HAND MONITORING IN NUCLEAR MEDICINE DEPARTMENTS IN CROATIA – FIRST RESULTS

by

Marija SURIĆ MIHIĆ [1*], ***Robert BERNAT*** [2], ***Jerko ŠIŠKO*** [1],
Maja VOJNIĆ KORTMIŠ [2], ***Luka PAVELIĆ*** [1], ***Ivica PRLIĆ*** [1], ***and Nikolina MIŠAK*** [2]

[1] Institute for Medical Research and Occupational Health, Zagreb, Croatia
[2] Rudjer Boskovic Institute, Zagreb, Croatia

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Individual hand monitoring for workers who manipulate unsealed radioactive sources in nuclear medicine is a necessity and the results can serve as the base for optimization processes. We performed an analysis of individual hand doses for medical staff preparing and applying radiopharmaceuticals (^{99m}Tc, ^{123}I, ^{201}Tl, ^{131}I, or ^{125}I) in three Croatian clinical hospitals, for a period of one year since extremity monitoring became legally mandatory in Croatia. The majority of annual hand doses for workers were below or slightly above 150 mSv per year with only a few workers exceeding the annual dose limit of 500 mSv. The analysis confirmed that the radiation protection expert's role in an individual monitoring programme and personal dosimetry is crucial in order to achieve the optimal radiation protection of workers.

Key words: hands monitoring, nuclear medicine, Hp(0,07), occupational exposure, equivalent dose to hands, ring dosimetry

INTRODUCTION

In nuclear medicine (NM) procedures, unsealed radioactive sources are used for diagnostic and therapeutic purposes. The most frequently used radiopharmaceuticals are ^{99m}Tc, ^{123}I, ^{131}I and ^{18}F (^{18}F-FDG) for diagnostic purposes [1], and ^{131}I, ^{32}P, ^{90}Sr and ^{90}Y for therapy [2]. In such procedures, workers manipulate high activities of various radionuclides via contact to the hands and/or in close proximity of their hands. The number of NM procedures is increasing as well as the associated risk of radiation exposure of NM staff. Radiation protection measures that should be undertaken to optimize the exposure of workers in NM strongly rely on personal dosimetry measurements. Individual monitoring data are the base of successful optimization programs. Occupationally exposed workers in NM are generally individually monitored using whole body dosimeters for effective dose assessment and extremity dosimeters (ring dosimeters) to evaluate the equivalent dose to the skin and hands. The dose limit on the equivalent dose for the skin and extremities is 500 mSv per year, and it is applied to the dose averaged over any area of 1 cm^2, regardless of the area exposed, as given in the EURATOM BSS directive [3] and in the ICRP Publication 103 [4]. The results of the ORAMED project [5, 6] strongly emphasized the necessity of extremity monitoring and determination of the position of ring dosimeter at the most exposed part of the hand. The recommendation for workers in NM, given as a result of the ORAMED project, was to wear the ring dosimeter at the base of the index finger of the non-dominant hand with the sensitive part of the dosimeter placed towards the palm side of the hand [5, 6]. In case the ring dosimeter is worn elsewhere, a correction factor for the corresponding position is proposed, for the dominant and non-dominant hand [6].

In the Republic of Croatia, workers in NM were regularly individually monitored using only whole body dosimeters for Hp(10) measurements, and routine monitoring of extremities of the staff manipulating unsealed radioactive sources in NM departments was not legally obligatory, until June 2018, when new legislation based on the EURATOM BSS directive [3] came into force. The majority of the sources used in NM are unsealed radioactive sources with high activity at the time of manipulation. Having said that and having in mind the already mentioned close proximity of the sources, equivalent doses to hands and skin in NM can often exceed annual dose limits. Equivalent doses are generally not easily correlated with whole body monitoring doses [7], which are usually low [8]. Since the data on extremity exposure for workers in NM in Croatia were scarce [9, 10], due to the fact that ring dosimetry was not legally obligatory, we col-

* Corresponding author; e-mail: msuric@imi.hr

lected dosimetry data for NM workers for a period of one year, since the new regulations came into force. We estimated the equivalent dose to hands of workers of NM departments in three Croatian clinical hospitals based on the personal dose equivalent Hp(0.07) measurements using ring dosimeters. The clinical departments included in this study performed conventional diagnostic scintigraphy using ^{99m}Tc, ^{123}I, ^{201}Tl, ^{131}I, and ^{125}I for radioimmunoassay (RIA) analyses.

MATERIALS AND METHODS

Dosemeters and detectors

The Hp(10) and Hp(0.07) measurements were performed by two approved individual monitoring services (out of three) in the Republic of Croatia, Institute for Medical Research and Occupational Health (IMROH) and Rudjer Bošković Institute (RBI).

The IMROH dosimetry service used Panasonic UD-802AT or UD-803AS whole body dosimeters and a single Panasonic UD-807ATN thermoluminescent (TL) element containing $Li_2B_4O_7$ phosphor within a plastic ring dosimeter. The readout of the dosimeters was performed on a Panasonic UD-716AGL13-C TL dosimeter reader. The corrections for energy/angle and fading were applied in the Hp(10) or Hp(0.07) calculation algorithms as well as background subtraction for Hp(10) only. The calibration factor $K_{Hp(0.07)}$ for Hp(0.07) was applied since the TLD reader was calibrated using internal parameters [11] for Hp(10) measurements, due to the accreditation of the IMROH dosimetry laboratory for Hp(10) measurements in compliance with the ISO/IEC 17025 standard.

The RBI dosimetry service used Harshaw four element cards with two TLD-100 dosimeters (LiF:Mg, Ti) at positions 2 and 4 and in a Harshaw 8814 holder as a whole body dosimeter and single TLD-100 dosimeter in a plastic Harshaw finger ring. Except for the element correction factor and reader calibration factor, no additional calibration factors were applied. Background subtractions were used for both whole body and extremity dosimeters. The readout of the dosimeters was performed on a Harshaw 6600 dosimeter reader.

Both dosimetry services successfully participated in several international comparisons organized by the European Dosimetry Group EURADOS (for whole body and extremity dosimetry).

The monitoring period was one month, and data were collected for a one-year period. The total number of NM workers included in this study was 97 (88 by IMROH and 9 by RBI).

Estimation of the equivalent dose to hands

The NM workers in hospital 1 were instructed to wear the ring dosimeter at the base of the index finger of the non-dominant hand with the sensitive part of the dosimeter placed towards the palm side of the hand, in accordance with the ORAMED recommendation [5, 6]. The equivalent dose to hands was calculated multiplying the measured value of Hp(0.07) with a correction factor of 6 [6] to estimate the maximum dose. The NM workers in hospitals 2 and 3 were not previously given instructions on the ring dosimeter wearing position so the information of the wearing position of the ring dosimeter on the hand (dominant/non dominant hand, particular finger) in the routine monitoring for a particular worker was unknown. In order to overcome this problem, we calculated a dose interval within which the equivalent dose was situated. The lower value of the interval was calculated using a correction factor of 6 [6] (for the ring position at the base of the index finger of the non-dominant hand) and the higher value was calculated using a correction factor of 10 [6] (for the ring position at the base of the ring finger of the non-dominant hand). These factors were the lowest and the highest recommended by the ORAMED study [5, 6].

Although many individual Hp(0,07) measurement values were below the recording level of 4.2 mSv [12] in one month, when multiplied with the abovementioned correction factors, the estimated maximum values were above the recording level.

Structure of NM workers

For the purposes of this research, we sorted the medical staff according to the NM procedures they performed into groups as follows: technical staff (preparation, administration), technical staff (analysis), and medical doctors. The work activities of the particular group, as well as number of NM workers in a particular hospital included in the group, are described in tab. 1.

All the workers declared using protective equipment in their work, including led aprons, thyroid shields, protective led glasses and protective shields but rarely syringes or vials shields [13]. It should be emphasized that although Croatian legislation [14] prescribes mandatory advice from a radiation protection expert (RPE), considering the choice of dosemeter type and its wearing position for a particular NM worker, this was not adhered to in all of the hospitals included in this study. The decision which NM worker should use a ring dosemeter was made by the management of a particular NM department without previous consultation with a RPE. Therefore, the structure and number of NM workers using ring dosimetry varies significantly between hospitals, as shown in tab. 1. The number of NM workers using whole body dosimetry in all of the hospitals included in this study (138, 91 and 28 for hospitals 1, 2, 3, respectively) is up to several times higher than the ones

Table 1. Tasks of the NM workers and number of NM workers

Group	Task	Number of NM workers (hospital number)
Technical staff (preparation and administration)[1]	Preparation of radiopharmaceuticals, radioisotope administration and RIA analyses	12 (1) 35 (2) 9 (3)
Technical staff (analysis)[2]	Laboratory work – RIA analyses only	22 (1) 0 (2) 0 (3)
Medical doctors	Radioisotope administration, work with patients to whom radiopharmaceuticals were administrated	0 (1) 19 (2) 0 (3)

[1] Including chemists, radiological technologists, laboratory technicians, nurses, nuclear technician *etc*.

[2] Including biochemists, molecular biologists, laboratory technicians, *etc*.

monitored using both whole body and ring dosimeters (34, 54 and 9 for hospitals 1, 2, 3, respectively).

RESULTS AND DISCUSSION

The analysis of the effective doses confirmed that the annual effective doses for all groups of NM workers were low. In the NM workers group classified as technical staff (preparation, administration), of all the hospitals included in the study, the annual effective doses ranged from 0 to 0.82 mSv of which 93 % were 0 mSv. In the technical staff (analysis) group, the highest annual effective dose was 1.25 mSv where 71 % of workers had zero annual doses. In the medical doctors group, the highest value of annual effective dose was 0.3 mSv with 98 % doctors having an annual effective dose value of 0 mSv. The high percentage of zero doses was predominantly due to the position of the whole body dosemeter under the protective apron, which NM workers regularly wear during their work.

The estimated equivalent dose to hands for all groups showed high variations among doses received between hospitals and within a single NM department. The results of hand dose range for a particular group/hospital are presented in tab. 2. In the same table, the percentage of NM workers having zero annual hand doses (less than recording level 4.2 mSv) within the group is also given. The annual dose limits was exceeded for workers in the technical staff (preparation, administration) group for hospital 2 and hospital 3 (only for correction factor of 10 [6]) and in the technical staff (analysis) group for hospital 1.

Table 2. Estimated equivalent doses to hands and share of zero doses for clinical hospitals included in the study

Group	Range of annual equivalent doses to hands (mSv) and fraction of zero doses[1]		
Hospital	1	2	3
Technical staff (preparation and administration)	0-261	0-1425[2] 0-2375[3]	0-330[2] 0-550[3]
Zero doses	33 %	40 %	11 %
Technical staff (analysis)	0-719	–	–
Zero doses	18%		
Medical doctors	–	0-2.4[1] 0-4[2]	
Zero doses		100 %	

[1]Zero doses – doses lower than recording level 4.2 mSv
[2]Correction factor of 6 [6] for ring dosemeter position at the base of the index finger of the non-dominant hand
[3]Correction factor of 10 [6] for ring dosemeter position at the base of the ring finger of the non-dominant hand

A detailed distribution of hand doses within the technical staff (preparation, administration) and technical staff (analysis) group for all of the hospitals is given in figs. 1 and 2.

In the technical staff (preparation, administration) group, there were 3 or 5 NM workers exceeding

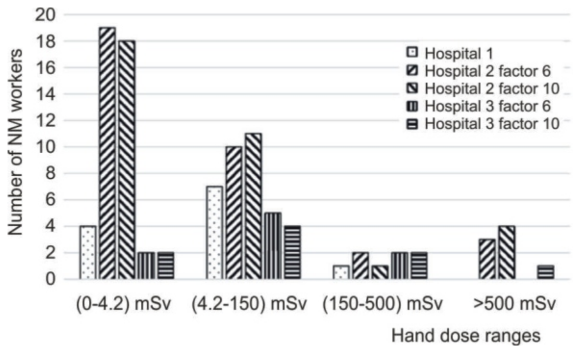

Figure 1. Number of NM workers in the technical staff (preparation, administration) group for all three hospitals in a particular annual hand dose range group; for hospitals 2 and 3, the number of NM workers with annual hand doses estimated using a correction factor of [6] 6 or 10, are presented next to one another in each hand dose range group

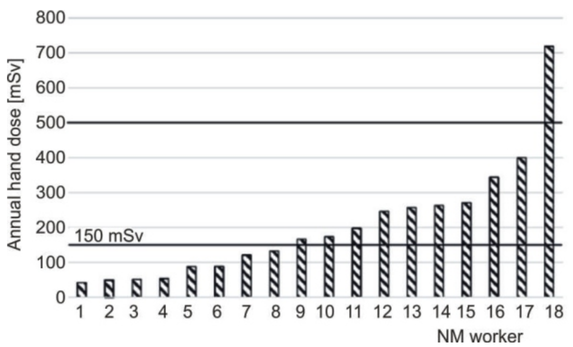

Figure 2. Annual hand doses above the recording level for NM workers in the technical staff (analysis) group; the horizontal lines mark 150 mSv, as 3/10 of annual dose limit, and 500 mSv as annual dose limit

the annual dose limit, with the use of correction factor [6] 6 or 10, respectively. The highest doses were received by two chemists working in the hot lab, following by two nurses performing administration of isotopes and radiological technologist involved in the preparation of radioisotopes. In all of the hospitals, the majority of workers received an annual hand doses lower than 150 mSv, which would lead to the conclusion that they should be categorized as B workers and hand monitoring should not be mandatory. Due to uncertainty caused by the ring dosimeter position, it can be observed that the use of a correction factor of 6 or 10 could cause a NM worker's annual dose to exceed either 150 mSv or the annual dose limit. In this group, we also observed frequent variations in monthly hand doses that could be explained either due to a non-uniform workload or failing to wear the dosimeter regularly. The latter possibility would suggest that real hand doses might be even higher than estimated from the available data.

In the medical doctors group, all of the annual hand doses were under the recording level of 4.2 mSv, regardless of the corrective factor (as presented in tab. 2).

In the technical staff (analysis) group, annual hand doses were generally higher than in the technical staff (preparation, administration) group. The number of NM workers with hand doses below and over 150 mSv is similar. Since in this group there were no significant variations among monthly hand doses, suggesting that the dosimeters had been worn regularly and the workload was uniform, the median and the mean for all annual hand doses above recording level was calculated. The median was 170 mSv and the mean was 444 mSv (173 mSv if the highest dose is excluded). The high mean value was affected by one annual hand dose above the annual dose limit, otherwise it was almost equal to the median value. In this group, only one NM worker, a laboratory technician, received an annual hand dose exceeding the annual dose limit.

CONCLUSIONS

In this study, we evaluated the equivalent dose to the hands of NM workers working in three Croatian clinical hospitals performing conventional diagnostic scintigraphy using ^{99m}Tc, ^{123}I, ^{201}Tl, ^{131}I, and ^{125}I for RIA analyses. The analysis of one year monitoring data, since hand monitoring became legally obligatory in Croatia, revealed that the majority of annual hand doses were below or slightly above 150 mSv per year, which is a dose value above which radiation workers must be monitored using extremity dosimeters (category A workers) [12, 14]. However, taking into account that regular use of dosemeter and proper position of the sensitive part of the dosimeter significantly affect the estimation of the maximum hand dose, we strongly suggest that all NM workers involved in any kind of manipulation of unsealed sources should be regularly monitored using ring dosemeters. The RPE advice on dosimeter type and wearing position for a particular NM worker is essential. Although the presented results show that annual hand doses for only a few workers exceed the annual dose limit, which require immediate optimization measures, another issue should also be addressed. Detailed analysis of monthly hand doses revealed that for many NM workers included in this study, there were significant variations in monthly values or all hand doses were zero, although all of the NM workers included in the study stated they manipulated unsealed sources and the workload was usually constant. There were many zero monthly doses among the monthly doses above the recording value, for many NM workers. This could indicate that in these periods dosimeters might not be worn and real hand exposure might be much higher, even exceeding the dose limits, but not being recorded. Therefore, the use of this analysis to assess the quality of radiation protection in particular NM department should still be taken with due caution.

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AUTHORS' CONTRIBUTIONS

Dosimetry measurements were performed by J. Šiško and N. Mišak, all of the authors analyzed and discussed the results. The manuscript was written by M. Surić Mihić and R. Bernat.

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**Марија СУРИЋ МИХИЋ, Роберт БЕРНАТ, Јерко ШИШКО,
Маја ВОЈНИЋ КОРТМИШ, Лука ПАВЕЛИЋ, Ивица ПРЛИЋ, Николина МИШАК**

ДОЗИМЕТРИЈСКИ НАДЗОР ШАКА У ОДЕЉЕЊИМА НУКЛЕАРНЕ МЕДИЦИНЕ У ХРВАТСКОЈ – ПРВИ РЕЗУЛТАТИ

Индивидуални дозиметријски надзор шака радника који рукују отвореним радиоактивним изворима у нуклеарној медицини нужан је, и резултати тог надзора могу послужити као основа процеса оптимизације. Спровели смо анализу индивидуалних доза за шаке медицинског особља које припрема и примењује радиофармаке (^{99m}Tc, ^{123}I, ^{201}Tl, ^{131}I, ^{125}I) у три хрватске клиничке болнице, у периоду једне године након што је дозиметријски надзор екстремитета постао законска обавеза у Хрватској. Већина годишњих доза за шаке радника била је испод или нешто изнад 150 mSv при чему је само неколико радника премашило вредности изнад годишње границе озрачења од 500 mSv. Анализа је потврдила кључну улогу стручњака за заштиту од јонизујућег зрачења у програму индивидуалног дозиметријског надзора и индивидуалној дозиметрији у циљу постизања оптималне заштите од озрачивања радника.

Кључне речи: дозиметријски надзор шака, нуклеарна медицина, Hp(0,07), професионална изложеност, еквивалентна доза за шаке, прстен дозиметрија