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OCCUPATIONAL EXPOSURE IN OPERATIONAL RADIOLOGY

BOŻENNA NOWAK and JERZY JANKOWSKI

Department of Radiation Dosimetry, Institute of Occupational Medicine, Lodz, Poland

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Abstract. Measurements of dose-rate on the body surface of workers engaged in operational radiology permit the assessment of average annual effective dose equivalent, and dose equivalents in eye lenses and in hands. Measurements were made in 20 hospitals in the course of different operations in which x-radiation was used. Individual values of annual effective dose equivalent ranged from about 0.1 to about 45 mSv. In the majority of cases this did not exceed 5 mSv at the current workload. For the eye lens, the respective dose equivalent range was from 0.01 to about 70 mSv; only in one case, due to the engagement of a totally inappropriate operating procedure, could the eye dose reach 1.9 Sv per year. The individual values of the dose equivalent to hands ranged from 0.5 to 140 mSv.

INTRODUCTION

Personal dosimetry in Poland indicates that the exposure to x-rays of workers engaged in operational radiology is higher than that observed among other radiologists and auxiliary personnel. An average dose equivalent, calculated from the results of the individual dose measurements done in 1985–1989, is 0.83 mSv per capita per annum for operational radiology workers, and 0.35 mSv per capita per annumm for the total monitored population. This information, however, does not provide enough detailed insight into the peculiarities of exposure.

METHOD OF MEASUREMENT

In order to estimate the real exposure of the personnel engaged in operations where x-rays are used, the exposure rate on the body surface of the

Address reprint requests to B. Nowak, Department of Radiation Dosimetry, Institute of Occupational Medicine, P.O. Box 199, 90-950 Lodz, Poland

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participants was measured. These measurements were made in 20 hospitals during the following operations:

- cardiac pacemaker insertion – 5 hospitals (I–V)
- haemodynamic examination of the heart – 3 hospitals (VI–VIII)
- extracorporeal lithotrypsy – 1 hospital (IX)
- transcutaneous removal of kidney stone – 5 hospitals (X–XIV)
- radiological control of biliary routes – 3 hospitals (XV–XVII)
- orthopaedic surgery – 3 hospitals (XVIII–XX).

The individuals taking part in the operations were dressed in special coats in which thermoluminescent dosemeters were placed. Due to the sensitivity of TL dosemeters, the coats were worn on the top of protective lead aprons. It allowed the measurements to be made quickly and the adequate estimation of the exposure in the case where the lead aprons would not be used. The TL dosemeters were distributed at the front of the trunk at regular distances of 20 cm in three vertical lines and four horizontal rows. At the back of the trunk TL dosemeters were placed along the central line of the body also at 20 cm distances. Additional dosemeters were placed on the forehead, on the wrist and the shoulder, and on the chest (on the site where the film badge is normally worn). There were three TL dosemeters at each point of the measurement.

Doses recorded during a single operation are often lower than the sensitivity threshold of the measurement method. In order to obtain measurable values i.e. higher than background, the same sets of TL dosemeters were used during a sufficient number of operations. Calibration of the dosemeters was made with known doses, using x-rays of the same quality as those applied in the operating theatre. On the basis of readings of the dosemeters, an average value of the dose at each point was determined. In order to compare the results obtained in different hospitals the average dose at each point was divided by total time of exposure.

These measurements were performed during 228 operations or examinations. In the majority of cases 3 persons were subjected to the measurements: an operating physician, an assistant physician and a nurse. Only during haemodynamic examinations of the heart and during the course of orthopaedic operations made in one hospital did the measurements involve two persons only: a physician and a nurse.

RESULTS

In all hospitals the operating physician was the one who received the highest doses. This is understandable because the operating physician was – as a rule – positioned next to an x-ray tube. The remaining participants stayed farther away from the source of radiation or sometimes even left the room during exposure.

The dose-rate distributions on the body surface obtained in particular hospitals were similar to those received in our earlier study on the relationship between the effective dose equivalent and the exposure measured by the

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dosimetric film placed on the chest. It was found that the ratio of those two quantities was 0.005 mSv/mR (1). Taking into consideration the above value, the annual effective dose equivalent for the studied workers was estimated. The value was calculated on the basis of the average surface exposure rate measured, at the site where the personal film badge was worn, x-ray emission time for a given procedure in particular hospitals and an average annual number of operations performed by a single worker. It was assumed that the average number of operations performed by one operator per year was 150 in the case of cardiac and urological, and 50 in the case of other examinations.

TABLE 1. Annual effective dose equivalent.

Type of procedure	No of hospital and number of operations	Annual effective dose equivalent (mSv)		
		operating physician	assisting physician	nurse
Cardiac pacemaker insertion	I – 36	1.11	0.23	0.11
	II – 13	18.00	7.02	9.59
	III – 6	3.66	1.78	0.56
	IV – 15	4.46	1.61	0.89
	V – 7	4.45	0.86	0.66
Haemodynamic examination of the heart	VI – 3	23.1	–	0.71
	VII – 5	3.67	–	0.76
	VIII – 10	13.6	–	0.12
Extracorporeal lithotrypsy	IX – 12	0.13	0.11	0.16
Transcutaneous removal of kidney stones	X – 10	1.71	0.03	0.35
	XI – 17	1.71	0.13	0.16
	XII – 8	3.53	1.18	0.18
	XIII – 18	5.92	1.91	0.02
	XIV – 1	44.0	35.2	1.85
x-ray control of biliary routes	XV – 2	2.22	0.54	0.04
	XVI – 11	0.16	0.04	0.04
	XVII – 16	0.09	0.07	0.17
Orthopaedic surgery	XVIII – 3	17.9	5.76	2.03
	XIX – 5	3.9	5.69	1.09
	XX – 30	33.0	0.09	–

The values of the estimated annual effective dose equivalents are presented in Table 1. The individual values range from about 0.1 to about 45 mSv. In the majority of cases, at the current workload, the value did not exceed 5 mSv per year. (Annual limit of effective dose equivalent is 50 mSv (2)).

It is also important to remember that measurements were made on the surface of a protective apron equivalent to 0.25 mm Pb. It is well known that

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TABLE 2. Annual dose equivalent to the eye lens.

Type of procedure	No of hospital	Annual dose equivalent to the eye lens (mSV)		
		operating physician	assisting physician	nurse
Cardiac pacemaker insertion	I	0.47	0.21	0.26
	II	41.5	21.1	14.9
	III	4.06	3.04	1.42
	IV	1.47	0.49	1.63
	V	2.81	2.34	0.57
Haemodynamic examination of the heart	VI	10.4	–	3.68
	VII	2.76	–	5.52
	VIII	26.7	–	5.63
Extracorporeal lithotrypsy	IX	0.1	0.19	0.24
Transcutaneous removal of kidney stones	X	4.48	0.01	0.86
	XI	0.39	0.24	0.15
	XII	4.51	0.03	0.49
	XIII	10.2	4.3	0.23
	XIV	1890.0	156.0	1.81
x-ray control of biliary routes	XV	2.61	0.42	0.13
	XVI	0.26	0.02	0.13
	XVII	0.16	0.16	0.32
Orthopaedic surgery	XVIII	33.8	12.3	8.89
	XIX	5.36	6.02	2.71
	XX	65.8	0.22	–

an 0.25 mm layer of lead reduces the dose by a factor of 10 to 30. Thus, if a lead protective apron is used, the real value of annual effective dose equivalent will be at least 10 times lower than those mentioned above.

A similar procedure was applied to estimate the annual dose equivalent to the eye lens, and the hands. The values of dose absorbed in the lens of eyes and hands were calculated using the method given by Kramer and Drexler (3). In this calculation, the difference between the absorption coefficient in the soft tissue, and in the air, was taken into account (4). The calculation was made for the quanta energy range 20 to 100 keV.

The values of estimated annual dose equivalent to the eye lens and hands are presented in Tables 2 and 3, respectively.

Individual values of annual dose equivalent to the eye lens ranged from 0.01 to about 70 mSv per year. In most cases the doses to the eyes constituted only a fraction of current annual limit, i.e. 150 mSv (2). Only in one case, due to

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TABLE 3. Annual dose equivalent to hands.

Type of procedure	No of hospital	Annual dose equivalent to hands (mSV)		
		operating physician	assisting physician	nurse
Cardiac pacemaker insertion	I	1.46	0.26	0.21
	II	–	–	–
	III	15.8	8.31	0.81
	IV	24.8	2.45	10.9
	V	20.5	1.15	0.89
Haemodynamic examination of the heart	VI	136.0	–	2.6
	VII	54.1	–	1.76
	VIII	43.2	–	1.84
Extracorporeal lithotrypsy	IX	0.05	0.24	0.29
Transcutaneous removal of kidney stones	X	7.77	0.16	0.7
	XI	0.54	0.2	0.2
	XII	11.8	0.85	1.13
	XIII	8.09	2.35	0.01
	XIV	74.4	128.0	6.98
x-ray control of biliary routes	XV	1.37	2.5	0.21
	XVI	1.33	0.18	0.24
	XVII	0.44	0.38	0.5
Orthopedic surgery	XVIII	5.52	19	5.87
	XIX	6.47	28.2	0.99
	XX	20.5	0.09	–

a totally inappropriate operating procedure applied, could the eye dose reach 1.9 Sv per year for the operating physician and 0.16 Sv per year for the assisting physician. In order to reduce the exposure of workers this procedure was immediately modified.

Individual values of annual dose equivalent to hands ranged from 0.5 to about 140 mSv per year and were much lower than the annual limit, i.e. 500 mSv (2).

The estimated dose equivalent reflects to a large extent the function performed by individuals. In all hospitals the operating physician was the most highly exposed person. The magnitude of exposure reflects also the adopted operational technique, the quality and characteristics of x-ray equipment and physical parameters applied, such as the anode current, high voltage and x-ray beam dimensions. There is no doubt that some further reduction of the exposure via improvement of these factors is still possible. On average, the workload could be substantially increased without approaching current dose limits.

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