

NUMBER OF X-RAY EXAMINATIONS PERFORMED ON PAEDIATRIC AND GERIATRIC PATIENTS COMPARED WITH ADULT PATIENTS

A. Aroua^{1,*}, F. O. Bochud¹, J.-F. Valley¹, J.-P. Vader² and F. R. Verdun¹

¹University Institute of Radiation Physics (IRA-DUMSC), University of Lausanne, Grand-Pré 1, CH-1007 Lausanne, Switzerland

²University Institute of Social and Preventive Medicine (IUMSP-DUMSC), University of Lausanne, Bugnon 17, CH-1005 Lausanne, Switzerland

Received April 20 2006, revised August 28 2006, accepted September 6 2006

The age of the patient is of prime importance when assessing the radiological risk to patients due to medical X-ray exposures and the total detriment to the population due to radiodiagnostics. In order to take into account the age-specific radiosensitivity, three age groups are considered: children, adults and the elderly. In this work, the relative number of examinations carried out on paediatric and geriatric patients is established, compared with adult patients, for radiodiagnostics as a whole, for dental and medical radiology, for 8 radiological modalities as well as for 40 types of X-ray examinations. The relative numbers of X-ray examinations are determined based on the corresponding age distributions of patients and that of the general population. Two broad groups of X-ray examinations may be defined. Group A comprises conventional radiography, fluoroscopy and computed tomography; for this group a paediatric patient undergoes half the number of examinations as that of an adult, and a geriatric patient undergoes 2.5 times more. Group B comprises angiography and interventional procedures; for this group a paediatric patient undergoes a one-fourth of the number of examinations carried out on an adult, and a geriatric patient undergoes five times more.

INTRODUCTION

The age of the patient is quite an important parameter for the evaluation of the detriment of medical X-ray exposures. The risks associated with an exposure for elderly patients (induction of cancer with 20 y latency, hereditary disorders in the offspring) are less important than those for adult patients, whereas children are more radiosensitive than adults.

To take into account the effect of age in estimating the radiological risk, various models are proposed in literature to correct the effective dose, such as the BfS model⁽¹⁾ or the NRPB model⁽²⁾. They all suggest the use of a multiplying factor decreasing with age to weight the effective dose. Usually three age categories are used: children, adults and the elderly with boundaries that may change slightly from one model to another.

It is, therefore, important, when assessing the impact of diagnostic and interventional radiology on the population, to establish the age distribution of patients undergoing X-ray examinations and to determine the fraction of these examinations associated with paediatric, adult and geriatric patients.

This work aims at determining the number of X-ray examinations performed on children and the elderly, considering adults as a reference, for a

number of radiological modalities and a series of common radiological examinations.

METHODS

In this work the following age groups are adopted:

- (1) Paediatric patients: below age 15.
- (2) Adult patients: between age 15 and age 64.
- (3) Geriatric patients: age 65 and above.

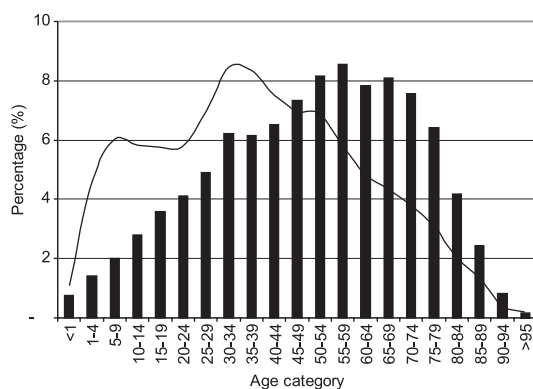


Figure 1. Patient age profile (histograms) related to all radiological modalities (average age of 50). The age profile of the Swiss general population is shown in solid line; with a corresponding average age of 39.

*Corresponding author: abbas@aroua.com

X-RAY EXAMINATIONS IN PAEDIATRICS AND GERIATRICS

Table 1. Number of X-ray examinations performed on paediatric and geriatric patients relative to adult patients for various radiological modalities.

Radiological modality	A	Age group					All ages	
		(0-14)	(15-39)	(40-64)	(15-64)	(65+)		
Population	39	N	1,242,329	2,507,375	2,270,978	4,778,353	1,076,212	7,096,894
Medical and dental X-ray examinations	50	N	666,713	2,376,014	3,660,720	6,036,734	2,826,757	9,530,204
		N_a	7	25	38	63	30	100
		N_p	537	948	1,612	1,263	2,627	1,343
		R	0.42	—	—	1.00	2.08	—
Dental X-ray examinations	42	N	269,532	1,630,979	1,724,134	3,355,113	498,833	4,123,478
		N_a	7	40	41	81	12	100
		N_p	217	650	759	702	464	581
		R	0.31	—	—	1.00	0.66	—
Medical X-ray examinations	56	N	397,207	744,212	1,936,394	2,680,606	2,328,913	5,406,726
		N_a	7	14	36	50	43	100
		N_p	320	297	853	561	2,164	762
		R	0.57	—	—	1.00	3.86	—
Radiography	48	N	466,160	1,206,473	1,511,371	2,717,844	1,375,460	4,559,465
		N_a	10	27	33	60	30	100
		N_p	375	481	666	569	1,278	642
		R	0.66	—	—	1.00	2.25	—
Conventional fluoroscopy	48	N	20,713	30,954	57,928	88,882	46,205	155,799
		N_a	13	20	37	57	30	100
		N_p	17	12	26	19	43	22
		R	0.90	—	—	1.00	2.31	—
Conventional tomography	52	N	—	2,931	5,326	8,257	3,107	11,364
		N_a	—	26	47	73	27	100
		N_p	—	1.2	2.3	1.7	2.9	1.6
		R	—	—	—	1.00	1.67	—
Computed tomography	54	N	6,703	71,339	139,124	210,463	111,318	328,484
		N_a	2	22	42	64	34	100
		N_p	5	28	61	44	103	46
		R	0.12	—	—	1.00	2.35	—
Mammography	55	N	63	19,120	158,840	177,960	44,554	222,577
		N_a	0	9	71	80	20	100
		N_p	0.05	8	70	37	41	31
		R	0.00	—	—	1.00	1.11	—
Angiography	60	N	2,930	5,374	28,742	34,116	33,024	70,070
		N_a	4	8	41	49	47	100
		N_p	2.4	2.1	13	7.1	31	10
		R	0.33	—	—	1.00	4.30	—
Bone densitometry	61	N	272	376	18,999	19,375	12,573	32,220
		N_a	1	1	59	60	39	100
		N_p	0.22	0.15	8.4	4.1	12	4.5
		R	0.05	—	—	1.00	2.88	—
Interventional procedures	63	N	534	1,711	9,768	11,479	14,734	26,747
		N_a	2	6	37	43	55	100
		N_p	0.4	0.7	4.3	2.4	14	3.8
		R	0.18	—	—	1.00	5.70	—

A: mean value of the age distribution

N: number of examinations performed annually in Switzerland (or Swiss population) within the corresponding age group

N_a : fraction (%) of the number of examinations for the corresponding age group

N_p : number of examinations per 1000 population of the corresponding age group;

R: N_p for the corresponding age group/ N_p (15-64).

Table 2. Number of X-ray examinations performed on paediatric and geriatric patients relative to adult patients for two broad groups of X-ray examinations.

Group of X-ray examinations	Paediatric patients (0–14)	Adult patients (15–64)	Geriatric patients (65+)
Group A			
Radiography, Conventional fluoroscopy, Computed tomography	0.5	1	2.5
Group B			
Angiography, Interventional radiology	0.25	1	5

In this study patients above 65 are considered as geriatric patients. The United Nations Scientific Committee on the Effects of the Atomic Radiation (UNSCEAR)⁽³⁾ provides age data in different age groups: 0–15, 16–40 and >40. In order to provide data in the present work that can be used in the UNSCEAR format, the group of adult patients (15–64) is divided into two subgroups (15–39 and 40–64). The second subgroup added to the geriatric group leads to the third UNSCEAR group.

If $n_{pa}(a)$ and $n_{gp}(a)$ represent the age distribution of patients who undergo X-ray examinations and that of the general population, respectively, the fractions of paediatric, adult and geriatric patients may then be expressed, respectively, as follows:

$$\int_0^{15} n_{pa}(a) da, \quad \int_{15}^{65} n_{pa}(a) da, \quad \int_{65}^{\infty} n_{pa}(a) da.$$

Similarly, the fractions of children, adults and the elderly within the general population may be expressed, respectively, as follows:

$$\int_0^{15} n_{gp}(a) da, \quad \int_{15}^{65} n_{gp}(a) da, \quad \int_{65}^{\infty} n_{gp}(a) da.$$

If the adult patients are taken as a reference, the relative number of examinations for paediatric patients, R_{ped} , may be written as follows:

$$R_{ped} = \frac{\int_0^{15} n_{pa}(a) da / \int_0^{15} n_{gp}(a) da}{\int_{15}^{65} n_{pa}(a) da / \int_{15}^{65} n_{gp}(a) da}.$$

Similarly, the relative number of examinations for geriatric patients, R_{ger} , may be written as follows:

$$R_{ger} = \frac{\int_{65}^{\infty} n_{pa}(a) da / \int_{65}^{\infty} n_{gp}(a) da}{\int_{15}^{65} n_{pa}(a) da / \int_{15}^{65} n_{gp}(a) da}.$$

The age distributions used in this work, $n_{pa}(a)$, are established from the data collected during the 1998 nationwide survey on the exposure of the Swiss

population by radiodiagnostics^(4–6), while the age distribution of the Swiss general population, $n_{gp}(a)$, for the same year, is established using the official published data⁽⁷⁾.

Figure 1 shows the age distribution $n_{pa}(a)$ for the total number of X-ray examinations carried out in Switzerland considering all the radiological modalities and compares it with the age distribution of the Swiss general population.

The number of X-ray examinations performed on paediatric and geriatric patients, relative to adult patients, is determined for eight radiological modalities: (1) radiography (except mammography), (2) conventional fluoroscopy (non-vascular, used mainly in gastro-enterology, urology and gynecology), (3) computed tomography, (4) angiography, (5) interventional radiology, (6) mammography, (7) conventional tomography, and (8) bone densitometry, as well as for 40 types of examinations covering these eight radiological modalities.

RESULTS AND DISCUSSION

Table 1 presents the number of X-ray examinations for paediatric and geriatric patients, relative to adult patients, R , first for the whole radiological profession, then separately for dental and medical radiology and last for eight medical radiological modalities. These modalities are sorted by ascending average age (A). In each case, the annual total number of examinations (N), the fraction of that number (N_a in %) for each age group and the number of examination per 1000 population (N_p) are given as well.

Table 1 indicates that if all medical and dental examinations are considered, then a geriatric patient undergoes twice the number of X-ray examinations as that of an adult patient, whereas a paediatric patient undergoes less than half the number as that of an adult.

When splitting the total number of X-ray examinations into dental and medical, two significantly different distributions are obtained with average ages of 42 and 56, respectively. In the case of dental examinations, geriatric patients undergo on average two-thirds the number of dental examinations as that of adult patients whereas paediatric patients undergo less than one-third. As regards medical examinations, the relative number of examinations for geriatric patients is ~ 4 and that for paediatric patients is ~ 0.6 .

If the eight medical radiological modalities are looked at separately, one finds that except for mammography where a geriatric patient has only 10% more examinations than an adult patient, in all other modalities the relative number of examinations in geriatrics is high and ranges between 1.7 for conventional tomography and 5.7 for interventional radiology. Concerning paediatrics, the relative

X-RAY EXAMINATIONS IN PAEDIATRICS AND GERIATRICS

Table 3. Number of X-ray examinations performed on paediatric and geriatric patients relative to adult patients for a series of 40 types of examinations.

X-ray examination	A	Age group					All ages	
		(0-14)	(15-39)	(40-64)	(15-64)	(65+)		
Population	39	<i>N</i>	1,242,329	2,507,375	2,270,978	4,778,353	1,076,212	7,096,894
Micturating cysto-urethrography (MCU)	11	<i>N</i>	9,583	597	540	1,137	617	11,337
		<i>N_a</i>	85	5	5	10	5	100
		<i>N_p</i>	7.7	0.24	0.24	0.24	0.57	1.6
		<i>R</i>	32.42	—	—	1.00	2.41	—
Skull radiography	35	<i>N</i>	20,263	35,407	21,308	56,715	13,467	90,445
		<i>N_a</i>	22	39	24	63	15	100
		<i>N_p</i>	16	14	9	12	13	13
		<i>R</i>	1.37	—	—	1.00	1.05	—
Hand radiography	36	<i>N</i>	32,637	48,591	37,301	85,892	20,728	139,257
		<i>N_a</i>	23	35	27	62	15	100
		<i>N_p</i>	26	19	16	18	19	20
		<i>R</i>	1.46	—	—	1.00	1.07	—
Bitewing radiography	37	<i>N</i>	115,132	847,054	640,935	1,487,989	91,326	1,694,447
		<i>N_a</i>	7	50	38	88	5	100
		<i>N_p</i>	93	338	282	311	85	239
		<i>R</i>	0.30	—	—	1.00	0.27	—
Orthopantomography (OPG)	41	<i>N</i>	21,712	93,330	87,982	181,312	33,638	236,662
		<i>N_a</i>	9	40	37	77	14	100
		<i>N_p</i>	17	37	39	38	31	33
		<i>R</i>	0.46	—	—	1.00	0.82	—
Cervical spine radiography	43	<i>N</i>	6,944	62,080	61,173	123,253	22,233	152,430
		<i>N_a</i>	5	41	40	81	15	100
		<i>N_p</i>	6	25	27	26	21	21
		<i>R</i>	0.22	—	—	1.00	0.80	—
Foot radiography	44	<i>N</i>	20,764	59,028	60,691	119,719	36,468	176,951
		<i>N_a</i>	12	33	34	67	21	100
		<i>N_p</i>	17	24	27	25	34	25
		<i>R</i>	0.67	—	—	1.00	1.35	—
Cerebral embolisation	44	<i>N</i>	18	200	233	433	68	519
		<i>N_a</i>	4	38	45	83	13	100
		<i>N_p</i>	0.01	0.08	0.10	0.09	0.06	0.07
		<i>R</i>	0.16	—	—	1.00	0.69	—
Thoracic spine radiography	46	<i>N</i>	6,717	24,518	24,757	49,275	18,644	74,637
		<i>N_a</i>	9	33	33	66	25	100
		<i>N_p</i>	5	10	11	10	17	11
		<i>R</i>	0.52	—	—	1.00	1.68	—
Apical radiography	47	<i>N</i>	85,591	619,628	949,679	1,569,307	363,763	2,018,661
		<i>N_a</i>	4	31	47	78	18	100
		<i>N_p</i>	69	247	418	328	338	284
		<i>R</i>	0.21	—	—	1.00	1.03	—
Intravenous urography (UIV)	48	<i>N</i>	1,421	10,054	14,104	24,158	7,027	32,607
		<i>N_a</i>	4	31	43	74	22	100
		<i>N_p</i>	1.1	4.0	6.2	5.1	6.5	4.6
		<i>R</i>	0.23	—	—	1.00	1.29	—
Knee radiography	48	<i>N</i>	21,921	103,423	106,521	209,944	96,028	327,893
		<i>N_a</i>	7	32	32	64	29	100
		<i>N_p</i>	18	41	47	44	89	46
		<i>R</i>	0.40	—	—	1.00	2.03	—
Abdomen radiography	49	<i>N</i>	11,485	41,815	48,051	89,866	42,846	144,197
		<i>N_a</i>	8	29	33	62	30	100
		<i>N_p</i>	9	17	21	19	40	20
		<i>R</i>	0.49	—	—	1.00	2.12	—
Barium meal	49	<i>N</i>	2,111	2,212	5,028	7,240	4,459	13,810
		<i>N_a</i>	15	16	36	52	32	100

Table 3. Continued

X-ray examination	A	Age group					All ages	
		(0-14)	(15-39)	(40-64)	(15-64)	(65+)		
Pelvis CT	49	N_p	1.7	0.9	2.2	1.5	4.1	1.9
		R	1.12	—	—	1.00	2.73	—
		N	186	1,932	2,395	4,327	1,587	6,100
		N_a	3	32	39	71	26	100
		N_p	0.15	0.8	1.0	0.9	1.5	0.9
Lumbar spine radiography	50	R	0.17	—	—	1.00	1.63	—
		N	9,254	79,492	111,130	190,622	73,091	272,967
		N_a	3	29	41	70	27	100
		N_p	7	32	49	40	68	38
		R	0.19	—	—	1.00	1.70	—
Lumbar spine CT	52	N	134	9,485	18,583	28,068	9,542	37,744
		N_a	0	25	49	74	25	100
		N_p	0.11	3.8	8.2	5.9	8.9	5.3
		R	0.02	—	—	1.00	1.51	—
		N	2,457	18,272	31,314	49,586	26,946	78,988
Skull CT	54	N_a	3	23	40	63	34	100
		N_p	2.0	7.3	14	10	25	11
		R	0.19	—	—	1.00	2.41	—
		N	399	2,091	3,839	5,930	3,827	10,155
		N_a	4	20	38	58	38	100
Ascending pyelography	54	N_p	0.3	0.8	1.7	1.2	3.6	1.4
		R	0.26	—	—	1.00	2.87	—
		N	126,040	226,768	536,620	763,388	599,528	1,488,956
		N_a	8	15	36	51	40	100
		N_p	101	90	236	160	557	210
Chest radiography	54	R	0.64	—	—	1.00	3.49	—
		N	5,367	42,661	60,786	103,447	63,439	172,253
		N_a	3	25	35	60	37	100
		N_p	4	17	27	22	59	24
		R	0.20	—	—	1.00	2.72	—
Shoulder radiography	54	N	1,251	9,227	21,159	30,386	16,044	47,682
		N_a	3	19	44	63	34	100
		N_p	1.0	3.7	9.3	6.4	15	6.7
		R	0.16	—	—	1.00	2.34	—
		N	63	19,120	158,840	177,960	44,554	222,577
Mammography	55	N_a	0	9	71	80	20	100
		N_p	0.1	7.6	70	37	41	31
		R	0.00	—	—	1.00	1.11	—
		N	18,659	43,172	69,564	112,736	109,520	240,914
		N_a	8	18	29	47	45	100
Pelvis radiography	56	N_p	15	17	31	24	102	34
		R	0.64	—	—	1.00	4.31	—
		N	800	16,729	40,543	57,272	38,890	96,962
		N_a	1	17	42	59	40	100
		N_p	0.6	6.7	18	12	36	14
Abdomen CT	58	R	0.05	—	—	1.00	3.01	—
		N	724	466	2,649	3,115	3,374	7,213
		N_a	10	6	37	43	47	100
		N_p	0.6	0.2	1.2	0.7	3.1	1.0
		R	0.89	—	—	1.00	4.81	—
Barium enema	58	N	28	243	1,105	1,348	1,135	2,511
		N_a	1	10	44	54	45	100
		N_p	0.02	0.10	0.49	0.28	1.0	0.35
		R	0.08	—	—	1.00	3.74	—
		N	30	799	1,902	2,701	2,507	5,238
Retrograde chol-angiography (ERCP)	60	N_a	1	15	36	51	48	100

X-RAY EXAMINATIONS IN PAEDIATRICS AND GERIATRICS

Table 3. Continued

X-ray examination	A	Age group					All ages	
		(0-14)	(15-39)	(40-64)	(15-64)	(65+)		
Biliary drainage	61	N_p	0.02	0.32	0.84	0.57	2.3	0.74
		R	0.04	—	—	1.00	4.12	—
		N	30	90	311	401	436	867
		N_a	3	10	36	46	50	100
Abdominal embolisation	61	N_p	0.02	0.04	0.14	0.08	0.41	0.12
		R	0.28	—	—	1.00	4.83	—
		N	8	26	89	115	125	248
		N_a	3	10	36	46	50	100
Chest angiography	61	N_p	0.01	0.01	0.04	0.02	0.12	0.03
		R	0.28	—	—	1.00	4.83	—
		N	—	200	541	741	690	1,431
		N_a	—	14	38	52	48	100
Coronary angiography	63	N_p	—	0.08	0.24	0.15	0.64	0.20
		R	—	—	—	1.00	4.13	—
		N	33	730	9,038	9,768	9,414	19,215
		N_a	0	4	47	51	49	100
Coronary dilatation (PTCA)	63	N_p	0.03	0.29	4.0	2.0	8.7	2.7
		R	0.01	—	—	1.00	4.28	—
		N	29	245	4,615	4,860	4,803	9,692
		N_a	0	2	48	50	50	100
Hip radiography	64	N_p	0.02	0.10	2.0	1.0	4.5	1.4
		R	0.02	—	—	1.00	4.39	—
		N	7,035	9,554	22,839	32,393	61,135	100,562
		N_a	7	9	23	32	61	100
Cerebral angiography	64	N_p	5.7	3.8	10	6.8	57	14
		R	0.84	—	—	1.00	8.38	—
		N	—	93	835	928	1,100	2,028
		N_a	—	5	41	46	54	100
Upper limb angiography	65	N_p	—	0.04	0.37	0.19	1.02	0.29
		R	—	—	—	1.00	5.26	—
		N	3	78	310	389	563	954
		N_a	0	8	33	41	59	100
Abdominal angiography	66	N_p	0.002	0.03	0.14	0.08	0.52	0.13
		R	0.03	—	—	1.00	6.43	—
		N	23	243	1,878	2,121	3,354	5,498
		N_a	0	5	34	39	61	100
Lower limb angiography	69	N_p	0.02	0.10	0.83	0.44	3.1	0.77
		R	0.04	—	—	1.00	7.02	—
		N	11	152	1,329	1,481	3,287	4,780
		N_a	0	3	28	31	69	100
Femoral dilatation	71	N_p	0.01	0.06	0.59	0.31	3.0	0.67
		R	0.03	—	—	1.00	9.85	—
		N	3	19	664	683	1,823	2,509
		N_a	0	1	26	27	73	100
Pacemaker insertion	74	N_p	0.003	0.008	0.29	0.14	1.7	0.35
		R	0.02	—	—	1.00	11.85	—
		N	52	125	235	360	2,785	3,197
		N_a	2	4	7	11	87	100
		N_p	0.04	0.05	0.10	0.07	2.6	0.45
		R	0.55	—	—	1.00	34.28	—

A: mean value of the age distribution

N: number of examinations performed annually in Switzerland (or Swiss population) within the corresponding age group

N_a : fraction (%) of the number of examinations for the corresponding age group

N_p : number of examinations per 1000 population of the corresponding age group

R: N_p for the corresponding age group/ N_p (15-64).

number varies between 0 or almost 0 for some modalities such as mammography, conventional tomography and bone densitometry and 0.9 for conventional fluoroscopy, where children seem to be almost equally exposed to X-ray examinations as adults.

From Table 1 it is possible to define two broad groups of common X-ray examinations with simple rounded values of the relative numbers of examinations for paediatric and geriatric patients, as shown in Table 2. For group A (radiography, conventional fluoroscopy and computed tomography), a paediatric patient undergoes half the number of examinations as that of an adult one, while a geriatric patient undergoes 2.5 times more. For group B (angiography, interventional radiology), the differences are doubled, since a paediatric patient undergoes one-fourth the number of examinations as that of an adult one, while a geriatric patient undergoes five times more.

Table 3 presents the same information given in Table 1 for 40 types of X-ray examinations (dental and medical, diagnostic and interventional). The types of examinations are sorted by ascending average age.

The series shown in Table 3 extends from what can be considered as mostly paediatric examinations such as micturating cysto-urethrography, a ratio of 30:1 paediatrics/adults in this study, to what can be seen as mostly geriatric examinations such as pacemaker insertion (more than 30 examinations on the elderly for one examination on adults). In most cases, paediatric patients undergo fewer X-ray examinations than adult patients who themselves undergo fewer X-ray examinations than geriatric patients, except for a limited number of cases. For four types of examinations (10% of the total), micturating cysto-urethrography, skull radiography, hand radiography and barium meal, paediatric patients undergo more X-ray examinations than adult patients, whereas for four other types of examinations (10% of the total), bitewing radiography, orthopantomography (OPG), cervical spine radiography and cerebral embolisation, geriatric patients undergo fewer X-ray examinations than adult patients.

CONCLUSION

The relative number of X-ray examinations performed on paediatric and geriatric patients, compared

with adult patients, was established using patient age distributions and that of the general population. This number was determined for 8 radiological modalities and 40 types of X-ray examinations covering medical and dental radiology. It was found that in most cases an adult patient undergoes more examinations than a paediatric patient and less than a geriatric patient. Two broad groups of examinations may be defined. The first one includes conventional radiography, fluoroscopy and computed tomography, while the second comprises angiography and interventional radiology. For the first group an adult undergoes twice as many examinations as a child and 2.5 times less than an elderly patient. For the second group, consisting of dose-intensive examinations, the difference is even larger, since an adult undergoes four times more examinations than a child and one-fifth the number of examinations performed on an elderly patient.

REFERENCES

- Bernhardt, J. H., Veit, R. and Bauer, B. *Radiation exposure of the German population from X-ray diagnostic procedures*. In: Proceedings of the Ninth Congress of the International Radiation Protection Association 3, Vienna, pp. 383–385 (1996).
- Shrimpton, P. C., Wall, B. F., Croft, J. R. and Webb, G. A. M. *Medical Exposure: Guidance on the 1990 Recommendations of ICRP*. In: Documents of the NRPB: Occupational, Public and Medical Exposure 4(2), Didcot (1993).
- United Nations Scientific Committee on the Effects of Atomic Radiation. *2000 Report to the General Assembly, Annex D: medical radiation exposures*. (NY: UN) (2000).
- Aroua, A., Burnand, B., Decka, I., Vader, J. P. and Valley, J.-F. *Nation-wide survey on radiation doses in diagnostic and interventional radiology in Switzerland in 1998*. Health Phys. **83**(1), 46–55 (2002).
- Aroua, A., Burnand, B., Decka, I., Vader, J. P. and Valley, J.-F. *Dosimetric aspects of a national survey of diagnostic and interventional radiology in Switzerland*. Med. Phys. **29**(10), 2247–2259 (2002).
- Aroua, A., Vader, J.-P. and Valley, J.-F. *A survey on exposure by diagnostic and interventional radiology in Switzerland in 1998*. Institut Universitaire de Radio-physique Appliquée, Lausanne. Available on: www.hospvd.ch/public/instituts/ira. (2000).
- Service cantonal de recherche et d'information statistique. *Annuaire statistique du Canton de Vaud*, Lausanne (1999).