

Evaluation of Whole-Body Radiation Doses for Nuclear Medicine Staff in the Preparation and Application of Radiopharmaceuticals in Iraqi Hospitals

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ABSTRACT

Nuclear medicine staff are routinely exposed to ionizing radiation while preparing radioisotopes, administering them, and imaging patients. With radiation dangers growing with exposure, safety assessments are essential to ensure that practice adheres to international recommendations and dose limitations. The purpose of this study is to quantify staff exposures during specific molecular imaging methods, such as positron emission tomography with computed tomography (PET/CT) and single photon emission computed tomography (SPECT). We assessed the radiation exposure of technologists working on dose rate measurement with a dosimeter for cumulative dose confirmation. Occupational exposures for 15 nuclear medicine staff at three Iraqi hospitals were tracked over a period of 3 months. Whole body dose equivalent values were measured. In mSv, the respective mean effective dose in PET/CT and SPECT were 0.069 ± 0.086 , and 0.066 ± 0.049 , respectively. Extremity dosage values were, in all cases, much below the yearly dose limit. Still, given personnel dosages vary greatly, rigorous evaluation of working situations is advised to help to guarantee occupational exposures stay below annual dose limits.

Keywords: Nuclear Medicine; PET/CT, SPECT, Pocket Dosimeter, Radiation Dose

INTRODUCTION

Positron emission tomography (PET) combined with computed tomography (PET/CT) was first used in clinical nuclear medicine in 1998. Combined with conventional single photon emission computed tomography [1]. PET/CT is becoming the preferred method for treating a wide range of cancers. It provides physiological and anatomical images of solid organs, bones, and bone marrow. The patient can be scanned from the base of the cranium to the middle of the thigh, or from the vertex to the toes. PET/CT is also the preferred modality for evaluating treatment outcomes following radiation therapy and chemotherapy [2]. As a result of the significant demand for clinical PET/CT treatments, advances in PET/CT technology and the installation of medical cyclotrons in hospitals are rapidly growing [3]. In the PET procedure, the body is administered short-lived positron-emitting radioisotopes [4]. An increase in the number of patients undergoing PET may result in an increase in radiation exposure for the personnel who are responsible for patient care. The 511 keV gamma radiation generated by the annihilation process in PET can result in a higher level of radiation exposure for staff than the 140 keV γ -rays of technetium 99m (^{99m}Tc) [5, 6]. The 140-keV photons from ^{99m}Tc have a half-value layer of 0.28 mm for lead under narrow beam geometry whereas for 511-keV photons this value is 4.1 mm. The specific gamma-ray constant for ^{18}F is practically six times larger than for ^{99m}Tc . As such, the quantity of lead required to suitably control the high-energy emissions from ^{18}F is similarly increased. According to a 2000 United Nations Scientific Committee on the Effects of Atomic Radiation report, radiation exposure to workers could vary 10-to 20-fold depending on precautions given by the health care provider even among patients getting the same radiologic examination [7]. Consequently, appropriate shielding should sufficiently restrict the exposure from ^{18}F -FDG to reduce the radiation level to staff members. Apart from this, the observed radiation dose is connected to the degree

of activity in the source and the length of time a person is exposed to the source. Since the dose to the technologist is substantially larger when a patient requires complete assistance than in an ambulant patient, the length of each step of PET imaging varies from one technician to another and relies also on the patient's state. Consequently, the issues of radiation safety in a PET/CT facility have to be sufficiently addressed. The evaluation of radiation safety and dosage received by staff members using conventional nuclear medicine tracers is the subject of many studies accessible in the literature [8]. Although published statistics on personnel working in a dedicated PET/CT facility are available, there is no agreement among them on the anticipated dosage to workers [9]. Measuring nuclear medicine department staff exposures and assessing the dosage for staff members in view of present practices are the objectives of this study.

MATERIALS AND METHODS

Radiologists' occupational radiation levels were recorded and examined during a three-month period, from March 2024 to May 2024. The overall number of employees was 15, including technologists. The availability of current hybrid equipment (PET/CT, and SPECT) within the department allows performance of all the investigations of interest, use being made of the great variety of radiotracers available. Before imaging patients were appropriately ready, for example, fasting for six hours before several tests, especially those requiring FDG. The total activity ranges from (150-450 and 300-750) mCi for PET/CT center A, B, respectively. (40-50 and 30) GBq for SPECT center A and C, respectively. To ensure proper radiopharmaceutical uptake, picture capture typically begins 45-90 minutes post-administration for all participants in the study. We received ethical and research committee permission for the study. Table 1 shows the equipment utilized in this study.

Table 1: Nuclear Medicine Equipment

Equipment	Vendor/ Model	Hospital
PET/CT	Discovery IQ PET/CT scanner (GE Healthcare, Milwaukee, WI, USA)	Al- Andalus
SPECT	Discovery IQ PET/CT Scanner (Manufactured by GE2 Healthcare in Milwaukee, WI, USA) GE Healthcare (Al- Andalus and AL Amal)	Al-kawthar

The measurements were conducted in three nuclear medicine departments: two PET/CT departments (center A- Al- Andalus hospital) in Baghdad, Iraq, and (center B-Al-kawthar Hhospital) in Basra, Iraq, which dealt with F-18-labeled radiopharmaceuticals, and a department of scintigraphy, primarily handling Tc-99m, at center C- AL Amal hospital and center A- Al- Andalus hospital. The study was conducted throughout all departments over a period of three months. Doses of radiation were quantified for a total of 15 employees. The PET/CT centers (A and B) were surveyed and had staffs of 3 and 5 persons, respectively. Similarly, the SPECT centers (A and C) were surveyed and had staffs of 3 and 4 persons, respectively. The procedures in all centers were conducted with lead-shielded vials, shielded syringes, and specialized shielded manipulation chambers. The staff nurse begins the day workflow by welcoming the patients and performing examinations of their body mass, height, and glucose levels. Subsequently, the technician performs a concise validation of crucial data (such as the patient's fasting condition and latest chemotherapy/radiotherapy procedure) through an interview in the uptake chamber. A technologist provides a detailed explanation of each stage of the examination to the patient. The staff technologist uses the autoinjector to insert a peripheral intravenous (IV) line for administering the ^{18}F -FDG. Once enclosed within a protective lead syringe shield, the syringe is then delivered to the injection chamber using a container that provides additional shielding. The duration of the injection ranges from 30 to 60 minutes. The patient next is instructed to lie on the bed or reclining chair in a supine position. A closed-circuit television system housed in the nursing stations tracks the patient's condition over this period. The door to the absorption room will be closed and a notice stating the room is occupied after the patient has got the injection. This helps to prevent inadvertent entry of housekeepers and other paramedical personnel inside the room. The patient is advised to empty their bladder using the toilet in the uptake room using an intercom system linked to the nurse station before the scan. The PET/CT technologist will next show the patient to the scanning room. Installations of PET scanners included extra radiation protection measures. High-density doublebrick walls enclosed the scanning room. Between the scanner and console rooms were lead glass windows measuring 1.5 mm lead equivalent. Syringes were transported from the hot lab to the injection chamber using lead

containers. Every staff member in Al-Andalus Hospital wore instadose badges in the top pocket of their overalls to ascertain the comparable dosage from external exposure. Whole-body instadose readouts equated to one month's cumulative dose measurements, as required by country regulations [9]. The Direct Ion Storage systems operate by using a gas-filled ion chamber with a floating gate to generate interactions that separate ions by the difference between electrodes. These ions (+, -) are stored in the memory cell element until they are "read" electronically to quantify the amount of radiation dose. Al-kawthar and AL Amal hospital Hospital carried out whole-body exposure measurement utilizing Mirion Technologies' electronic personal dosimeters, RAD-50/62 Instruments. Their component is a single silicon diode solid state semi-conductor detector. Within the x-ray and gamma energy range of 55 keV to 3 MeV, the radiation dosage from 1 μSv to 9.99 Sv or dose rates from 5 $\mu\text{Sv/h}$ are measured. These EPDs have accuracy falling between 10%. These EPDs were run in autonomous mode; dosages were monthly read and recorded in milivert (mSv). During the duration of this investigation, each staff member's behaviors were watched and documented. The following data were collected: staff time spent and distance from the radioactive source, the syringe holding the radiopharmaceutical, or the injected patient, as well as patient data on administered activity and status.

Statistical Analysis

The mean and standard deviation (SD) were used to represent all results. Microsoft Office Excel 2016 was used for all statistical analysis. In order to compare data between variables, a paired and unpaired Student's t-test was used. The result was considered statistically significant if $P < 0.05$.

Results

Table (2) shows the total number of patients in center A was 292 during period 1, 244 during period 2, and 263 during period 3. In center B, the number of analyzed procedures was 170, 177, and 184 during periods 1, 2 and 3 respectively, PET/CT department. For center C the total number of patients for 3 months was 170 during period 1, 177, and 184 during period 2 and 3, respectively. In center A there are (177, 76, 60) patients during period (1,2,3) months, respectively.

Table 2: Analysis of the Workload and Personnel Involved in PET/CT and SPECT Operations at two Different Sites.

TABLE 2: Analysis of the Workload and Personnel Involved in PET/CT and SPECT Operations at two Different Sites						
Period	Centre A			Centre B		
	PET/CT					
Time Period (Months)	1	2	3	1	2	3
Number of Patient	292	244	263	170	177	184
Total Number of Staff Analyzed, including those Involved in PET/CT.		3			5	
	SPECT					
Period	Centre A			Centre C		
Time Period (Months)	1	2	3	1	2	3
Number of Patient	177	76	60	170	177	184
Total Number of Staff Analyzed, including those Involved in SPECT.		3			4	

Note: Center A- Al- Andalus Hospital, Center B- Alkawthar Hospital, Center C Al- Amal Hospital.

The data shown in table 3 represents the average values $\pm$ standard deviation ($\pm$ SD) for various characteristics, including weight in kilograms, height in meters, body mass index (BMI) in kilograms

per square meter, age in years, sex, and activity. Additionally, the table includes the effective dosage values in milli-sieverts. We computed the average and the measure of variability by utilizing the Excel software

application. Out of the total number of workers, 15 were radiographers. Among these, 8 were assigned to work in PET/CT and 7 were assigned to work in SPECT, as indicated in Table 3. At baseline, the mean $\pm$ SD age of the workers in the PET/CT and SPECT departments was (32.85 ± 5.69) and (36.57 ± 6.80) years, respectively, and 7 (87.5%), 1 (12.5%), were male and female, respectively, in the PET/CT unit. And 4 (57.14%), and 3 (42.85%) were male and female, respectively, in the SPECT unit. The mean BMI (kg/m^2) was 28.88 ± 6.57 and $27.81 \pm$

3.79 for staff workers in PET/CT and SPECT, respectively. The routine personal dosimeter readings over a 3-month period revealed that 1330 patients received injections totaling 363.79 mCi. Based on these readings, the average effective dose for all workers in the PET/CT department was between 0.069 ± 0.086 mSv. By using the total activity of 37.28 GBq/ $^{99\text{m}}\text{Tc}$ in the 3-month period, the average effective dose for all workers throughout the study period ranged from (0.066 ± 0.049) mSv in the SPECT department.

Table 3: Characteristics of Cases included in the Study

Parameters		Mean $\pm$ SD	
		PET/CT Scan (n=8)	SPECT (n=7)
Age, Years		32.85 ± 5.69	36.57 ± 6.80
	Sex		
	Male	7(87.5%)	4 (57.14%)
	Female	1(12.5%)	3 (42.85%)
Body Mass, kg		87.85 ± 22.16	81.42 ± 17.10
Height, m		1.74 ± 0.10	1.70 ± 0.12
BMI, Kg/m^2		28.88 ± 6.57	27.81 ± 3.79
Activity		(363.79 ± 154.20) mCi	(37.28 ± 7.160) GBq
Effective Dose (mSv)		0.069 ± 0.086	0.066 ± 0.049

Whole-body measurement radiation doses were reported in table 4. The ^{18}F -FDG injection activity per patient was between (150 to 450) mCi (272.86 ± 99.47) mCi for all staff in center A. The measurement was performed in male and female in PET/CT. The mean doses per study was (0.04 ± 0.019) mSv for male, and (0.196 ± 0.23) mSv.

The mean effective dose received by whole-body for all radiation worker in center B according to dosimeter are illustrated in table 3. The effective dose of male was 0.052 ± 0.008 mSv when the ^{18}F -FDG injection activity per patient was between (300 to 750) mCi (493.47 ± 122.38) mCi.

Table 4: Occupational Radiation Dose (mSv), and Activity (mCi) in PET /CT Units

Gender	No.	Effective dose (mSv)	Activity (mCi)
Center A			
Male	2	0.04 ± 0.019	273.008 ± 98.77 (150-450)
Female	1	0.196 ± 0.23	272.54 ± 102.01 (150-450)
Overall	3	0.096 ± 0.14	272.86 ± 99.47
Center B			
Male	5	0.052 ± 0.008	493.47 ± 122.38 (300-750)
Female	0	-	-
Overall	5	0.052 ± 0.008	493.47 ± 122.38

A: AndulusHospital, B: Alkawthar Center.

Table 5 presents whole body effective doses and activities for staff member for the observed 3 months. During preparation and injection of $^{99\text{m}}\text{Tc}$ radiopharmaceutical, average effective dose was (0.051 ± 0.019) mSv for center A. For the technologists in center C the effective dose for male was (0.083 ± 0.055) mSv and (0.076 ± 0.066) mSv for female, respectively. The average doses received by nuclear medicine technologists were higher in center C (0.07 ± 0.061) mSv

than center A (0.051 ± 0.019 mSv). The mean doses per study was higher in male for center C than center A.

Occupational exposure was measured using dosimeters for technologist working in the nuclear medicine department. Table 6 shows a descriptive statistic of the personal effective dose readings for 3 centers in Iraq.

Table 5: The SPECT Units for Measuring occupational Radiation Dose are Expressed in Millisieverts (mSv).

Gender	No.	Effective Dose (mSv)	Activity (GBq)
Center A			
Male	3	0.051 ± 0.019	42.73 ± 4.47 (40-50) GBq
Female	0	0	0
Overall	3	0.051 ± 0.019	42.73 ± 4.47
Center C			
Male	1	0.083 ± 0.055	30.00 ± 0.00 30 GBq
Female	3	0.076 ± 0.066	30.00 ± 0.00
Overall	4	0.07 ± 0.061	30.00 ± 0.00

The mean of the occupational exposure for whole body for center A were (0.19, 0.05, and 0.045) mSv and average administered dose per activity were (0.00072, 0.00018, 0.00016) mSv mCi⁻¹ for technologist 1,2,3, respectively. The mean $\pm$ SD of the effective doses for staff in

center B were (0.053 ± 0.005 , 0.053 ± 0.005 , 0.05 ± 0.01 , 0.05 ± 0.01 , 0.056 ± 0.015) mSv, The dose per injection was $0.0001 \pm 4.63 \times 10^{-5}$, $0.0001 \pm 4.63 \times 10^{-5}$, $0.0001 \pm 8.026 \times 10^{-5}$, $0.0001 \pm 8.026 \times 10^{-5}$, 0.0001 ± 0.0001) mSv mCi⁻¹ for technologist 1,2,3,4,5, respectively.

Table 6: Staff Members Working with 18F-FDG PET/CT Procedures Receive an Effective Whole-Body Dosage.

Center A			
Radiation Worker	Activity (mCi)	Effective Dose (mSv)/Study	Dose Per Injected Activity (mSv mCi ⁻¹)
Technologist 1	272.54 ± 102.01	0.19 ± 0.23	0.00072 ± 0.0023
Technologist 2	272.32 ± 102.1	0.05 ± 0.026	0.00018 ± 0.00025
Technologist 3	272.32 ± 102.1	0.045 ± 0.021	0.00016 ± 0.00022
Center B			
Technologist 1	493.47 ± 124.59	0.053 ± 0.005	0.0001 ± 4.63×10 ⁻⁵
Technologist 2	493.47 ± 124.59	0.053 ± 0.005	0.0001 ± 4.63 ×10 ⁻⁵
Technologist 3	493.47 ± 124.59	0.05 ± 0.01	0.0001 ± 8.026×10 ⁻⁵
Technologist 4	493.47 ± 124.59	0.05 ± 0.01	0.0001 ± 8.026×10 ⁻⁵
Technologist 5	493.47 ± 124.59	0.056 ± 0.015	0.0001± 0.0001

Table 7 presents our results. This table shows the dose rate per 3 months and activity for nuclear medicine staff working in the centers (A, C) covered by the study. The average dose to the whole body of the technologist per procedure was 0.056 ± 0.015 mSv, 70.066 ± 0.0057 mSv, and 0.03 ± 0.01 mSv, respectively, and similarly, the average activity of the technologists per procedure was 40.45±2.10 mCi, 47.08±4.59 mCi, and 40.42 ± 2.04 mCi, respectively, for center A.

Technologist 3, rotating through SPECT, received a higher radiation dose than those other technologists in center C and A.

The average dosimeter reading over the 3 months investigated was (0.05 ± 0.043, 0.056 ± 0.055, 0.12 ± 0.089, and 0.083 ± 0.055) mSv for technologists (1, 2, 3, 4), respectively, compared with activity of 30.00 GBq. Table 6 displays the dose per activity reading procedure.

Table 7: Staff Members Working with SPECT Procedures Receive an Effective Whole-Body Dosage.

Center A			
Radiation Worker	Activity (mCi)	Effective dose (mSv)/study	Dose Per Injected Activity (mSv GBq ⁻¹)
Technologist 1	40.45±2.10	0.056 ± 0.015	0.001 ± 0.007
Technologist 2	47.08 ± 4.59	0.066 ± 0.0057	0.0014 ± 0.0012
Technologist 3	40.42 ± 2.04	0.03 ± 0.01	0.0007 ± 0.0049
Center C			
Technologist 1	30.00±0.00	0.05 ± 0.043	0.0016±0.00
Technologist 2	30.00±0.00	0.056 ± 0.055	0.0018±0.00
Technologist 3	30.00±0.00	0.12 ± 0.089	0.0041 ± 0.00
Technologist 4	30.00±0.00	0.083 ± 0.055	0.0027±0.00

The dosage rates were measured at various distances from the ¹⁸F-FDG-injected subjects. The exposure rates for technicians vary accordingly.

After 370 MBq (10 mCi), ¹⁸F-FDG levels were significantly higher at close contact (0.087 ± 0.10) compared to 0.03 ± 0.012 at <75 cm. This suggests that each technician may place up to 25 patients every

day, which exceeds the capacity of any department (Table 8). Table 9 displays the average rates of radiation exposure recorded at different distances from patients who were injected with ^{99m}Tc, both 1 and 120 minutes following the injection.

The external dosage rate exhibited a substantial decrease in correlation with the distance from the patient.

Table 8: Dose Rate Measurements at Various Distances for Technologists Working with a PET/CT Unit:

Distance (cm)	Average Dose (mSv/study) Mean ± SD	Average Activity (mCi) Mean ± SD
15-25	0.087 ± 0.10	455.22 ± 152.77
25-45	0.06 ± 0.092	355.62 ± 148.94
45-75	0.056 ± 0.021	271.11 ± 104.71
< 75	0.03 ± 0.012	243.75 ± 88.74

Table 9: Dose Rate at Different Distances for Technologists, SPECT Unit:

Distance (cm)	Average Dose (mSv/study) Mean ± SD	Average Activity (mCi) Mean ± SD
20-40	0.076 ± 0.11	40.51±2.23
40-60	0.07 ± 0.00	38.00 ± 4.21
60-90	0.069 ± 0.009	35.38 ± 5.18
90-120	0.063 ± 0.004	34.54 ± 5.03
120-140	0.057 ± 0.008	33.86 ± 5.79
<140	0.05 ± 0.00	31.53 ± 3.75

Discussion

When preparing and administering the labeled radionuclides as well as imaging patients, nuclear medicine technologists may be exposed to a significant amount of ionizing radiation from various sources. In each case, staff members may spend up to 2.5 hours following the injection in close proximity to the source. Furthermore,

individuals undergoing ¹⁸F-FDG PET/CT may need to completely relax for 15 minutes before the treatment begins. Approximately 6000 SPECT operations and up to 4000 PET CT procedures are conducted annually at three hospitals in Iraq; the personnel are obviously operating in an atmosphere with a particularly high workload. It is essential to continuously evaluate the staff's dosage to make sure they are under the annual dose limits that have been given. Additionally,

work practices for limiting radiation exposure must be improved. It has been found that staff members using traditional nuclear medicine receive a lower average whole-body dosage per procedure than those receiving PET therapy. This makes sense because positron-emitting radiopharmaceuticals have a larger exposure rate constant and penetrate annihilation rays [8]. The results of occupational exposure for technologists using two PET/CT units are displayed in Table 4. Regarding the entire body and the survey period, the findings indicate that, for the same PET/CT group, female staff at center A received higher doses than male staff, whereas male staff at center B received higher doses than male staff at center A. Additionally, Table 4 lists seven persons' occupational exposures from SPECT examinations. The results for the SPECT group indicate that male employees at Center C received a higher dose than those at Center A. The result can be ascribed to the workload for each group; in PET/CT, for example, there is only one female technician who does all operations, as opposed to 33% of male staff in center A, and none at center B. Male employees made up 57.14% of the workforce in SPECT, which is higher than the percentage of female employees. Only slight variations were noted when Shi et al. [10] evaluated global gender variance and dose in best practice nuclear cardiology in the literature. Therefore, taking into account the current findings, careful assessment of working conditions and training of staff are recommended in seeking to reduce occupational exposure gender differences at the present study center. The impact of extending the distance on the external dosage rate reduction is Table 9, 10 illustrates how radiation safety rules can be optimized to reduce the external dose rate. For instance, staff should handle injected patients more quickly and at a safe distance. Regular bladder emptying is recommended for the patient since it significantly reduces the external dose rate.

As the distance increased, the external dosage rate of the injected individuals decreased noticeably. Technologists' exposure to radiation varies depending on a number of circumstances, including as their training, experience working with radioactive materials, the amount of activity they administer, the state of their patients, their distance from radioactive sources, the existence of shielding, and the length of time they spend in close proximity to them. As evidenced by several research [11, 12], working with radioactive patients increases a technologist's radiation exposure during PET/CT scans. This study's findings are summed up in Table 6. In order to ensure that the workers' exposure to radiation remains within the acceptable limit, it is advisable to hire more staff when there is a plan to increase the number of patients, the number of working shifts, or the number of scanners [11]. It is noteworthy that the settings and unique elements of each PET/CT facility, such as the patient administered doses, the imaging protocol, the personnel performance, and the facility design, make it difficult to compare doses across different facilities. On the other hand, this study's maximum dose to the technician per PET/CT session was 0.069 mSv. The average dosage for a nuclear medicine technologist per ventilation/perfusion lung scan and bone scan was

1.09 mSv and 1.31 mSv, respectively, according to Smart [12]. The most widely used isotope in conventional nuclear medicine is ^{99m}Tc , which has a photon energy of 140 keV compared to the 511 keV of ^{18}F . Staff members exposed to the 511 keV radiation of ^{18}F -FDG may be exposed to higher occupational risks than those using conventional procedures (^{99m}Tc). In the latter case, Mettler et al. [13] noted that, at the time of the investigation, ^{99m}Tc was used in up to 90% of nuclear medicine procedures; additional radionuclides that were used included ^{131}I , ^{123}I , and ^{201}Tl . There was no difference in the occupational doses between the SPECT and PET/CT groups. The two groups' effective doses are shown in Tables 6 and 7. According to these findings, there have been no cases of dosing limit exceedance in the current practice. Consequently, additional protective measures are needed to bring the dosage down to as low as reasonably feasible (ALARA). The current dose is equivalent to the majority of earlier studies conducted on occupational exposure at nuclear medicine departments [14-16]. The design of the department, the patient's interaction following radionuclide administration, the availability and use of appropriate protective equipment, the management of administered activity, radionuclide uptake, and the interval between injection and image acquisition all affect occupational exposure for nuclear medicine personnel. These investigations demonstrated that, given the current workload, PET/CT staff members are adequately safeguarded. According to Seierstad et al. [17], 60% of the dose received by technologists in PET/CT imaging is attributed to handling radiopharmaceuticals, while 40% is due to interacting with patients. On the other hand, Costa et al. [18] found that 41.5% of occupational doses in PET/CT imaging are caused by injecting radiopharmaceuticals, and 51.1% of the dose is received during patient setup and positioning. The preparation and delivery of unsealed source beta emitters, which may result in large skin doses to the upper extremities, is obviously the cause of extremity doses to nuclear medicine technologists. Thus, efforts to reduce occupational dose can be greatly aided by the use of automatic injectors. The personnel will not be exposed to avoidable radiation-induced cancer risk or tissue response risk if nuclear medicine procedures are properly justified, optimized, and supported by appropriate protective gear and accessories.

Conclusion

Over a three-month period, 15 nuclear medicine personnel at three hospitals in Iraq had their occupational doses recorded. with staff exposed to relatively high-energy gamma rays. the worker's effective whole-body dose within the ICRP-recommended permitted limits.

Wide variations in dose were found in the survey among the staff members (male and female), and as a result, a thorough evaluation of working conditions is advised in an effort to guarantee that occupational exposures stay within annual dose limits.

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