75)
Ecuador [b]	Target Surface	1.5 (2.5) 1.8 (3.0)	1.5 (2.0) 1.8 (3.0)	2.0 (2.3) 2.4 (2.9)	2.0 (4.0) 2.4 (4.8)	2.0 (2.5) 2.4 (3.0)	1.0 (1.25) 1.2 (1.5)		2.0 (3.0) 2.4 (8.6)
Iraq [b]	Target Surface	20 (18-24) 0.32	35 (35-40) 0.20	45 (40-45) 0.45	30 (30-40) 0.35	50 (45-55) 0.32	35 (30-40) 0.45	40	
Jamaica	Target Surface		35 40	40 47	40 46	50 56	40 47	40 47	15 18

Table 24
Target organ doses to patients in radiation brachytherapy, 1985-1989
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

Country	Target absorbed dose (Gy) *(Range in parentheses)*						
	Breast tumour	Prostate tumour	Gynaecological		Brain tumour	Other tumours	Benign disease
			Radium	Afterloading			
HEALTH CARE LEVEL I							
Australia	20 (10-30)		25 (20-50)			25-40 (20-)	
Czechoslovakia			25 (20-60)	25 (20-60)			
Kuwait	20 (20-40)		40 (30-40)	40 (30-40)			20
Malta				70 (65-75)			
New Zealand				35 (15-75)			
Norway		160 (160-)	40 (40-)	25 (25-)	54 (54-)	20-30 (20-)	
Sweden		20 (15-20)	60	(20-45)		(30-60)	
HEALTH CARE LEVEL II							
Barbados			60 (40-80)				
Ecuador			30 (40)	30 (32)			
Iraq			20 [a]				
Jamaica			26 (39)				36
Peru			44 (30-45)			38-60 (30-80)	
HEALTH CARE LEVEL III							
Myanmar [b]			40 (30-50)				
Thailand [c]	25 (20-30)		30 (25-30)	30 (25-30)			

[a] Combined with external beam.
[b] Statistics from Yangon Hospital only.
[c] Statistics from Department of Radiology, National Cancer Institute, Bangkok, only.

Table 26
Age- and sex-distribution of patients in therapy treatment with radiopharmaceuticals, 1985-1989
Data from UNSCEAR Survey of Medical Radiation Usage and Exposures

Organ/ procedure	Health care level	Country	Age distribution (%)			Sex distribution (%)	
			0-15 years	16-40 years	> 40 years	Male	Female
Thyroid tumours	I	Canada [a]	0	25	75	10	90
		Czechoslovakia	0	74	26	31	69
		Kuwait				37	63
		Netherlands	2	20	78	33	67
		New Zealand	0	40	60	7	93
		Norway	0	32	68	20	80
		Yugoslavia [b]	0	0	100	50	50
	II	Ecuador	0	32	68	10	90
		Iraq				40	60
		Peru				20	80
	III	Thailand [c]	0.7	15	84	23	77
Hyperthyroidism	I	Canada [a]	0	26	74	25	75
		Czechoslovakia	0	49	51	26	74
		Netherlands	0	32	68	19	81
		New Zealand	0	28	72	25	75
		Norway	0	14	86	22	78
		Yugoslavia [b]	0	0	100	10	90
	II	China [d]	0	67	33	29	71
		Ecuador	0	33	67	15	85
		Iraq				21	79
		Jamaica	0	58	42	33	67
		Peru				30	70
	III	Thailand [c]	0	31	69	17	83
Polycythaemia vera	I	Czechoslovakia	0	57	43	51	49
		New Zealand	0	0	100	53	47
		Yugoslavia [b]	0	17	83	90	10
Other tumours	I	Czechoslovakia	0	9.8	90	61	39
		Norway	0	23	77	0	100
Benign diseases	I	Canada [a]	0	0	100	50	50
		Czechoslovakia	0	0	100	19	81

[a] Nova Scotia Province only (about 3.5% of the population).
[b] Statistics from Serbia only (about 40% of the population).
[c] Statistics from Department of Radiology, National Cancer Institute, Bangkok, and Rajavithi Hospital only.
[d] Beijing area only (about 3% of the population).

Table 27, continued

Country	Year	Average activity administered (MBq) *(Range in parentheses)*						
		Thyroid tumours	Hyperthyroidism	Polycythaemia vera	Other tumours		Benign diseases	
		I-131 iodide	*I-131 iodide*	*P-32 phosphate*	*Y-90 colloid*	*Other*	*Au-198 colloid*	*Other*
HEALTH CARE LEVEL I, continued								
Sweden	1974 1985-1989	1700	344	230 224 (140-335)	185	 2874 [i] (2000-3700)	160 150 (110-185)	150 [e] 187 [e] (150-200)
Yugoslavia [j]	1970-1974 1985-1989	3700 3700	185 (100-200) 185 (100-200)					
HEALTH CARE LEVEL II								
Barbados	1985-1989		296 (222-296)	294 (222-370)				
China [k]	1970-1974 1985-1989		296 (148-740) 259 (111-740)					
Ecuador	1970-1974 1985-1989	3700 (-9250) 3700 (-9250)	296 (-444) 296 (-444)					
Iraq	1985-1989	1850 (-5550)	200 (-1000)	200 (-400)				
Jamaica	1970-1974 1985-1989	370	182 370					
Peru	1985-1989	3700 (2960-4440)	259 (185-370)					
LEVEL OF HEALTH CARE III								
Thailand	1985-1989	270						

Table 29
Doses to various categories of medical staff in three regions of Germany, 1987
[D5]

Profession	Number monitored	Annual average effective dose equivalent (mSv)	
		Staff with recorded doses only	All staff
Orthopaedists	2452	1.67	0.11
Radiologists	2109	1.38	0.53
Internists	4153	1.00	0.12
General practitioners	1021	0.88	0.06
Nuclear medicine specialists	2528	1.76	0.50

Table 30
Distribution of dose to medical staff

Country	Year	Ref.	Annual effective dose equivalent (mSv)	Number of staff exposed			
				X-ray staff	Radiotherapy staff	Nuclear medicine staff	All staff
Canada [a]	1984	[S20]	0-0.19 0.2-5.0 5.1-15.0 15.1-50.0 > 50	21493 [b] 3282 [b] 16 [b] 0 0	262 364 20 2 0	2439 850 103 0 0	24194 4495 139 3 0
France	1988	[P4]	0-0.19 0.2-5.0 5.1-15.0 15.1-50.0 > 50	44210 3305 363 113 17	3988 757 65 22 1	3873 380 23 6 0	
Germany [c]	1985-1986	[R12,R13]	0-5.0 5.1-15.0 15.1-50.0 > 50	40332 68 12 0	2184 70 7 0	1703 15 0 0	50229 166 28 0
Germany [d]	1986	[B21]	0-0.2 0.21-5.0 5.1-15.0 15.1-50.0 > 50				165421 13628 411 76 16
Sweden	1988	[K6]	0-0.09 0.1-5.0 5.1-10.0 10.1-20.0 20.1-50.0 > 50				6901 4004 24 1 2 3
United Kingdom	1986	[H10]	0-5.0 5.1-15.0 15.1-50.0 > 50	10212 14 0 0	3766 56 4 0	2667 5 0 0	

[a] Numbers calculated from published distribution parameters.
[b] May include some therapy and nuclear medicine staff.
[c] Former German Democratic Republic.
[d] Former Federal Republic of Germany.