

# Occupational Radiation Exposure among the Staff of Departments of Nuclear Medicine and Diagnostic Radiology in Kuwait

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## Key Words

Occupational exposure · Radiation dose · Nuclear medicine · Radiology

## Abstract

**Objectives:** To investigate radiation exposure among the staff of departments of nuclear medicine (NM) and diagnostic radiology (DR) during 2008 and 2009 and to compare the mean doses received with the limit of 20 mSv/year of the International Commission of Radiological Protection (ICRP).

**Materials and Methods:** The whole-body dose or effective dose, i.e. Hp(10), and the skin dose, i.e. Hp(0.07), of the staff of departments of NM and DR in Kuwait for the period of 2008 and 2009 were taken from the national thermoluminescent dosimetry database. A total of 1,780 radiation workers, grouped as NM physicians, radiologists, NM technologists, and DR technologists, from 7 departments of NM and 12 departments of DR were included. The annual average Hp(10) and Hp(0.07) were calculated for each group and comparisons were made between the groups and the years. A two-sided Mann-Whitney test was carried out, at the  $p = 0.05$  level, to compare the means. The mean Hp(10) was compared with the limits of the ICRP. **Results:** Of the 16 distributions of Hp(10) and Hp(0.07), 10 were normal, with a mean annual Hp(10) in 2008 of 1.06, 1.03, 1.07, and 1.05 mSv for NM physicians, radiologists, NM technologists, and DR technologists, respectively. The corresponding Hp(0.07) val-

ues for 2008 were 1.03, 1.00, 1.05, and 1.03 mSv, respectively. Small but significant ( $p < 0.001$ ) reductions in Hp(10) and Hp(0.07) were observed in 2009 for NM technologists and DR technologists. In all other cases, no significant ( $p > 0.072$ ) differences were found. **Conclusion:** The annual average Hp(10) was well below the limit of the ICRP. © 2013 S. Karger AG, Basel

## Introduction

One of the hazards of working in a department of nuclear medicine (NM) or diagnostic radiology (DR) is the possibility of long-term exposure to low-level radiation and any associated biological effects. Evidence of reversible and irreversible genotoxic effects during periods of radiation exposure has been reported [1]. Although biological effects due to moderate and high doses ( $>100$  mGy) are evident, there is still considerable debate regarding the biological effects due to low-dose exposures ( $<100$  mGy) [1–4]. During the last decade, the number of persons who work in departments of NM and DR has increased [2, 5]. With the introduction of advanced imaging technologies, such as positron emission tomography (PET) and multislice computed tomography (MSCT), the number of workers in departments of NM and DR, the different types of imaging examinations performed, the number of patients undergoing imaging procedures, and

hence the amount of radiation used have increased [2, 6]. However, a historical review of the radiation exposure of workers indicates that the doses have decreased with time due to improved radiation protection practices since the discovery of X-rays [4].

The radiation dose of workers in these departments has been reported to vary between 1 and 50 mSv/year in many parts of the world [7–12]. The United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) has reported that the worldwide mean annual occupational dose in NM and DR is below 2 mSv [13]. The large variation in exposure among staff working with radiation in departments of NM and DR has been attributed to the nature of the work the individual carries out. Interventional radiological and MCST procedures present much higher radiation exposure risk for the staff than general radiographic procedures [4, 14]. The higher-energy (511 keV) gamma rays used in PET imaging present higher radiation exposure for the staff compared to the technetium-99m gamma rays of 140 keV commonly used in imaging procedures.

The International Commission on Radiological Protection (ICRP) recommends the establishment of dose constraints which are acceptable and achievable to avoid inequitable exposures of individuals within the workplace [15]. The ICRP has set dose limits of 20 mSv/year, averaged over any 5-year period, for occupational exposure. It also emphasizes that the radiation exposure of patients and workers should be kept as low as reasonably achievable (ALARA principle) [16].

A previous study reviewed the occupational dose in Kuwait during a 4-year period from 1980 to 1983 and reported values in the range of 2–6 mSv [17]. This study included occupational exposure not only in hospitals but also in other nonmedical industries. Another study will establish the current levels of occupational exposure.

In this study, we investigated the level of radiation exposure of staff working in departments of NM and DR during 2008 and 2009. A comparison of personnel doses received by the staff was also carried out. The mean annual occupational dose of each group was compared with the dose limits set by the ICRP.

## Materials and Methods

The radiation exposure of each staff member working in departments of NM and DR is routinely monitored using thermoluminescent dosimeter (TLD) badges. Generally, 2 dose quantities, i.e. Hp(10) and the Hp(0.07), are reported for each staff member. The staffs were divided into the following 4 groups: NM physi-

**Table 1.** Number of TLD records in the different groups for each of the 2 years

	2008	2009
NM physicians	49	54
NM technologists	112	121
Radiologists	98	109
DR technologists	612	625

cians, NM technologists (department of NM) and radiologists, and DR technologists (department of DR). Hp(10) is the dose received by tissue at a 10-mm depth from the skin surface and is considered to be the dose to the whole body or the effective dose. Hp(0.07) is the dose at a depth of 0.07 mm and is considered to be the dose received by the skin of the workers [14].

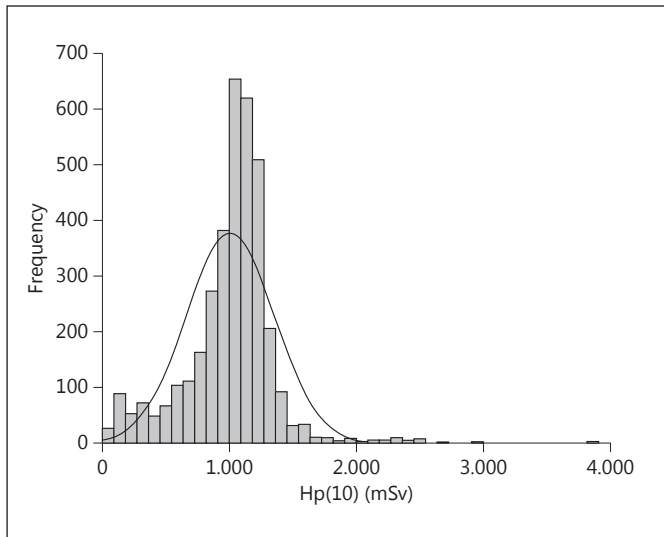
The occupational dose analysis included TLD records over 2 years (2008 and 2009), for a total of 1,780 worker records. The number of workers in each group for the corresponding years is given in table 1. The Radiation Protection Department of the Ministry of Health, Kuwait, provides personnel dose-monitoring services to all radiation workers in public and private hospitals in the country. Each worker who is likely to be occupationally exposed to radiation is required to be monitored for radiation exposure and carries a TLD badge at waist level to monitor exposure on a monthly basis. The measurement, analysis, and calibration of the TLD badges was conducted according to standard procedures [18, 19].

The annual dose values for each of the 2 years were calculated from these monthly records and compared for any significant changes. Within each department, a comparison was made between the annual doses of the technologists and those of the physicians for each year. The occupational dose of NM technologists was also compared with the dose of DR technologists, while those of NM physicians were compared to those of radiologists for the respective years.

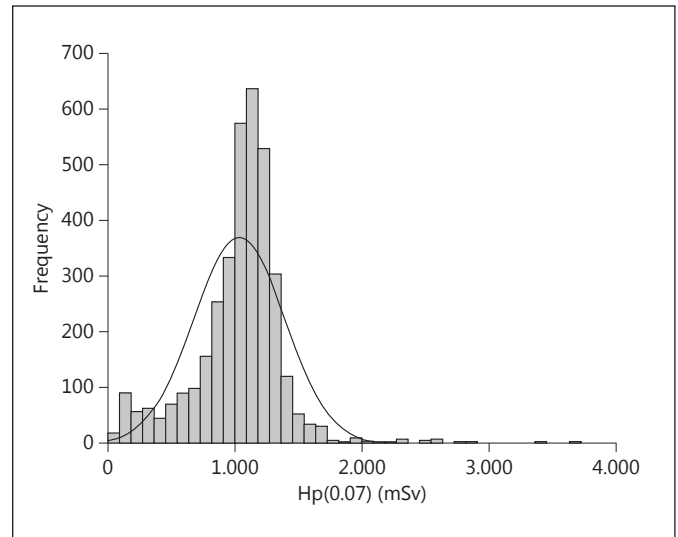
The normality of the distribution of doses within each group was tested using the Kolmogorov-Smirnov test. Since some distributions were not normal, the statistical analysis of personnel dose, i.e. Hp(10) and Hp(0.07), between pairs of groups was tested with a Mann-Whitney U test using the Statistical Package for the Social Sciences (SPSS), version 17. For all statistical tests,  $p < 0.05$  was considered statistically significant. Based on the average occupational exposure, the risk of developing radiation-induced cancer was calculated using a risk factor of 0.041/Sv [16].

## Results

Ten of the 16 distributions of Hp(10) and Hp(0.07) were normal. The distributions of Hp(10) and Hp(0.07) are illustrated in figures 1 and 2, respectively, for all workers during 2008 and 2009. The mean annual occupational exposures  $\pm$  SE for the different groups of workers for 2008 and 2009 are listed in table 2. The occupational dose



**Fig. 1.** Distribution of Hp(10) for all workers combined for 2008 and 2009 together with the normal distribution, generated using SPSS version 17, shown as a line graph.



**Fig. 2.** Distribution of Hp(0.07) for all workers combined for 2008 and 2009 together with the normal distribution, generated using SPSS version 17, shown as a line graph.

**Table 2.** Annual occupational doses

Group	Year	Mean Hp(0.07) ± SE (range), mSv	Mean Hp(10) ± SE (range), mSv
NM physicians	2008	1.03±0.03 (0.11–1.96)	1.06±0.03 (0.10–1.98)
	2009	0.96±0.03 (0.08–3.85)	1.01±0.03 (0.08–3.43)
NM technologists	2008	1.05±0.01 (0.84–3.96)	1.07±0.01 (0.08–3.70)
	2009	0.94±0.01 (0.08–2.92)	1.00±0.01 (0.08–2.85)
Radiologists	2008	1.00±0.03 (0.09–1.96)	1.03±0.03 (0.10–1.83)
	2009	0.90±0.04 (0.08–3.95)	0.94±0.04 (0.08–1.53)
DR technologists	2008	1.03±0.01 (0.08–2.86)	1.05±0.01 (0.08–2.81)
	2009	0.93±0.01 (0.08–2.18)	0.99±0.01 (0.07–2.11)

between the 2 years revealed that the Hp(10) and Hp(0.07) for 2008 were small but significantly higher than in 2009 for NM and DR technologists ( $p < 0.001$ ). In the cases of NM physicians and radiologists, the annual dose quantities did not show any differences between 2008 and 2009

**Table 3.** Ranges of annual occupational doses reported in the literature for comparison with this study

Study	Annual effective occupational dose (mSv)
Wu et al. [11]	1.0–2.2
Al Haj and Lagarde [7]	0.5–1.2
Mustafa et al. [17]	2.04–6.20
Martins et al. [8]	0.80–3.45
This study	0.07–3.70

( $p > 0.05$ ). In all other comparisons, the occupational exposures were the same among the 4 groups. All annual dose records were less than 4 mSv.

The Hp(10) and Hp(0.07) records were below 2 mSv/year for 99% and below 1 mSv/year for 35% of the workers. The maximum annual dose received by any person was 3.700 mSv, which is significantly below the annual occupational limit of 20 mSv/year averaged over any 5-year period and 50 mSv in any one year set by the ICRP. The average annual dose for all workers during the 2-year period was 1.02 mSv for Hp(10) and 0.98 mSv for Hp(0.07). The range of annual effective doses for workers reported in various studies from different countries is shown in table 3. The risk of cancer induction from occupational exposure in Kuwait was found to be about 40

per million (exposed workers). With less than 1,000 currently exposed workers in Kuwait, the number of radiation-induced cancer cases expected due to occupational exposure is less than 1.

## Discussion

The public health system in Kuwait serves a population of about 3.5 million, performing in excess of 2.5 million NM and DR imaging procedures per year [20]. Most workers in Kuwait do not wear lead aprons during work, but those in fluoroscopy and interventional procedures wear lead aprons, thyroid shields, and gloves. Despite this, our study showed that the mean annual occupational exposure of workers was less than 1.07 mSv/year, which is similar to the occupational dose reported in studies from different parts of the world [4, 5, 8, 13] and also the worldwide average of less than 2 mSv quoted by UNSCEAR [13]. It is evident, from this study, that the technologists and physicians of departments of NM and DR in public hospitals were exposed to minimal amounts of radiation. The low calculated risk (40 cases per million) of developing radiation-induced cancer from occupational radiation exposure for these workers in public hospitals of Kuwait should provide sufficient confidence that the work environment is safe.

The extent of the annual radiation exposure of the workers depends on several factors within the workplace [3, 4, 7]. These factors include, but are not limited to, the annual workload, the distribution of the workload among workers, the radiation protection practices followed by the workers, and the radiation safety facilities provided by the employers. An evaluation of how such factors affect occupational exposure is beyond the scope of this study. The nature of occupational exposure is different within departments of NM compared to departments of DR.

There are some general limitations in measuring occupational exposures accurately. One of the major difficulties is the nature of exposure itself. In medical imaging, workers are not exposed uniformly throughout their body and TLD measure exposure only at one location. This location is either at waist level or at collar level depending on where the worker wears it. Hp(10) is a useful quantity to measure the effective dose if the exposure is uniform over the worker's body [14]. Some authors [14, 15] have recommended the use of two TLD measurements estimation of the effective dose instead of a single measurement. However, the use of two TLD measurements becomes more expensive and difficult when dealing with large

numbers of workers. Radiation workers in many countries, including Kuwait, wear a single TLD badge at waist level over any protective clothing they may wear [4–5, 8–13]. Currently, there is no consensus among researchers on an algorithm suitable for the assessment of the effective dose of the workers. Another problem with monitoring occupational exposure is the absence of dose measurements for the extremities and the eyes of the workers. This is due to the wide range of interventional procedures and different techniques used by different workers in medical imaging [14]. In addition to the limitations described above, the following limitations apply particularly to this study: the distribution of the workload among workers, radiation protection facilities, and trends in safe practices were not evaluated. A review of these aspects and continuing education for workers on radiation safety can help minimize the radiation exposure of the workers. Furthermore, this study did not evaluate differences in occupational exposure within a group of workers performing the same procedure, nor did it evaluate the efficacy of safety protocols put in place in different hospitals.

## Conclusion

This study showed that the Hp(10) and Hp(0.07) of radiation workers during the 2-year period were well below the limits set by the ICRP. Continuous evaluation of occupational dose records is recommended due to the increasing number of medical imaging procedures that are currently being performed.

## Acknowledgement

This work was supported by Kuwait University research grant No. NR02/10. We would like to acknowledge the staff of the Radiation Protection Department, Kuwait, for their assistance and support.

## References

- 1 Shain A, Tatar A, Oztas S, et al: Evaluation of genotoxic effects of chronic low-dose ionizing radiation exposure on nuclear medicine workers. *Nucl Med Biol* 2009;36:575–578.
- 2 Pauwels EKJ, Bourguignon MH: Radiation dose features and solid cancer induction in pediatric computed tomography. *Med Princ Pract* 2012;21:508–515.
- 3 Covens P, Berus D, de Mey J, et al: Mapping very low level occupational exposure in medical imaging: a useful tool in risk communication and decision making. *Eur J Radiol* 2012; 81:e962–e966.

- 4 Linet MS, Kim KP, Miller DL, et al: Historical review of occupational exposures and cancer risks in medical radiation workers. *Radiat Res* 2010;174:793–808.
- 5 Smith-Bindman R, Miglioretti DL, Johnson E, et al: Use of diagnostic studies and associated radiation exposure for patients enrolled in large integrated health care systems: 1996–2010. *JAMA* 2012;307:2400–2409.
- 6 Smith-Bindman R, Miglioretti DL, Larson EB: Rising use of diagnostic medical imaging in a large integrated health care systems. *Health Aff (Millwood)* 2008;27:1491–1502.
- 7 Al Haj AN, Lagarde CS: Statistical analysis of historical occupational dose records a large medical centre. *Health Phys* 2002;83:854–860.
- 8 Martins MB, Alves JN, Abrantes JN, et al: Occupational exposure in nuclear medicine in Portugal in the 1999–2003 period. *Radiat Prot Dosimetry* 2007;125:130–134.
- 9 Mettler FA Jr, Bhargavan M, Thomadsen BR, et al: Nuclear medicine exposure in the United States, 2005–2007: preliminary results. *Semin Nucl Med* 2008;38:384–391.
- 10 Shrimpton PC, Wall BF, Hart D: Diagnostic medical exposures in the UK. *Appl Radiat Isot* 1999;50:261–269.
- 11 Wu W, Zhang W, Chen R, et al: Occupational exposure of Chinese medical radiation workers in 1986–2000. *Radiat Prot Dosimetry* 2005;117:440–443.
- 12 Jabeen A, Munir M, Khalil A, et al: Occupational exposure from external radiation used in medical practices in Pakistan by film badge dosimetry. *Radiat Prot Dosimetry* 2010;140:396–401.
- 13 United Nations Scientific Committee on the Effects of Atomic Radiations: Summary of low-dose radiation effects on health. UN-SCEAR report. New York, UN Press, 2010, pp 1–14.
- 14 Covens P, Berus D, Buls N, et al: Personal dose monitoring in hospitals: global assessment, critical applications and future needs. *Radiat Prot Dosimetry* 2007;124:250–259.
- 15 International Commission on Radiological Protection: General principles for the protection of workers. ICRP Publication 75. Oxford, Pergamon Press, 1997, pp 1–7.
- 16 International Commission on Radiological Protection: The 2007 recommendations of the ICRP. ICRP Publication 103. Oxford, Pergamon Press, Oxford, 2007, pp 1–4.
- 17 Mustafa AA, Sabol J, Janeczek J: Dose from occupational exposure: a study of radiation dose to workers in Kuwait over a four-year period. *Health Phys* 1985;49:1197–1204.
- 18 International Atomic Energy Agency: International basic safety standards for protection against ionizing radiation and for the safety of radiation sources. Safety Series 115-1. Vienna, International Atomic Energy Agency, 1994, pp 33–40.
- 19 International Atomic Energy Agency: Calibration of radiation protection monitoring instruments. Safety Series 16. Vienna, International Atomic Energy Agency, 2000, pp 45–76.
- 20 Ministry of Health, Kuwait: Statistics of imaging procedures in public hospitals: internal statistics compilation (unpublished). Kuwait, Ministry of Health, 2010.