Rad Hrvatske akad znan umj med [469] XXVIII (1996), 79–86

VLADIMIR LOKNER, ZVONKO KUSIĆ

Department of Oncology and Nuclear Medicine, "Sestre Milosrdnice" University Hospital, Zagreb

ESTIMATE OF AN AVERAGE OCCUPATIONAL DOSE FOR WORKERS IN A NUCLEAR MEDICINE DEPARTMENT

Dose limits for professional exposure recommended by the International Commission on Radiological Protection (ICRP) were in 1990 set to 20 mSv y^{-1}, to be averaged over a period of five years with no more than 50 mSv in a single year ICRP has also re-confirmed that the dose limit for the public should be 1 mSv y^{-1}, averaged over five years[1] This new recommendation for professional exposure is described as an evolution of the 1977 dose limit of 50 mSv y^{-1}[2] The limit was adjusted due to the accumulation of results from 11 years of intensive nuclear bombs survivors studies as well as the analysis of long-term effects of radiation used in medical treatments. New estimates for the level of risks from low dose irradiation of fatal cancers and genetic effects have been raised by about a factor of four[3,4]

The ICRP recommendations provide the framework for radiological protection Although they have no legal status, most national and international regulatory agencies base their own regulations and standards of good-practices on them Impending changes in the Croatian dose limitation system should certainly reflect new ICRP recommendations Therefore, the implication of lowered annual dose limits for professional exposure should be considered for a typical nuclear medicine department where they could have an impact on radiation protection, organization of work and medical practices.

Past personal dosimetry records for the workers at the Department of Oncology and Nuclear Medicine, "Sestre Milosrdnice" University Hospital from Zagreb were reviewed to assess the situation and trends

In individual dosimetry, the main aim of monitoring is control and book-keeping of the doses a person has received The measured absorbed dose is the fundamental quantity in radiation protection However, it is the weighed absorbed dose that is of interest in controlling radiation exposure. It is not easy to correlate a straightforward physical quantity such as the absorbed dose (measured value due to radiation field in single point) with the traditional concept of dose equivalent of newly introduced equivalent dose[1] as useful operational quantities describing biological effects of a particular type and energy of radiation However, since most of the radiation field in a nuclear medicine department is a relatively constant external diffuse gamma radiation, it could be assumed that a personal dosimeter measures a dose equivalent value at a point in the body near to the position where the dosimeter is worn If the dosimeter is worn at a representative position, the measured absorbed dose value could be simply converted and taken to be the upper limit or an approximation of the effective dose received by the wearer[5]

DOSE DATA

The Department of Nuclear Medicine and Oncology, "Sestre Milosrdnice" University Hospital, performs all common nuclear medicine diagnostic and therapeutic procedures in accordance with standard rules or recomendations for *per* patient quantities of radioactive material The volume of work could be described through the daily used total activity of material, which varied during years, but on an average it could be estimated to be in the range of 14 8 - 22 2 GBq (400-600 mCi), mostly technetium-99m and iodine-131

The work is organized in such a way that various tasks related to preparation and administration of radioactive material (eluation from the radionuclide generators, dispensing and injection) are spatially separated according to the complexity and/or activity handled Standard procedures for safe handling of radioactive material and radiation protection measures are respected Additionally, the time spent in the zone with elevated level of ionizing radiation is limited to 4 hours daily

The Department for Radiation Protection, Institute for Medical Research and Occupational Medicine of the Zagreb University is responsible for personal film dosimetry of all the workers The sensitivity threshold of the standard film dosimeters used is 500 μGy

Film dosimetry data reviewed cover the period of 7 years (from 1986 to 1992) for 63 workers, most of whom worked at the Department all the time (apart from holidays) Each year was divided into 12 control intervals, roughly corresponding to the months of the year This study was based on approximately 3800 man-control interval values

For the purpose of this analysis, the workers were divided into three groups (1) eluation from generators and preparation of iodine therapies (total of 28 workers, mark **gen**), (2) injection of radiopharmaceuticals, positioning of patients and operations with measuring instruments (24, **dia**), (3) control, cleaning and administrative tasks (11; **adm**) The study period was enough to assume that the time spent at the workplace and/or number of handled patients were averaged and thus the same for all the workers within a group

RESULTS

Ten percent of all of the measured values of absorbed doses were above the film dosimeter threshold sensitivity It has been suggested that the distribution of occupational doses generally follows a long-normal form[2,3] If so, the missing part of the distribution would have suggested that almost 40% of all the doses were not registered at all, although they could be relevant for the analysis of the average or collective doses (Figure 1) Those ≈ 1500 missing dose values represent roughly a 300 mSv addition to the collective dose, since occupational irradiation, in the case of nuclear medicine, is prevalently of a systematic nature and not the result of accidents or unusual conditions

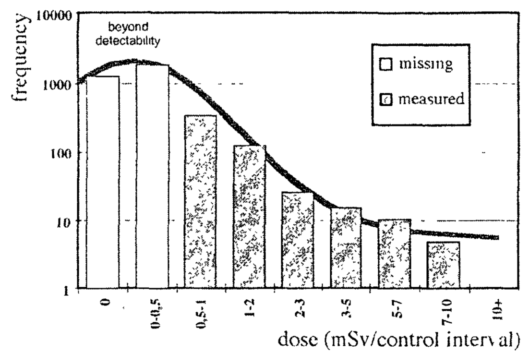

FIGURE 1 Distribution of measured dose values

This was also seen when the median dose for all received doses was determined for each individual (as the most representative for an individual over a prolonged period of time) and the corresponding distribution of calculated values plotted (Figure 2) The point representing 15 individuals with no measured dose was added to the distribution The shape of the curve suggests that higher doses *per* interval were sporadic and quite rare, and therefore they could not be attributed to a particular task or workplace If the values for missing doses were introduced in this type of data presentation, distribution would probably be of the same shape but shifted to the left, towards lower doses The maximum of such a curve, where all the received doses were taken into account, would be a better indicator for a typical dose *per* control interval for the population as a whole than simple data averaging

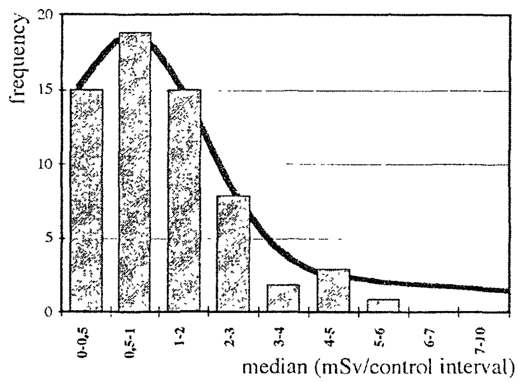

FIGURE 2 Distribution of individual median dose values

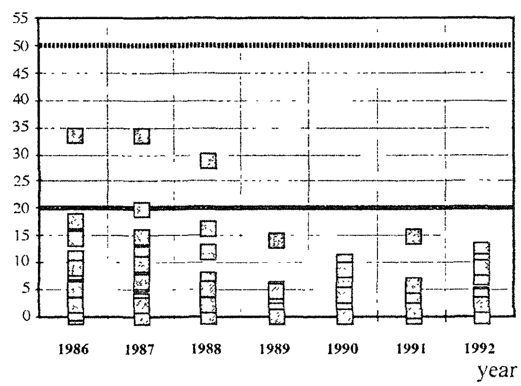

FIGURE 3 Annual doses for 11 workers and dose limits

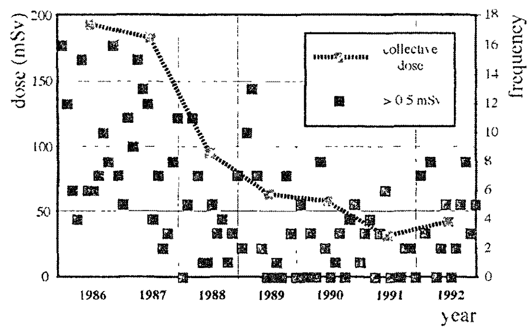

FIGURE 4 Annual collective dose and number of workers with more than 0 5 mSv per control interval

For 11 individuals from the right tail of the median distribution (most likely candidates to approach new dose limits), values of the measured annual doses over the years were plotted (Figure 3) Although an alarming possibility of approaching and even exceeding new dose limits in some of the workers seemed apparent, general behavior of the population (e g , through approximate collective dose) (Figure 4) clearly indicated that improvements in the radiation protection introduced at the department in 1988 and 1989 considerably reduced the overall irradiation This and a slight decrease in the number of patients passing through the department in recent years, have significantly lowered the probability of approaching the 20 mSv y^{-1} dose limit

Intergroup differences using group average as an indicator, are presented in Figure 5.

DISCUSSION

It is clear that most doses were delivered to **gen** and **dia** groups So, in the estimation of a representative approximation of the average occupational dose for the department, it appeared justified to exclude the **adm** group members. However, although having considerably lower doses than the **gen** and **dia** groups, the **adm** group members could not be treated as members of the general public because (a) on several occasions, and for several workers, doses above 0 5 mSv/control interval were observed, (b) some **adm** jobs at a nuclear medicine department could not be entirely separated from "hot" zones; and (c) theoretically, due to a very high sensitivity threshold, the members of this group could receive a notable dose of just under 6 mSv y^{-1} without detection!

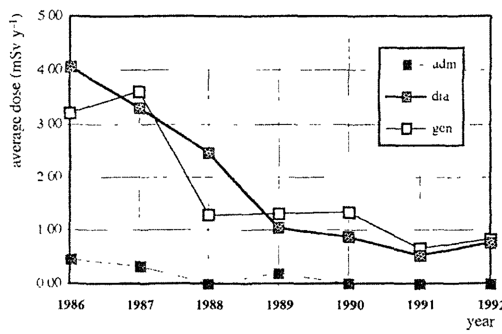

FIGURE 5 Annual average doses for three groups of workers
(**adm** - control, cleaning and administration, **dia** - injecting and patient positioning, **gen** - eluation from generators)

Also, it should be stressed that considerable intragroup differences were recorded (e g , in **dia** group, one individual average was 5-fold the group average due to systematically higher doses). Differences among workers were due to various reasons, mostly the type of workplace (type of duties and background radiation), but part of the differences were due to the individual approach to work and radiation protection (use of protective barriers, syringe shields and protective aprons) as well as individual capabilities (knowledge, experience and even handiness)

The average dose at the department decreased over the years from approximately 3 5 mSv y^{-1} to 0 8 mSv y^{-1} From these results, we can assume that 1 mSv is an acceptable estimate for the present average annual dose This value should be increased by at least 40% for missing doses due to high film dosimeter sensitivity Such a value must then be normalized to 8-hour work time (e g., multiplied by a conservatively chosen factor of 1.7) in order to compared it with other occupational doses for the same or similar type of work. The resulting value of the average annual dose ≈ 2.4 mSv is comparable with the 2 2 mSv estimate for staff in British nuclear medicine departments (6,7), but this value is, as expected, considerably higher than the average annual doses to ward nurses in radiotherapy departments (≈ 0 55 mSv), radiotherapists (≈ 0 4 mSv) or radiologists (≈0 2 mSv) [8,9]

Since the main phases in the use of radionuclides are eluation from the generator, preparation, dispensing and injection of radioactive material, most of the occupational dose involves hands In that respect, as an orientation it was estimated that ≈ 20 mSv y^{-1} is received to the hands, if the total body dose is ≈ 2 mSv y^{-1} (6)

REFERENCES

1 ICRP Publication 60 1990 Recommendations of the ICRP (1991), Ann ICRP, 21 1-3

2 ICRP Publication 26 1977 Recommendations of the ICRP (1977), Ann ICRP, 1 1

3 United Nations Scientific Committee on the Effects of Atomic Energy Sources and Effects of Ionising Radiation UNSCEAR 1988 Report United Nations, New York, 1988

4 Committee on the Biological Effects of Ionizing Radiation Health Effects of Exposure to Low Levels of Ionizing Radiation BEIR V National Research Council Washington, D C , National Academy Press, 1990

5 Dietze G Do we need definitions of dose equivalent and equivalent dose in radiation protection metrology? Radiation Protection Dosimetry 1991, 37 3

6 Shaw KB, Huges JS, McDonough L, Gelder R Trends in population dose and examples of occupational dose reduction Goldfinch EP, in Proceedings of the Fourth International Symposium of the Society for Radiological Protection Bristol IOP, 1989

7 Kendall GM, Greenslade E, Pook EA, Ball AM Distribution of annual doses to some UK radiation workers J Radiol Prot 1988, 8 234-38

8 Johnstone PD, Brenot J, Kendall GM A study of worker dose distributions with respect to ICRP dose limitation recommendations Health Phys 1986, 51 579-99

9 Kumazawa S, Nelson DR, Richardson ACB (1984) Occupational exposure to ionising radiation in the United States EPA 520/1-84-005, US Environmental Protection Agency, Washington DC

SUMMARY

The doses of irradiation received by the workers at the Department of Nuclear Medicine and Oncology, "Sestre Milosrdnice" University Hospital, Zagreb, Croatia, were reviewed to assess the trends and impact of new annual dose limits of 20 mSv recommended by ICRP Film dosiometry data obtained monthly for the workers (N=63) at the department (for the period from 1986 to 1991) were analyzed A data set consisted of ≈ 3800 men/control interval values The workers were classified into three groups, according to the type and areas of work (1) preparation of radioactive material, (2) injection and patient positioning under diagnostic equipment; and (3) control, cleaning and administration. It is estimated that approximately 40% of doses are not registered at all due to a high threshold of film dosimetry Our estimate of the average annual dose was ≈ 2 4 mSv for two critical groups of workers Thermoluminiscent dosimetry is indicated as a better tool for monitoring at nucler medicine departments

PROCJENA PROSJEČNE PROFESIONALNE DOZE ZA DJELATNIKE U ODJELIMA NUKLEARNE MEDICINE

SAŽETAK

Pregledane su doze koje primaju zaposleni na Klinici za nuklearnu medicinu i onkologiju KB "Sestre Milosrdnice", kako bi se ocijenili kretanje i utjecaj novih godišnjih granica doze od 20 mSv koje preporuča ICRP Analizirani su podaci mjesečne filmske dozimetrije u razdoblju 1986-1991. g za 63 zaposlena Skup podataka sastojao se od vrijednosti za ≈ 3800 čovjek/kontrolni interval doza Zaposleni su razvrstani u tri skupine prema vrsti i području rada (1) priprava radioaktivnoga materijala, (2) injiciranje i postavljanje bolesnika pod dijagnostičkim instrumentima i (3) kontrola, čišćenje i administracija Procjenjuje se kako se približno 40% doza ne registrira zbog previsoka praga osjetljivosti filmske dozimetrije Naša je procjena kako prosječna godišnja doza iznosi ≈ 2 4 mSv za dvije kritične skupine zaposlenih Termoluminiscentna dozimetrija je znatno bolji vid praćenja za zaposlene u odjelima nuklearne medicine.

Adresa

Dr Vladimir Lokner

Klinika za onkologiju i nuklearnu medicinu,
Kliničke bolnice "Sestre milosrdnice"

Vinogradska c 29

10 000 Zagreb

Primljeno na 9 sjednici IV Razreda 22 XII 1993