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Assessment of Radiological Doses to Radiation Workers in [F-18] FDG Production Facility at AFIRI Rawalpindi

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ABSTRACT

Objective: Present study conducted for the measurement of radiation doses received by the radiation workers due to their direct involvement in handling of unsealed radionuclides for the PET/CT scanning.
Study Design: Quasi Experimental Study.
Place and Duration of Study: PET-CT and Cyclotron Department, Armed Forces Institute of Radiology and Imaging, Rawalpindi Pakistan, from Aug 2020 to Jul 2021.
Methodology: TLD film badges and ring dosimeters, based on LiF:Mg:Ti material, were used for the detection and measurement of radioactivity. The measurements were performed for both whole body and extremity (fingers) dose measurements.
Results: The measured radiation doses were in the range of 362.75 mSv/y to 409.74 mSv/y and 0.08 mSv/y to 4.35 mSv/y for extremities and whole body, respectively. Number of injections was calculated for extremity workers and found to be 720±27 injections per worker per year.
Conclusion: The measured results clearly show that the annual doses for whole body (20 mSv/y) and extremity (500 mSv/y) of radiation workers are under the recommended limits. However, radiation workers with direct access to radioisotopes were more exposed to radiation. The results of present study were also in good correspondence with the published data.

Keywords: Contamination, Extremity, F-18 FDG, Ionizing Radiation, Nuclear Medicine, Occupational Exposure, Unsealed Radioactive Sources.

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INTRODUCTION

The nuclear medicine practices engage handling of unsealed radionuclides and establish direct contact of radiation workers with radioactive vials and syringes. The possibility of contamination also applies while managing radioactivity, resulting unwanted anthropogenic radiation exposure to the occupational workers.[1] The procedures involve intravenous administration of radiopharmaceuticals and the most commonly used radioisotope in our department was flouro-deoxyglucose 18FDG injection. Fluorine-18 was major radioactive element in the solution having half-life of 109.74 min and it provides gamma energy of 511 keV with the help of two photons. In this regard, this study was conducted in PET-CT and Cyclotron department of AFIRI, Rawalpindi in order to evaluate the potential exposure of radiation workers while performing routine activities for PET-CT scan. The intent was assessment and quantification of possible radiation exposure to the occupational workers during routine production of [18F] FDG. This study would help to identify individual exposure levels, individual work load and the radiation levels of nuclear medicine department.[2,3]

Regular radiation monitoring not only assists for the identification of radiation doses received by radiation workers but also provide an idea of the environmental conditions of nuclear medicine department. The basic rules of radiological protection for the workers namely, As Low As Reasonably Achievable (ALARA) and Time, Distance and Shielding (TDS) were also introduced to occupational workers and their performance was monitored occasionally for the safe handling of radiopharmaceuticals. The occupational radiation was assessed during image acquisition procedures on PET-CT scanner, production and quality control of FDG. The widely used thermo-luminescent dosimeters (TLD) and ring dosimeters were utilized for the assessment

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of radiation doses received by occupational workers on monthly basis. The radiation doses of occupational workers were assessed in order to ensure that the radiation exposure was under standard limits[4,5] for nuclear medicine department during the preparation and administration of radiopharmaceuticals.

METHODOLOGY

This study was conducted at Imaging Department of Armed Forces Institute of Radiology and Imaging (AFIRI) Rawalpindi. The study span was one year and the target was to overview the radiation doses received by occupational workers where our scan routine covers PET-CT scan of 45 patients per week. Sample size was calculated using WHO sample size calculator taking confidence interval 95%, margin of error 5% reported prevalence of 1.5% and sample size came out to be 23.[6]

Inclusion Criteria: The workers having direct interaction with liquid radioactive material that is F-18 FDG were included in the study using systematic sampling precisely.

Exclusion Criteria: Workers administering radioactive doses to patients, patient positioning workers on PET-CT scanner, and the department management staff. Moreover, pregnant workers, overdose workers and comforters were excluded from study.

Present study integrate twenty six occupational workers including medical physicist, radio pharmacist, lab technologists, radiographers, patient management staff, sanitary workers, visitors, students, engineers and doctors and they were monitored in order to assess the radiation doses received in PET/CT scan department on monthly basis. Radiation workers in PET/CT and Cyclotron department of AFIRI were provided with TLD badges and ring dosimeters for recording their radiation doses and the doses were assessed after every two months. The TLD-100 dosimeters consist of LiF:Mg:Ti material having absorption coefficient 8.2 which is close to human tissue 7.4. These dosimeters were convenient to wear during working hours, can be used in dry, wet and humid environment and have the capability of measuring radiation doses in the range of 10 μSv to 10 Sv. The current study spanned a period of one year from August 2020 to July 2021 after acquiring approval of research via IERB certificate no. 0061.

The radiation workers were included from both production and scanning departments. A total of twenty six TLD badges and eight ring dosimeters (TLD-100) were provided to radiation workers for the evaluation of whole body and extremities doses. Each worker was provided with one TLD badge whereas, production staff was additionally provided with ring dosimeter to estimate extremity dose. All workers were right handed and they were advised to wear the TLD in index figure of their working hand with face towards the injection containing radiopharmaceutical. Ring dosimeters were worn in the mentioned formation in order to cover the maximum exposure as the index finger was comparatively more exposed to radiation. The radiation workers were randomly observed to follow the instructions and wearing procedures for TLD usage during working hours. The exposed TLD dosimeters were examined after every two months in the facility of Pakistan Institute of Nuclear Science and Technology (PINSTECH), Islamabad in radiation dosimetry group (RDG) and processed with Harshaw Bicron Model 6600E automatic TLD reader. In order to read exposed TLD, preheat temperature adjusted at 50°C, temperature rate 15°C and annealing temperature fixed at 300°C. The exposed ring dosimeters were processed for evaluation of received radiation dose and then again utilized after invigoration as the TLD chips have the capability of reuse.[7,8] Data was analyzed using MS Excel 2010 software and Mean$\pm$SD was calculated for continuous variable and bar chart was used to compare present study with similar works.

RESULTS

The study examined radiation doses received by 26 occupational workers where the method of calculation was TLD Rings (8 workers) and TLD cards (26 workers). After calculation of radiation doses, the patient administration staff doses were further inspected due to high received doses and radiation dose per injection per worker was estimated. The measured radiation doses for patient administration staff were in the range of 362.75 mSv/y to 409.74 mSv/y for extremities doses. Number of injections was also calculated for extremity workers and found to be 720±27 injections per worker per year. Furthermore, the whole body doses for occupational workers ranged from 0.08 mSv/y to 4.35 mSv/y.

The study was spanned over one year and measurements were taken after a period of every two months. The extremity (figure) doses were estimated using ring dosimeters on annual basis having TLD-100 chips and the results are shown in Table-I. The workers included in the study were medical physicist, radio pharmacist, lab technologists, radiographers, and radiation nurses with measured extremity doses of 0.90, 1.89, 398.75 & 362.76, 41.60 & 2.42, 0.99 & 0.97 mSv/y, respectively.

Table-I: Extremity Doses to Production Staff (mSv)

Sr.	Worker	Aug19-Sep19	Oct19-Nov19	Dec19-Jan20	Feb20-Mar20	Apr20-May20	Jun20-Jul20
1	Medical Physicist	0.34	0.19	0.01	0.2	0.01	0.15
2	Radio Pharmacist	0.45	0.38	0.16	0.25	0.30	0.35
3	Lab Technologist 1	54.97	16.93	0.01	77.51	108.23	105.11
4	Lab Technologist 2	45.58	30.77	0.01	105.29	109.88	107.22
5	Radiographer 1	0.37	0.18	0.01	0.98	0.71	0.17
6	Radiographer 2	0.44	0.31	0.01	0.37	8.9	31.57
7	Radiation Nurse 1	0.32	0.19	0.01	0.01	0.25	0.13
8	Radiation Nurse 2	0.16	0.41	0.01	0.21	0.01	0.19

The radiation doses of lab technologists were towards higher side because they are involved in both quality control and administration of radiopharmaceuticals. The radiographer received higher dose was involved in patient positioning on the PET-CT scanner.

In the studied period, TLD based ring dosimeters were utilized for the determination of equivalent doses received by radiation workers. The measured doses of radiation workers were within the acceptable limits. However, extensive attention was paid to the ring dosimeters as their readings closer to the acceptable limit, Table-II.

Table-II: Ring Dosimeter Doses for Lab Technologists (mSv)

	Lab Technologist 1			Lab Technologist 2		
Sr.	Period	Injections	Dose (mSv)	Period	Injections	Dose (mSv)
1	Aug-Sep	120	54.97	I	120	45.58
2	Oct-Nov	110	16.93	II	130	30.77
3	Dec-Jan	115	34.25	III	125	43.50
4	Feb-Mar	125	77.51	IV	115	95.29
5	Apr-May	120	89.10	V	120	97.38
6	Jun-Jul	110	89.99	VI	130	97.22
7	Total	700	362.76	Total	740	409.74
8	Mean	116±5	60.46±27.67	Mean	124±5	66.46±28.72
9	Unit	1	0.52	Unit	1	0.53

The F-18 FDG injection was found to be the most significant source of radiation to the radiation workers and the ring dosimeter dose was available for the record of extremity doses. Table-II also indicates the number of injections administered by each lab technologist during the study period. The unit dose per injection is also estimated as 0.52-0.53 mSv per injection.

Table-III indicates the whole body doses to the radiation workers of PET-CT and Cyclotron department and the total whole body dose for the year was in the range of 0.08 mSv/y to 4.38 mSv/y for all workers based on interaction with radioisotopes and administered patients. It should be noted that all the doses received by AFIRI staff was well within the safety limit 20 mSv/y.

Table-III: Whole Body Doses for the Occupational Workers (mSv)

Sr.	Radiation Worker	Aug19-Sep19	Oct19-Nov19	Dec19-Jan20	Feb20-Mar20	Apr20-May20	Jun20-Jul20	Total
1	Radiology Consultant I	0.03	0.01	0.01	0.01	0.01	0.01	0.08
2	Radiology Consultant II	0.08	-	-	-	-	0.21	0.29
3	Radiology Consultant III	-	0.23	0.44	0.69	-	-	1.36
4	Nuclear Medicine Consultant I	0.47	0.24	0.35	0.29	0.2	-	1.55
5	Nuclear Medicine Consultant II	-	-	-	-	-	0.11	0.11
6	Medical Physicist	0.94	0.01	0.89	0.45	0.01	0.01	2.31
7	Radio Pharmacist	0.05	0.01	0.33	0.01	0.01	0.01	0.42
8	Cyclotron Engineer I	0.57	0.01	0.01	0.01	0.01	0.01	0.62
9	Cyclotron Engineer II	0.26	0.29	0.31	-	-	0.12	0.98
10	Lab Technologist I	0.93	0.01	0.75	0.36	0.01	0.01	2.07
11	Lab Technologist II	0.12	0.01	4.14	0.01	0.01	0.09	4.38
12	Radiographer I	0.31	0.13	0.08	0.2	0.18	0.11	1.01
13	Radiographer II	0.4	0.5	0.79	0.52	0.46	0.24	2.91
14	Radiographer III	0.3	0.57	0.82		0.4	0.31	2.4
15	Radiographer IV	-	0.2	0.29	-	1.44	0.22	2.15
16	Radiographer V	-	-	-	-	0.4	0.18	0.58
17	Radiation Nurse I	0.34	0.2	-	-	-	-	0.54
18	Radiation Nurse II	0.1	0.27	-	-	-	-	0.37
19	Radiation Nurse III	-	-	0.12	0.19	0.19	-	0.5
20	Radiation Nurse IV	-	-	-	0.28	0.28	-	0.56
21	Radiation Nurse V	-	-	-	-	-	0.32	0.32
22	Radiation Nurse VI	-	-	-	-	-	0.37	0.37
23	Office Staff	-	-	-	-	0.22	0.19	0.41
24	Waste Management Staff	-	0.13	0.19	-	-	0.37	0.69
25	Visitors	-	0.1	0.11	-	-	0.18	0.39
26	Student	-	0.19	0.35	-	-	-	0.54

DISCUSSION

Occupational radiation doses were measured during preparation and administration of radionuclides in PET-CT and Cyclotron department of AFIRI for the PET/CT scanning of the patients. Regardless of other sources of radiation in PET-CT and Cyclotron department the ring dosimeter doses were considerably high and considered for the rotation of duties of occupational workers. The highest dose recorded was 398.75 mSv/y which was close to the regulatory limits (500 mSv/y). Therefore, dose for the single injection was calculated for the radiation workers and it was estimated that 950 injections can be injected by a single worker per year.

The results of whole body doses measured in present study were evaluated against similar studies carried out in PET/CT departments of different countries and Figure indicate comparison of present study with other countries. Radiation doses of occupational workers can be substantially reduced to optimize the radiation protection protocols and follow the proper safety culture. The radiation doses should be regularly monitored and use of radiation protective devices and shields must be introduced in order to reduce occupational doses. Furthermore, rotation of staff can be considered if administratively feasible.

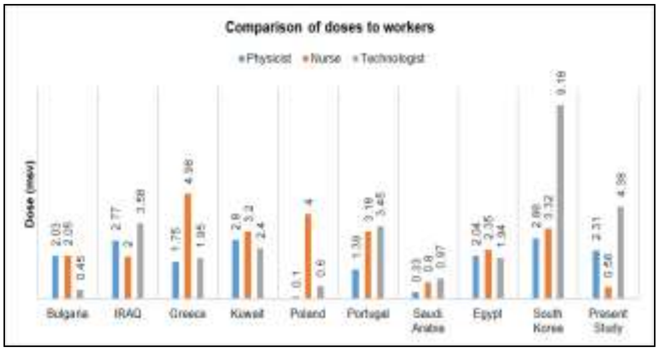

Figure: Comparison of Radiation Doses to Workers in Different Countries (9-22)

S.D. Ivanova studied radiation exposure in the similar where the measured dose rates were under 3mSv/y. Similar TLD badges and personal dose rate meters were utilized for 5 years and the radiation doses of nurses were towards higher side due to administration of radioactivity.[9]

CONCLUSION

The assessment of radiological doses to radiation workers was carried out at PET/CT and Cyclotron department of AFIRI Rawalpindi and the staff involved in the administration of radiopharmaceutical found more exposed to ionizing radiations. The radiation doses for all the workers were in the recommended range for whole body (20 mSv/y) and extremity (500 mSv/y). The injection staff was exposed to more ionizing radiation due to administration of F-18 FDG injection. The number of injections for the injection staff was 750 injections per worker per year with the average activity of 6 mCi F-18 FDG per injection. It is also concluded that single worker can be allowed to administer approximately 950 injections per year.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

SAM & RB: Data acquisition, data analysis, critical review, approval of the final version to be published.

AURS & AJ: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

MA & NA: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Rahman SU, Ahmad S, Mehdi A, Rafique M, Fatima S, et al. Measurement of extremities doses to occupational workers by using ring dosimeters. PJR 2018; 28(2): 145-149.
2. Mehdi A, Khan K, Jabbar A, Rashid A. Measurement of Gamma Emitting Radionuclides in Environmental Samples of Talagang Tehsil-District Chakwal. Nucl Sci 2017; 2(2): 54-58.
3. Mehdi SA, Rahman SU, Khan K, Jabbar A, Rafique M. Assessment of Annual Effective Dose from Measured Soil Radioactivity Levels Using HPGe Detector. Univers J Eng Sci 2016; 4(4): 79-83.
4. International Commission on Radiological Protection. ICRP Publication 103: Recommendations of the ICRP. Annals of the ICRP 2008.
5. International Atomic Energy Agency IAEA. Practical radiation technical manual, personal protective equipment. IAEA-PRTM-5. IAEA: Vienna, 2004.
6. Sarwar MR and Saqib A. Cancer Prevalence, incidence and mortality rates in Pakistan in 2012. Cogent Med 2017; 4(1): 1-13.
7. Martin CJ. Strategies for assessment of doses to the tips of fingers in nuclear medicine. J. Radiol. Prot 2016; 36(3): 405-418.
8. Dhanse S, Martin CJ, Hilditch TE and Elliott AT. A study of doses to the hands during dispensing of radiopharmaceuticals. Nucl. Med. Comm 2000; 21(6): 511-529.
9. Ivanova SD. Radiation Exposure to the Stuff Working in PET/CT and Cyclotron Facility. BgNS Trans 2016; 21(1): 63-66.
10. Wabdan AA, Yassin HM, El- Nagdy MS. Occupational Radiation Exposure to Workers Used 18-FDG. MJS 2018; 29(4): 100-105.
11. Santana PC, Oliveira PMC, Mamede M, Silveira MC, Aguiar P, Real RV, et al. Ambient radiation levels in positron emission tomography/computed tomography (PET/CT) imaging center. Radiol Bras 2015; 48(1): 21–25.
12. Wrzesień M and Napolska K. Investigation of radiation protection of medical staff performing medical diagnostic examinations by using PET/CT technique. J. Radiol. Prot 2015; 35(1): 197.
13. Li W, Fang L, and Li J. Exposure Doses to Technologists Working in 7 PET/CT Departments. DOS 2020; 18(3): 1-6.
14. Dalianis K, Kollias G, Nikaki A, Vlachou F, Efthimiadou R, Andreou J, et al. Staff Dose at Different Body Regions and at Different Stages of 18-F FDG PET/CT Procedures. Phys Med 2016; 32(3): 239-239.
15. Adliene D, Griciene B, Skovorodko K, Laurikaitiene J, Puiso J. Occupational radiation exposure of health professionals and cancer risk assessment for Lithuanian nuclear medicine workers. Environ Res 2020; 183(1): 1-10.
16. Alnaaimi M, Alkhorayef M, Omar M, Abughaith N, Aldouij M, Salhudin T, et al. Occupational Radiation Exposure in a Nuclear Medicine Department in Kuwait. Radiat Phys Chem 2017; 140(1): 233-236.
17. Alkhorayef M. Mayhoub FH. Salah H, Sulieman A, Al-Mohammed HI, Almuwannis M, et al. Assessment of occupational exposure and radiation risks in nuclear medicine departments. Radiat Phys Chem 2019; 170(1): 1-13.
18. Tulik P, Kowalska M, Golnik N, Budzynska A, Dziuk M. Measurements of the Ionizing Radiation Level at a Nuclear Medicine Facility Performing PET/CT Examinations. Radiat Prot Dosim 2016; 174(4): 501–509.
19. Jakubowska T, Długosz-Lisiecka M. Estimation of effective dose using two ICRP criteria, applied to radiation protection of personnel in an unshielded PET cyclotron facility. Radiat Phys Chem 2020; 171(1): 1-6.
20. Roberts F, Gunawardana DH, Pathmaraj K, Wallace A, Paul LU et al. Radiation Dose to PET Technologists and Strategies to Lower Occupational Exposure. J Nucl Med Technol 2005; 33(1): 44–47.
21. Emad El-din MM, Mahmoud RMM, Abaza A, Eid I, Ez El-din MR, Rizk RA. Occupational Radiation Exposure in PET/CT Units. Arab J. Nucl. Sci. Appl 2017; 50(3): 58-65.
22. Lee WJ, Choi Y, Ko S, Cha ES, Kim J et al. Projected lifetime cancer risks from occupational radiation exposure among diagnostic medical radiation workers in South Korea. BMC Cancer 2018; 18(1): 1206-1215.

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