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Occupational Exposure in Medicine

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1. Introduction

In the "early days" of medical application of ionizing radiations, reports on serious somatic effects in radiologists and radiographers were very numerous. In addition, late effects have been demonstrated in several studies which were carried out.

Certainly, the situation today bears no comparison. The first major step forward was the "invention" of the individual dosemeter (around 1923). Since that time consciousness and awareness have improved consistently; recommendations and limiting values have been published and introduced.

2. Designation of Workers

In most European countries if an employee is "likely to receive a dose of ionizing radiation which exceeds three tenths of any relevant dose limit" then he/she must be designated as a "classified person". Such a person must be subject to medical surveillance with periodic reviews of health at least every 12 months, the records of which must be kept for at least 50 years. In addition, the employer must also arrange for the radiation doses to be measured regularly and again for the records to be kept for at least 50 years.

However, this does not mean that persons who are not classified should not have dose records and medical records. There is simply no legal requirement to do so. In reality, regular monitoring of those who are not classified is the best way to justify the lack of designation.

Any employer, whether classified or not, whose annual dose exceeds 3/10 of the limit is generally subject to an investigation to see if the working practices involved are in keeping with the ALARA principle or whether improvements can be made which would lead to lower doses.

3. Personnel Monitoring

Regular monitoring of the radiation doses received by personnel is not only important from the individual's point of view, but may also yield important information on procedures adopted by that individual in everyday practice. The main method by which personnel monitoring has been carried out hitherto is by the use of film badges. These incorporate plastic, tin and aluminium filters so as to allow the type of radiation to be distinguished. Unfortunately, photographic film cannot be re-used and the data obtained is necessarily retrospective and may be difficult to relate to the event which caused it.

An alternative approach using thermoluminescent dosemeters obviates many of the disadvantages of the film badges. Amongst the advantages are the availability of specialized dosimeters, eg. for finger doses and the fact that the technique is easy to be computerized. However, the information is still retrospective.

When a prompt measurment of dose is required, pocket dosimeters are available, usually based on small GM tubes. When the dose rate exceeds some pre-set value a warning noise is emitted and the person is able to take prompt action. The more expensive models also record the dose received and display it in a digital form.

4. Actual situation

The number of occupationally exposed persons now constitute an appreciable part of the working population. A survey of the European countries, USA and Japan indicates similar situations in this respect.

In highly industrialized countries nearly half a percent of the population is monitored in connection with their employment. About 50% of the radiation workers are in the medical area.

Surveys carried out in W. Germany in 1987 showed, that in spite of the large number of people monitored in medical working places, the contribution to the collective dose was less than 20% . General X-ray and Nuclear Medicine practitioners together contribute approximately one-third of the doses received though employment in the medical areas.

It is important to consider the different approaches of personnel monitoring in medicine as compared to industrial applications. In medicine most people wear personal dosemeters to demonstrate that they are not exposed, while in industry the problem is more of complying with the radiation limits in each area.

5. X-Ray Diagnosis

In industrialized countries occupational doses can be considered "under control" for all kinds of traditional investigations. In 1987 in 3 regions of W. Germany the mean annual effective dose for all persons monitored (85,000) was 0.44 mSv and 2.56 mSv for those receiving at least a measurable dose in a calendar year (15,000). The number of people dealing with ionizing radiations was 55,000 and only 7,000 had measurable doses in a calendar year, with mean effective dose 0.15 mSv averaged over all and 1.19 mSv averaged over exposed persons only.

In the US in 1980, 584,000 medical staff were exposed to a mean effective dose = 0,7 mSv . For staff with recorded doses, the average was 1.5. mSv. Cardiologists formed the higher exposure group with up to 18 mSv.

Personal dosemeters should be worn at the place which gives the best indication of average exposure. For the whole body this is generally taken to be the upper trunk facing the incident radiation. Sometimes this is not applicable. In addition the "assumption" that the upper trunk is "representative" for total body is often overestimated.

Radiation may not only arise in AP directions. For this reason a detailed workplace analysis is essential for every worker, with particular attention being paid to the "geometry " of the beam, work load, weighting factors, eventual shieldings etc.

In terms of stochastic risks professional exposures were estimated around $1.65x10^4$ fatalaties x Sv of effective dose equivalent (nearly within the range of variation of the natural background).

In spite of all the good efforts and successful attempts made in industrialized countries to make radiation protection more effective and reduce individual dose almost to "zero", still remains the problem of the hands and unshielded parts (eyes etc.) in fluoroscopic examinations.

Of the personnel monitored with finger dosimeters, the exposures measured are 15-40 times higher than the mean personal dose. This impose the real limit to the number of investigations caried out by the physician.

Data on the hand doses cannot be generalized because they are very dependent on the measurement conditions (tube current, field-size, direction of beam, distance), and the movement of the hands. At best the data may be considered as orientating values and can serve as dose limit for a particular group of physicians.

While in radionuclide manipulation it is clear that the fingertips are the most exposed, in X-ray fluoroscopy, there are still different opinions about where the dosemeter should to be worn.

Finger rings are not convenient and might be disturbing in delicate work, raise sterility problems in operating theatres and damage gloves; therefore it is sometimes advisable to use wrist dosemeters. Finger and wrist measurements are generally correlated, however, in some procedures for example in angiography, the hands may be under the direct beam, and the wrist outside, leading to a gross underestimation of dose.

6. Diagnostic use of radioisotopes

Data on occupational doses in this field are scarce, as in published reports very often no distinction is made between X-ray diagnosis and nuclear medicine. The effective doses are relatively small, but doses to hands may approach the limits.

As a result, in nuclear medicine the use of finger dosemeters is essential and "easy", without the above mentioned problems of fluoroscopy.

Care has to be taken to avoid possible internal contamination and regular checks organized, but there is insufficient data on this point.

7. Radiotherapy

In industrialized countries occupational exposure in Radiotherapy is usually low due to the care taken in the design of departments.

In the UK in 1986 the mean effective dose was 0.41 mSv, about 1.5% of the staff had doses exceeding 5 mSv and 0.5% exceeded 15 mSv.

The main area of concern is brachytherapy; hand and finger doses are critical during insertion and removal of sources, relatively high doses may be received by nursing staff looking after the patient.

Afterloading systems have cut the doses by an order of magnitude - but unfortunately they are not common in all developing countries.

Data on doses received from radiotherapy use of unsealed sources is again scarce.

In Holland a study conducted for I^{131} therapy quotes very low effective dose (about 0.1 mSv per year) but this may not be representative as the center studied was extremely well organized with the constant presence of a medical physicist.

8. Conclusions

In diagnostic applications the total body radiation doses are not "critical". However, it is always necessary to evaluate the workplace carefully and estimate the possible exposure on the basis of the workload, geometry and technical parameters.

Special attention should be paid to the irradiation of the hands in any procedure requiring manipulation of the patient; other parts of the body (eyes etc.) can be protected.

Even though the trends of individual doses are in general decreasing because of better radiation protection, the development of new techniques (angioplasty etc.) has led to different critical groups of workers.

New technologies, rare earth, image intensifiers and pulsed fluoroscopy can reduce the dose considerably.

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

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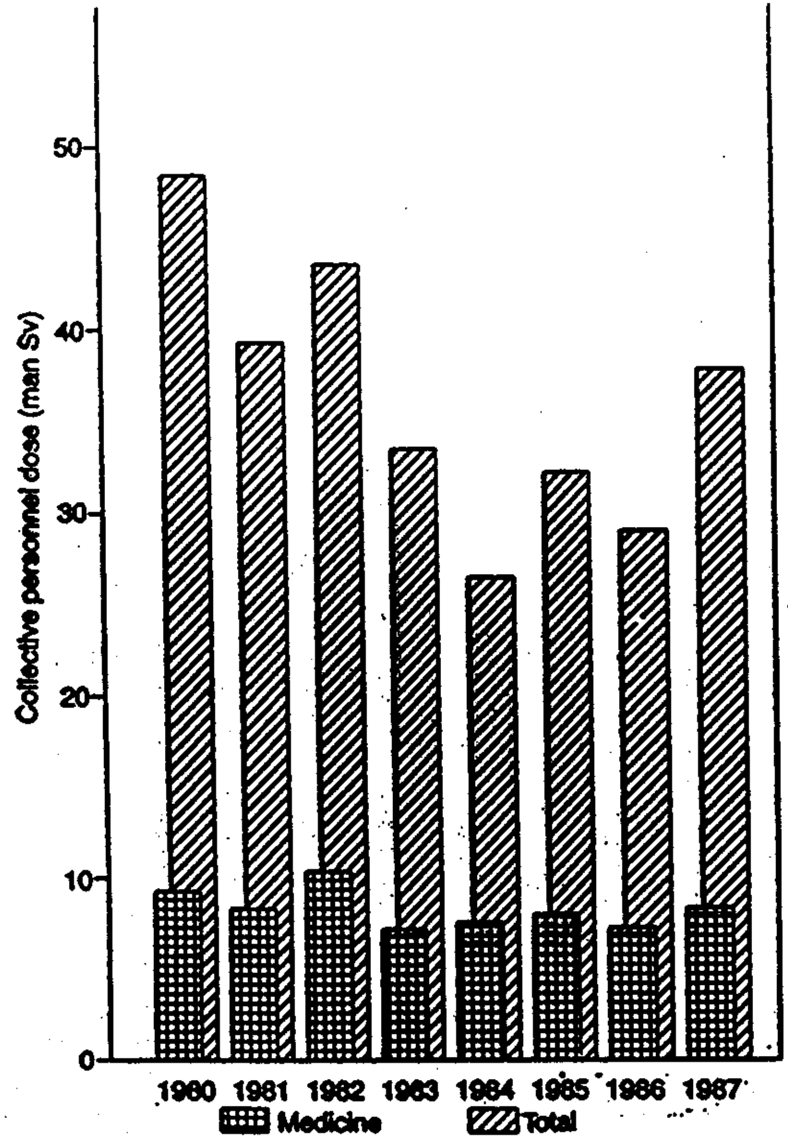

Figure 1. Collective personnel dose 1980 – 1987 (three states of the FRG; about 85,000 people monitored).

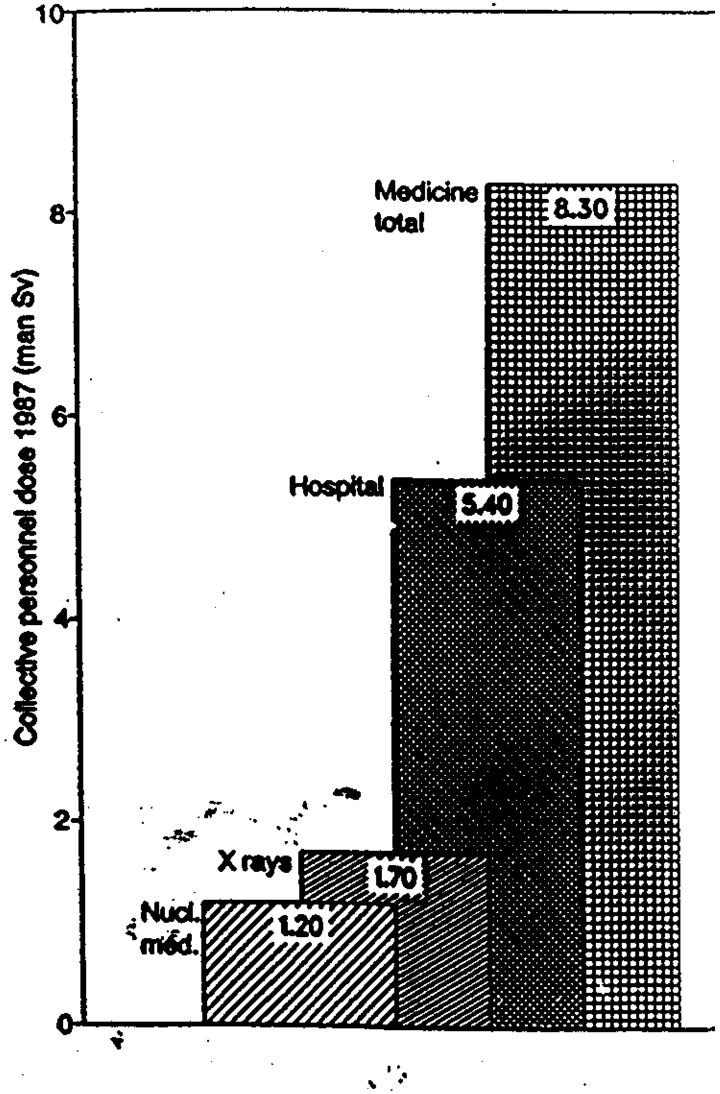

Figure 2. Collective personnel dose 1987 in the mec sector (three states of the FRG).

Table 1. Number of persons monitored for occupational exposure (1985).

Member state	Approximate number of persons monitored				
	Medical	Research and teaching	Nuclear industry	Other industry	Total
Belgium	12,000	8,500	3,400	6,500	30,400
Denmark	5,700		1,900		7,600
France	70,000	8,000	55,000	22,000	155,000
Germany	140,000				230,000
Greece	3,600	500		500	4,600
Ireland	1,600	300		600	2,500
Italy					100,000
Luxembourg	500			400	900
Netherlands	14,000	5,000	2,000	5,000	26,000
Portugal	3,500	500	500	1,000	5,500
Spain					34,000
United Kingdom	50,000	12,000	50,000	15,000	127,000
Total					723,500
Japan*	110,000	30,000	50,000	30,000	220,000
USA**	792,000		145,000	383,600	1,320,000

* Private Communication, Numakunai (1987).
** EPA 84.

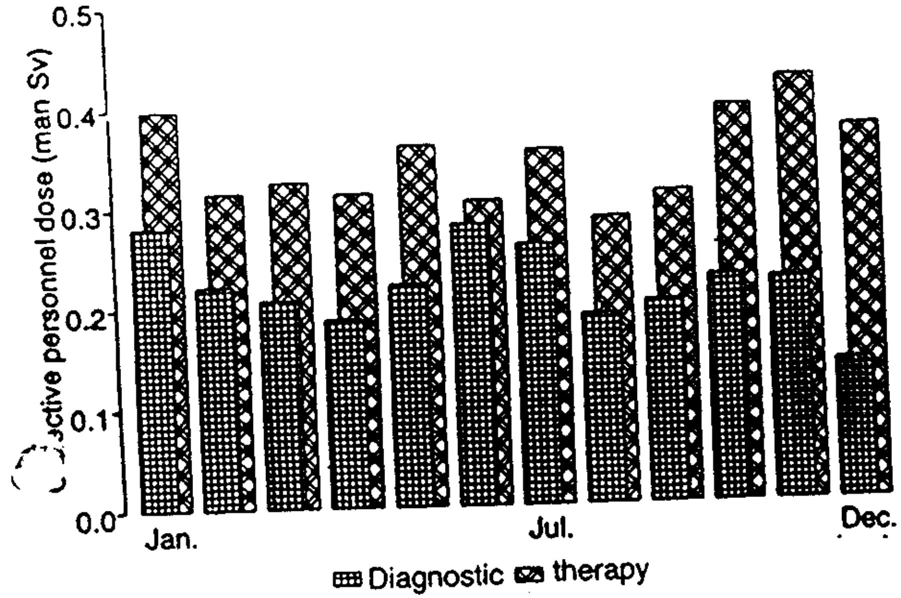

Figure 3. Collective personnel dose 1987 from diagnostic and therapy (three states of the FRG).

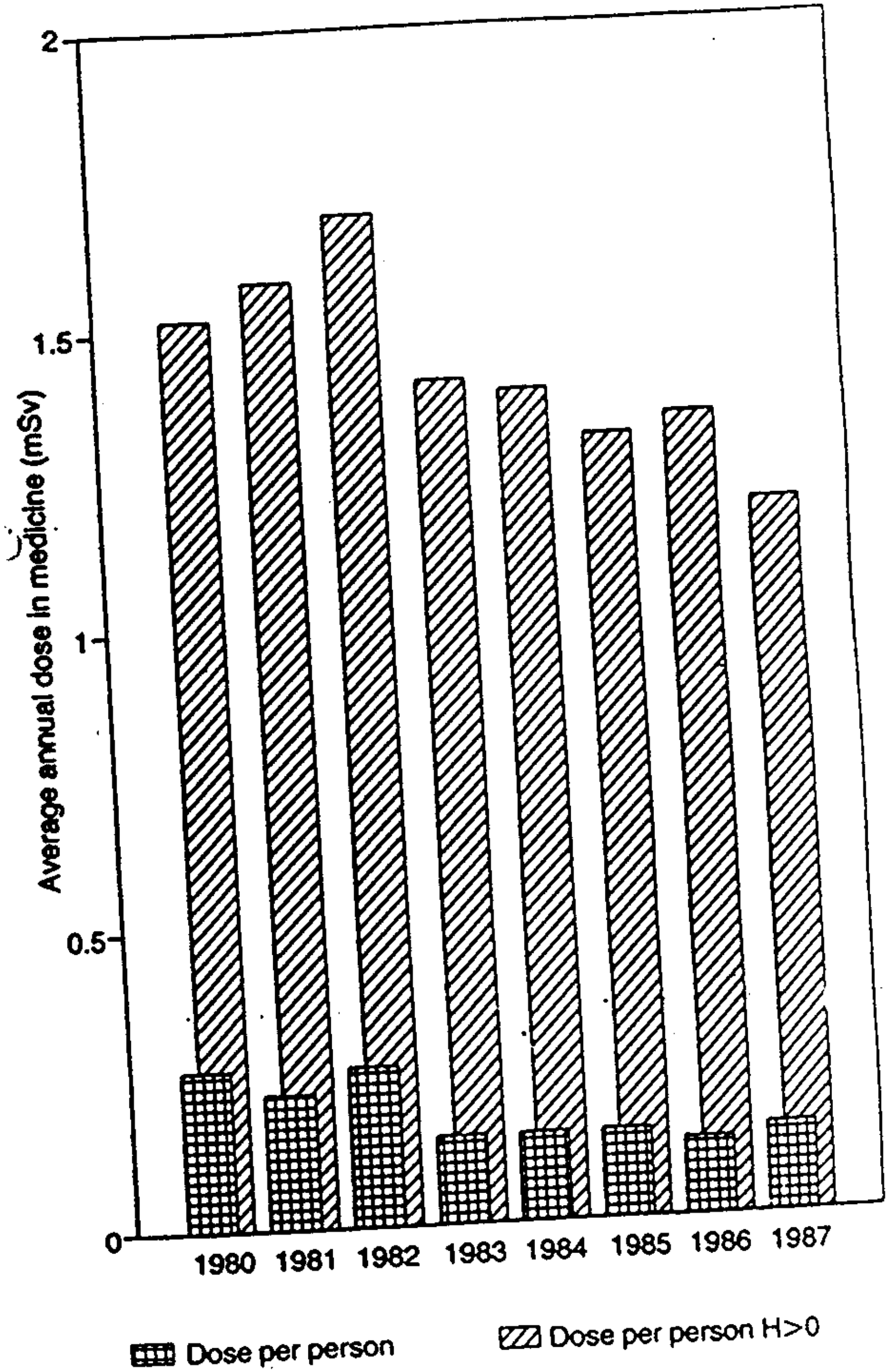

Figure 4. Average annual dose in medicine 1980 – 1987 (three states of the FRG).

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	21493 [b]	262	2439	24194
			0.2-5.0	3282 [b]	364	850	4495
			5.1-15.0	16 [b]	20	103	139
			15.1-50.0	0	2	0	3
			> 50	0	0	0	0
France	1988	[P4]	0-0.19	44210	3988	3873	
			0.2-5.0	3305	757	380	
			5.1-15.0	363	65	23	
			15.1-50.0	113	22	6	
			> 50	17	1	0	
Germany [c]	1985-1986	[R12,R13]	0-5.0	40332	2184	1703	50229
			5.1-15.0	68	70	15	166
			15.1-50.0	12	7	0	28
			> 50	0	0	0	0
Germany [d]	1986	[B21]	0-0.2				165421
			0.21-5.0				13628
			5.1-15.0				411
			15.1-50.0				76
			> 50				16
Sweden	1988	[K6]	0-0.09				6901
			0.1-5.0				4004
			5.1-10.0				24
			10.1-20.0				1
			20.1-50.0				2
			> 50				3
United Kingdom	1986	[H10]	0-5.0	10212	3766	2667	
			5.1-15.0	14	56	5	
			15.1-50.0	0	4	0	
			> 50	0	0	0	