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Active Personal Dosimeter in a Nuclear Medicine Center in Yazd City, Iran

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Abstract

Introduction: Active personal dosimeters (APDs) are well accepted as useful and reliable instruments for individual dosimetry measurements. APDs have many advantages compared with passive dosimeters for individual external radiation dose assessments. In routine monitoring, occupational exposure is carried out for verification and demonstration of compliance with the regulatory dose limits. So, it is one of the most important tools in order to achieve or demonstrate the level of radiation protection.

Methods: Yazd province has only one private nuclear medicine (NM) center. In this center, two NM technologists exposed to radioactive patients during radiopharmaceuticals preparation were monitored. NM technologists have to be close to the patient during radiopharmaceutical injection and patient positioning on the gamma camera table. An electronic personal dosimeter DKG-21 Ecotest made in Ukraine which records the ambient dose equivalent rate and equivalent dose was used to monitor the radiation exposure to the technologists and to record the accumulation dose in mSv throughout a working day. This study was accomplished between the time period of January to June 2011. The dosimeter is designed to measure individual equivalent dose $H_p(10)$. The dose range of gamma radiation was 0.01 mSv to 1 Sv and the energy range 0.05 to 6 MeV which was suitable for NM procedures. The planar and tomography NM images were performed by the 2 technologists in the morning and afternoon shifts.

Results: The average monthly occupational dose of each technologist was approximately 0.6 mSv. Their annual doses were 6.6 and 8.8 mSv, respectively. They were lower than the maximum permissible dose of 20 mSv/y. Total number of NM procedures performed in this NM center during June 2010 to June 2011 was 3265.

Conclusion: The use of APD for monitoring the NM technologists is a useful tool to check compliance with regulatory dose limits and radiation protection principals.

Keywords

Active personal dosimeter, Occupational dose, Nuclear medicine, Yazd, Radiation protection

Introduction

Nuclear medicine (NM) is a medical area that employs radioactive materials for imaging procedures in diagnosis, treatment and prevention of diseases. It allows the acquisition of anatomy and function organs data [1]. The most commonly used techniques in Iran are the planar (gamma camera) and the single photon emission computed tomography (SPECT). NM procedures are, by the standards of technology-intensive medicine, relatively low-cost, safe and minimally invasive [2]. However, the staff is potentially exposed to ionizing

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radiation; this is due to the fact that some of them have to stay close to the radionuclides during the preparation of radiopharmaceuticals and to the patient who becomes the radioactive source, after injection [3]. The dose of the patient in this procedure is usually low compared with the dose in a procedure that uses computed tomography, but the external occupational dose is higher [4-8]. So, routine monitoring of occupational exposures is carried out for several reasons. The most obvious reason is to verify and demonstrate compliance with the regulatory dose limits. It can help to observe the ALARA principle (as low as reasonable achievable). Routine personal dosimetry is also one of the most important tools to achieve or demonstrate an appropriate level of radiation protection [9]. Active personal dosimeters (APDs) have many advantages compared with passive dosimeters for individual external radiation dose assessments. In most countries APDs continue to be exclusively used for operational radiation protection monitoring [10].

The dose limit for employees exposed to radiation is 20 mSv/y in Iran, based on the recommendation of the International Commission for Radiological Protection (ICRP) No. 93 [11]. Such employees are required to be individually monitored for exposure to ionizing radiation. The high sensitivity and immediate reading of electronic semiconductor dosimeters may become very useful for exposure control under risky working condition. It may become an important help for optimizing radiation protection. The aims of the present study were a) the estimation of NM technologists' exposure to radiation in the sole NM center of Yazd province and b) the investigation of possible relationship between the dose of the personnel and the number of examinations.

Materials and Methods

Real-time dosimetry evaluation was performed in the sole private nuclear medicine center of Yazd. Individual whole-body doses

were measured daily for the two technologists for the time period of January 2011 to June 2011, that is six months, using the APD (DKG-21- Ecotest, made in Ukraine). The error range of this APD for 0.01 mSv to 0.1 mSv equivalent dose was 8%. The personal dose equivalent at a depth of 10 mm, $H_p(10)$ for dosimeter worn on the front of the chest was used as an estimator of the effective dose. The dosimeter was calibrated at the Ecotest Co laboratory. The minimum detection limit (MDL) of film badge system in Iran is 0.05 mSv. The corresponding detection limit of DKG-21 used in this study was 0.001mSv. A wide range of diagnostic procedures is performed at NM center: Bone scans, dynamic and static kidney studies, brain studies, myocardial perfusion imaging and thyroid investigations. All these diagnostic examinations are achieved using ^{99m}Tc tracer. The only therapeutic NM procedure performed in the center is the ^{131}I thyroid hyper function disease treatment. Maximum treatment dose for the out-patient ^{131}I therapy does not exceed 600 MBq. The administered diagnostic radiopharmaceutical dose given to the patient complies with the recommendations of UNSCEAR 2008 report ⁽¹²⁾. Radiopharmaceutical labeling was performed in the hot laboratory using lead shielded vials during generator eluting, labeling and dispensing procedures.

The technologist performing the acquisition was at a reasonable distance from the patient, shorter during patient positioning and longer (about 3–4 m) during acquisition time. There was no additional shielding between the patient and the technologist.

In NM center the technologist's tasks are labeling, injection of radiopharmaceuticals and patient imaging of the NM instrumentation, whereas the physicians' duty is examining the patients and reporting. The administrative staff are involved in the office work and patient registration. The dosimeters were programmed to record the dose from 8:00 AM until 1:00 PM and from 4:00 PM until 9:00 PM. The dosim-

Table 1: The number of NM procedures performed by the technologist in the morning shift and her effective doses (mSv) per month during the period January to June 2011 (All diagnostic examinations were achieved using ^{99m}Tc tracer.)

Procedure Month	Stress	Rest	MDP	Thy	DMSA	DTPA	Remain	Dose (mSv)
January	63	47	55	16	10	7	16	0.87
February	57	30	26	21	3	3	20	0.27
March	34	18	24	9	3	3	7	0.17
April	63	34	45	15	8	8	6	1.03
May	67	39	34	8	7	7	11	1.08
June	80	33	39	5	3	4	13	0.98
Sum	364	201	223	74	34	32	73	4.40
Average activities (mCi)	21±6	29±6	22±4	2.5±.6	4±.9	7.4±1.8	--	---

eters were also programmed to sound an alarm if the dose rate exceeded $3\mu\text{Sv/h}$.

Results

The number of NM diagnostic and therapeutic procedures was 1752 over the study period of January 2011 to June 2011. The total number of NM procedures during one year (from June 2010 to June 2011) was almost 3500. All of these procedures were performed by the two technologists that worked in the morning and afternoon shifts. The average daily doses for each technologist, based on a time schedule of 5 hour work in the morning or afternoon shift were $55\pm 31\mu\text{Sv}$ and $33\pm 15\mu\text{Sv}$, respectively. (Background equivalent dose per shift was $1\mu\text{Sv}$). The effective dose for each technologist during the six months was 4.4 and 3.29 mSv. Tables 1 and 2 show the number of NM procedures according to the various examinations and the monthly effective dose for each technologist. The most frequent examination performed in the morning shift was the stress cardiac examination, whereas the most frequent examination performed in the afternoon shift was bone scan examination. The sums of examinations in morning and afternoon shifts were 1001 and 751 examinations, respectively. The linear correlation between examination frequency and radiation dose for technologists

was 0.718 and 0.56 in the morning and afternoon shifts, respectively.

Discussion

Nuclear medicine technologists are exposed to ionizing radiation from many sources during their working day. Most measurements of technologists' exposure have been derived from measured external dose rates at various distances together with the average times that the technologist spends at each of those distances. Harding *et al.* reviewed such measurements and concluded that for three common procedures (bone, liver and kidney studies) the larger dose came from the patient procedure rather than from the handling of the syringe (dispensing and injecting) [13]. Greaves and Tindale used the same method to determine the dose to the technologist during rest/stress myocardial perfusion imaging with ^{99m}Tc -mibi. They determined an average dose of 12-14 μSv per patient for the technologist [14]. A number of investigators have used pocket electronic dosimeters to record directly the technologist's occupational exposure removing the limitation of dosimetry in each task of technologist [15,16]. However, these dosimeters will normally integrate the dose received by the wearer and will not allow the dose from individual tasks to be determined easily.

Table 2: The number of NM procedures performed by the technologist in the afternoon shift and her effective doses (mSv) per month during the period January to June 2011 (All diagnostic examinations were achieved using ^{99m}Tc tracer.)

Procedure Month	Stress	Rest	MDP	Thy	DMSA	DTPA	Remain	Dose (mSv)
January	0	12	55	12	11	16	20	0.372
February	0	13	66	26	12	23	9	0.335
March	9	3	36	1	4	9	8	0.212
April	0	9	83	5	12	14	22	0.758
May	0	5	87	4	18	17	13	1.07
June	0	8	69	4	13	17	6	0.541
Sum	9	50	396	52	70	96	78	3.29
Average activities (mCi)	25±.5	20±1	19±2.6	3.2±.7	4±2	8.4±5	--	--

Moreover, a single dosimeter may not record adequately the varying radiation fields as the technologist performs the various procedures. APDs have many advantages compared with passive dosimeters for individual external radiation dose assessments [17]. In 1994, a first approval was given in the UK to use an electronic dosimeter for the legal assessment of the occupational dose in a research centre [18]. However, nowadays very few countries use such devices to record the legal dose. In most countries APDs continue to be exclusively used for operational radiation protection monitoring. Of course the use of APD in X-ray radiology or pulsed fields is not recommended, in particular, in interventional radiology [19]. Another drawback for their use as official dosimeters for dose record was that, both the operational quantities, $H_p(10)$ and $H_p(0.07)$, had to be reported, whereas only a few APDs provided this information [19]. These new dosimeters did not generally show better results than the passive ones, but they improved the performance of older designs and provided the advantages of APDs, alarm signals and on-line information about the level

of exposure, as well as a much lower detection limit.

In this study a personal dose equivalent at a depth of 10 mm, $H_p(10)$ for dosimeters worn on the front of the chest was used as an estimator of the effective dose as Piwowska *et al.* did in their study. (They monitored the exposure of employees in a nuclear medicine department during the years 1991 – 2007) [10].

Based on our results, the frequency of NM examinations in the morning work shift was more than that in the afternoon shift. This was due to the referrals from the general hospitals of the city which were usually in the morning. The number of heart disease patients and angiography examinations in the morning shifts were higher than that in the afternoon shifts.

The correlation coefficient between the monthly equivalent dose and the number of performed NM procedures during the analyzed period was calculated and found to be not statistically significant ($r = 0.72$ and 0.56 for the morning and afternoon shifts, respectively).

This result was similar to the finding of Piwowska-Biliska *et al.* [10]. These low lin-

ear correlations were possibly due to the variations of age and weight of the patients which resulted in a wide variation in the administration of ^{99m}Tc . Furthermore, The technologist's skillfulness in labeling procedures, effectiveness in injection of radiopharmaceutical, time duration during patient positioning and application of radiation protection rules played an important role in the technologist daily dose.

As shown in the tables 1 and 2, the number of examinations in March was lower than that in the other months. This was, of course, due to the Iranian New Year vacations. The annual individual dose equivalents received by the technologists in this study was approximately 8 mSv. The average annual dose for a nuclear medicine technologist in Lithuania (1991–2003) was 2.12 mSv [8]. The Lithuanian results correspond to the average doses for the radio-pharmacy technicians presented in Piwowarska *et al.*'s paper [10]. The average annual doses for the nurses, technicians and radio-pharmacy technicians presented in Piwowarska *et al.*'s paper were 4.6, 1.9 and 2.3 mSv, respectively [10]. The difference between our results and their data was due to the fact that the duties of the three employees (nurse, radio-pharmacy technician and technician) were done by a single technologist in a shift in our study. In a Portuguese study, the average annual doses of nurses and technicians were 3.2 and 3.3 mSv, respectively [4]. Pratt *et al.* reported an average annual dose of 1.3 mSv and argued that the 2 technologists who dispensed radiopharmaceuticals received more than 5 mSv/y [20]. Harbottle *et al.* reported monthly doses of 200–400 μSv and annual equivalent dose of 4 mSv [21]. According to the Australian experience, the annual effective dose of a person working in a conventional nuclear medicine department was about 2.0 mSv [22]. This variation in radiation dose can be explained by various organisational differences in the duties of particular employees within different nuclear medicine departments. The International Atomic Energy Agency (IAEA)

recently reported effective doses for the personnel in nuclear medicine departments to be approximately 3–5 mSv/y (including positron emission tomography (PET)) [23]. Despite the fact that the average annual dose of the technologists in NM Yazd center was more than the value reported by the IAEA, it was lower than the allowable limit for radiation workers in Iran (20 mSv/y).

This paper encourages more involvement of the radiation protection officer and pays attention to radiation protection recommendation. In addition, NM occupational duties should be shared among different health providers; for example, injection of radiopharmaceutical should be performed by the doctor and patient positioning by the nurse and so on.

Conclusion

In the NM center of Yazd, the duties of nursing, labeling and data acquisition are performed by a single technologist in each working shift. Therefore, necessary measures must be taken to improve the radiation protection. Furthermore, it seems that the duties should be divided among more people.

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