Benefits of adopting good radiation practices in reducing the whole body radiation dose to the nuclear medicine personnel during ^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography imaging

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ABSTRACT

Introduction: Positron emission tomography has been established as an important imaging modality in the management of patients, especially in oncology. The higher gamma radiation energy of positron-emitting isotopes poses an additional radiation safety problem. Those working with this modality may likely to receive higher whole body doses than those working only in conventional nuclear medicine. The radiation exposure to the personnel occurs in dispensing the dose, administration of activity, patient positioning, and while removing the intravenous (i.v.) cannula. The estimation of radiation dose to Nuclear Medicine Physician (NMP) involved during administration of activity to the patient and technical staff assisting in these procedures in a positron emission tomography/computed tomography (PET/CT) facility was carried out. **Materials and Methods:** An i.v access was secured for the patient by putting the cannula and blood sugar was monitored. The activity was then dispensed and measured in the dose calibrator and administered to the patient by NMP. Personnel doses received by NMP and technical staff were measured using electronic pocket dosimeter. The radiation exposure levels at various working locations were assessed with the help of gamma survey meter. **Results and Discussion:** The radiation level at working distance while administering the radioactivity was found to be 106–170 μSv/h with a mean value of 126.5 ± 14.88 μSv/h which was reduced to 4.2–14.2 μSv/h with a mean value of 7.16 ± 2.29 μSv/h with introduction of L-bench for administration of radioactivity. This shows a mean exposure level reduction of 94.45 ± 1.03%. The radiation level at working distance, while removing the i.v. cannula postscanning was found to be 25–70 μSv/h with a mean value of 37.4 ± 13.16 μSv/h which was reduced to 1.0–5.0 μSv/h with a mean value of 2.77 ± 1.3 μSv/h with introduction of L-bench for removal of i.v cannula. This shows a mean exposure level reduction of 92.85 ± 1.78%. **Conclusion:** This study shows that good radiation practices are very helpful in reducing the personnel radiation doses. Use of radiation protection devices such as L-bench reduces exposure significantly. PET/CT staff members must use their personnel monitors diligently and should do so in a consistent manner so that comparisons of their doses are meaningful from one monitoring period to the next.

Keywords: Electronic pocket dosimeter, good radiation practices, Nuclear Medicine Physician, personnel radiation dose, positron emission tomography/computed tomography

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INTRODUCTION

The past 15 years have seen the transition of positron emission tomography (PET) from the research domain into mainstream clinical applications, particularly for oncology.[1-5] The emergence of PET as a functional imaging modality for diagnosis, staging, monitoring therapy, and assessment of recurrence in cancer has led to increasing demand for this new imaging technology. It is important to recognize that functional imaging modalities such as PET, in some instances, may provide an earlier diagnosis and more accurate staging than conventional anatomical imaging with computed tomography (CT). Moreover, the recent introduction of hybrid systems, where the PET component is coupled with a CT scanner, has enabled the addition of the precise anatomic detail provided by CT to the metabolic imaging provided by PET. As a consequence, the number of new PET facilities has steeply increased worldwide.

The increasing number of PET/CT scanner installations in Nuclear Medicine Departments with positron-emitting isotope imaging, raised the issue of radiation dose exposure of radiation professionals undertaking the preparation and administration of this radiopharmaceutical. Indeed, the higher radiation energy (511 keV) of positron-emitting isotopes means that Nuclear Medicine Physicians (NMPs), technologists, and others involved could receive a higher whole body dose than those working only with conventional nuclear medicine tracers. To date, however, few data have been published on technologist radiation doses received during work in dedicated PET Departments.[6,7] These studies measured whole body doses received during 1 workday in a PET center using various positron-emitting isotopes or dose rates at various distances from patients injected with 370 MBq of ^{18}F-fludeoxyglucose (FDG). Some other studies aimed to evaluate hand doses received during ^{18}F-FDG PET scanning per technologist.[8]

The main sources of radiation exposure for staff in the PET facility include: (1) Unshielded radiopharmaceuticals (present during preparation and dispensing); (2) Patients injected with PET radiopharmaceuticals; (3) Sealed calibration sources, QA phantoms, and (4) the CT scanner.

Factors affecting the staff radiation exposure include: (a) The number of patients imaged, (b) Type and amount of radiopharmaceutical administered per patient, (c) Length of time spent by the patient in each area of the PET/CT facility, and (d) Its physical layout. The highest staff exposures occur while performing the following tasks: (1) Assaying the amount of radiopharmaceutical; (2) Administering the radiopharmaceutical; (3) Performing tasks near the patient (postinjection) during the radiopharmaceutical uptake period; (4) Escorting the patient to and from the scanner; (5) Positioning the patient on the scanner bed; and (6) Calibration and QC of the PET scanner using sealed sources.[9] So, it is of paramount importance in today's Nuclear Medicine Department having PET/CT facility to identify the specific steps involving the higher radiation exposure in whole imaging procedure and adopt good practices to reduce the whole body dose to the radiation personnel involved in the practice as desired by ALARA principle of radiation protection. So, the present study has been undertaken to monitor the radiation exposures comprehensively to NMP and technical staff who are mostly involved with patients in the imaging process.

MATERIALS AND METHODS

As per the established protocol in the department; all the injections are being administered by the NMP. The radioactivity is supplied in a vial inside the lead container. Initially, an intravenous (i.v.) access was secured for the patient and blood sugar was monitored. The dose was then dispensed, and the preinjection activity was recorded in the dose calibrator and activity was administered to the patient by NMP. Since, the radiation level at working distance while administering the radioactivity was high; so it was decided to share the activity administration at least among three NMPs on rotation. After the injection of the tracer, the i.v. catheter was treated as radioactive waste. The postinjection residual dose in the syringe was measured to calculate the actual activity administered. For the estimation of radiation dose and to understand the efficacy of good radiation practices; we monitored the daily radiation doses received by NMPs involved during administration of activity to the patient and technical staff assisting in few of these procedures over a period of 3 months. The NMPs and technical staff assisting the NMPs during the procedure were provided Electronic pocket dosimeters (EPDs; MYDOSE mini, ALOKA Co., Ltd., Mitsuyama) apart from the routine personnel monitoring thermoluminescent dosimeter badge used by them. EPDs have silicon semiconductor detectors with an accuracy of $\pm 10\%$ and an energy response accuracy of $\pm 30\%$ between 50 keV and 3.0 MeV. The measurement range of the detector was from 1 to 9999 μSv. The EPD was worn by the NMP while administration of ^{18}F-FDG and by the technical staff while removing the cannula from the patient, once the procedure got over. The chest dose received was read directly from the dosimeters and recorded at the end of each activity administration and the dosimeters were reset prior to the next administration. For the assessment of radiation dose to the NMP's and technical staff, a calibrated survey meter (ROTEM - RAM GAM 1, ROTEM Industries, Israel) has been used. These survey meters have energy compensated with an accuracy of $\pm 15\%$ with an energy range of 50 keV to 1.3 MeV. The measurement range of this device is from 0.5 to 9999 μSv/h.

RESULTS

The amount of radioactivity administered ranged from 175 to 370 MBq with a mean value of 251 ± 50 MBq. The radiation level at working distance while administering the radioactivity was found to be 106–170 μSv/h with a mean value of 126.5 ± 14.88 μSv/h which was reduced to 4.2–14.2 μSv/h with a mean value of 7.16 ± 2.29 μSv/h with introduction of

L-bench for administration of radioactivity as shown in Figure 1. The L-bench is made up of lead which helps in absorption of photons, so it reduces the intensity of the transmitted radiation. This shows a mean exposure level reduction of 94.45 ± 1.03%.

The radiation level at working distance while removing the i.v. cannula postscanning was found to be 25–70 μSv/h with a mean value of 37.4 ± 13.16 μSv/h which was reduced to 1.0–5.0 μSv/h with a mean value of 2.77 ± 1.3 μSv/h with introduction of L-bench for removal of i.v cannula. This shows a mean exposure level reduction of 92.85 ± 1.78%.

The radiation dose as estimated by pocket dosimeter to the NMP and technical staff per patient was found to be 1 and 0.8 μSv, respectively. The total accumulated dose received by each of the NMPs were 92.5, 102.8 and 109.2 μSv over the whole study period of 3 months. The total accumulated dose received by the technical staff was 248.3 μSv over the whole study period of 3 months.

DISCUSSION

With time and growing technology, the use of PET/CT has shown the larger increase and its advantages have made it popular among the clinicians.[10,11] It is imperative to continually monitor the dose received by the staff to check if it is within the prescribed annual dose limits. It is advisable for the department, adding new PET CT facility that they should actively and meticulously monitor the radiation dose received by the staff and radiation levels at associated work places to have preliminary assessment and gain confidence regarding the radiation safety. It will also help in the improvement of the work practice.[12]

In our study, the radiation dose as estimated by pocket dosimeter to the NMP and technical staff per patient was found to be 1 and 0.8 μSv, respectively.

The typical values of personnel doses in PET CT practices as given by IAEA publication on radiation protection in PET CT for various PET CT procedures viz. initial measuring of vial: 2 μSv, dispensing and injection: 2–4 μSv/patient, positioning patient/scan: 1–2 μSv/patient, and escorting patient to toilet, and scanner room: 5–10 μSv/patient. Chiesa *et al.* showed that technologist dose per procedure in FDG PET CT was 5.9 ± 1.2 μSv.[6] It is very much evident in our study, also that adopting good radiation working practices reduces the personnel dosage significantly.

Figure 1: Injection of radioactivity to the patient behind L-bench

CONCLUSION

This study shows that by using L-bench the personnel radiation exposure can be reduced significantly. We identified that high radiation exposure to the personnel occurs in dispensing the dose, administration of activity, patient positioning and while removing the i.v. cannula. It is also observed that the radiation exposure to the technical staff involved in removing the cannula is less as compared to NMP who is administering ^{18}F-FDG because the activity got reduced in patients due to physical and biological decay of ^{18}F-FDG ($T^{1/2}$ = 110 min) during the study period of 1–1.5 h of PET/CT procedures. This study shows that the radiation dose received by clinical and technical staff during FDG PET CT study is within safe limits as stipulated by various national and international regulatory bodies. However, further dose reduction is possible by adopting good working practices. Typical annual whole body staff doses at conventional nuclear medicine facilities are 0.1 mSv, but are closer to 6 mSv at PET/CT facilities,[13] which is a substantially higher dose but still below the ICRP limit of 20 mSv/year. PET/CT staff members must use their personnel monitors diligently and should do so in a consistent manner so that comparisons of their doses are meaningful from one monitoring period to the next.

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Conflicts of interest
There are no conflicts of interest.

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