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Radiation exposure to nuclear medicine staffs during ^{18}F-FDG PET/CT procedures at Ramathibodi Hospital

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Abstract. The aim of this study is to estimate the whole body and finger radiation doses per study received by nuclear medicine staff involved in dispensing, administration of ^{18}F-FDG and interacting with radioactive patients during PET/CT imaging procedures in a PET/CT facility. The whole-body doses received by radiopharmacists, technologists and nurses were measured by electronic dosimeter and the finger doses by ring dosimeter during a period of 4 months. In 70 PET/CT studies, the mean whole-body dose per study to radiopharmacist, technologist, and nurse were 1.07±0.09, 1.77±0.46, µSv, and not detectable respectively. The mean finger doses per study received by radiopharmacist, technologist, and nurse were 265.65±107.55, 4.84±1.08 and 19.22±2.59 µSv, respectively. The average time in contact with ^{18}F-FDG was 5.88±0.03, 39.06±1.89 and 1.21±0.02 minutes per study for radiopharmacist, technologist and nurse respectively. Technologists received highest mean effective whole-body dose per study and radiopharmacist received the highest finger dose per study. When compared with the ICRP dose limit, each individual worker can work with many more ^{18}F-FDG PET/CT studies for a whole year without exceeding the occupational dose limits. This study confirmed that low levels of radiation does are received by our medical personnel involved in ^{18}F-FDG PET/CT procedures.

1. Introduction

Positron Emission Tomography accompanied with Computed Tomography (PET/CT) has played a major role in tumor imaging. Fluorine-18 FDG as a positron emitter radiopharmaceutical is the most widely and clinically utilized. It has been successfully used for assessing primary tumor and metastasis, to indicate prognosis, treatment planning and monitoring therapy as well as early detect recurrent tumor growth [1]. The 0.511 MeV annihilation photons associated with positron decay are much higher energy than other diagnostic radiations. The exposure rate constant from unshielded ^{18}F source in air (1.49×10^{-4} mSv. m^2/MBq.h) is approximately 7 times greater than ^{99m}Tc (2.06×10^{-5} mSv.m^2/MBq.h) which is commonly used for general Nuclear Medicine studies [2].

Fluorine-18 FDG PET/CT is being used increasingly to evaluate tumor response in addition to diagnosis and staging of tumors. Although PET scanner has been used widespread since about the year 2000, a dedicated PET/CT scanner at our institution was just installed in December 2010. Clinical PET/CT service has been started and increasing since May 2011. The average monthly PET/CT studies are almost double in 2012. More than ninety percent of our ^{18}F-FDG PET/CT studies are for oncologic purpose.

Increasing number of ^{18}F-FDG PET/CT studies and the high penetrating ability of ^{18}F raised the issue of radiation doses to medical staffs while performing their duties with ^{18}F-FDG PET/CT procedures i.e. preparation, handling and administration of the radiopharmaceuticals as well as patient positioning and monitoring during routine PET/CT examinations [3,4,5]. Workers do not have separate dosimeters for variety of tasks. The radiation doses from ^{18}F-FDG PET/CT procedures have assessed together with routine nuclear medicine procedures. The lack of separated radiation doses from ^{18}F-FDG PET/CT studies lead to our proposed study. In addition, the newly available optically stimulated luminescence ring type dosimeter (OSLRD) allows us to measure equivalent dose to fingers.

The objectives of this study are to assess the whole-body and finger radiation doses received by radiopharmacists, technologists and nurses while performing ^{18}F-FDG PET/CT procedures for tumor imaging at Ramathibodi hospital, Bangkok, Thailand, and to compare these occupational burdens with the dose limits recommended by the International Commission on Radiological Protection (ICRP Publication No. 103) [6].

2. Materials and methods

2.1 Dosimeter and readout system

Electronic dosimeter (ED) (ALOKA model PDM-112) was used to measure the Hp(10) from 40 keV gamma and above in a range from 1 to 9999 µSv. The energy dependence is within ±30% in the gamma range between 50 keV to 3MeV. The dosimeters were calibrated with a ^{137}Cs (662 keV) source in the Secondary Standard Dosimetry Laboratory (SSDL) of the Office of Atomic for Peace (OAP), Thailand. The new ring dosimeters developed by Hideaki Miyauchi *et al*. [7] was used for monitoring finger doses. The OSLD consists of two OSL elements and beta cut filter between the OSL elements (nanoDots) produced by Landauer Inc. The first nanoDot is used to measure the Hp(0.07) from gamma and beta rays. The second nanoDot is used for gamma rays only. To maintain dosimetry standard at national level, all measurements were monthly evaluated at the SSDL of the Division of Radiation and Medical Devices, Department of Medical Sciences, Ministry of Public health.

2.2 Exposed personnel

Properly trained radiopharmacists, technologists and nurses in handling radioactive sources who rotated to PET/CT center are groups of worker potentially exposed to ionizing radiation while carrying out tasks associated with ^{18}F-FDG PET/CT procedures. All of them were informed about the method for measuring their doses. In each ^{18}F-FDG PET/CT study, one radiopharmacist, one nurse and two technologists worked together.

Radiopharmacists perform 3 steps of task in the preparation of ^{18}F-FDG dose. The first step is measurement of the total activity of the ^{18}F-FDG multi-dose syringe and drawing up of each 185 MBq (5 mCi) ^{18}F-FDG dose in a syringe and mounted in a tungsten shield. The multi-dose ^{18}F-FDG is sent from the Thailand National Cyclotron and PET Center. The dose withdrawal is always performed within hot laboratory, being drawn up behind a bench-mounted lead shield with a lead equivalent glass insert. The second step is transportation of ^{18}F-FDG dose from the hot laboratory to the injection room. The last step is measurement of the post-injection residual dose in the syringe. The total radiation dose received by each radiopharmacist was timed from the first step and ending when the radiopharmacist threw the syringe into radioactive trash container.

The nurses perform 3 steps in the administration of radiopharmaceutical. The first step is injection the tracers into the patient through pre-canalized intravenous (IV) line. The second step is flushing of normal saline into the IV line. The last step is removal of IV line. The nurses were stand behind a bench-mounted lead shield with a lead equivalent glass insert while performing all steps. The total radiation dose received by each nurse was measured from the first step and ending when leaving the injection room.

The technologists perform all PET/CT imaging tasks. These include escorting the patient to void in a reserved bathroom. After voiding the patient is positioned on the tomograph for the procedure. These include positioning, acquiring images and helping the patient during and until the study is completed. During the time of camera operation, patients were viewed via lead glass window between the scanner and console room. The total radiation dose received by technologist was measured from the time the patient was escorted to void to the time when patient is released to the waiting area. The acquiring time was 60 minutes after injection. Patient was kept in a quiescent state during an uptake phase in a designated room. For PET/CT (Philips Gemini TrueFlight) imaging, spiral CT is firstly performed from the level of the skull vertex to the level of upper thighs by using a scout view with 30 mA and 120 kVp, followed by a spiral CT scan with 50 mA and 120 kVp. This is followed by 3D PET acquisition with 2 minutes per bed positions.

2.3 Whole-body dose [$H_p(10)$] measurement

The ED was placed on the upper left pocket of the coat. Each individual worker carried one dosimeter throughout a FDG PET/CT study. The radiation doses received by each worker were read directly from the dosimeter and recorded at the end of each procedure. The dose was multiplied by calibration factor obtained from the SSDL of the OAP and calculated as the mean value. The time spent of each procedure was recorded. This study was conducted over 4-months period.

2.4 Finger dose [$H_p(0.07)$] measurement

Two OSLRDs were placed on the base of index finger of both hands and noted the dominant hand. The finger dose was calculated as the mean value, corrected for environmental background and the differences in photon energy between the radiopharmaceuticals and reference radiation. The overall finger doses to each personnel were measured for 4 months. OSLRDs were worn during the procedures only otherwise, they were kept in the shielded box.

3. Results

3.1 Effective whole-body dose

Over 4-months period, a total number of 70 ^{18}F-FDG PET/CT studies were included. The ^{18}F-FDG injection activity per patient was between 3.68 to 7.20 mCi (5.89±0.60 mCi). The mean time spent and effective dose per study were reported in Table 1.

Table 1. Effective whole-body dose [$H_p(10)$] to nuclear medicine staffs while performing duties with ^{18}F-FDG PET/CT procedures.

Medical staff	N	Time spent (minutes)/study	Effective dose (µSv)/study
Radiopharmacist 1	30	5.90 ± 2.88	1.01 ± 0.84
Radiopharmacist 2	40	5.85 ± 2.60	1.13 ± 0.93
Mean ± SD		5.88 ± 0.03	1.07 ± 0.09
Nurse 1	34	1.20 ± 0.29	Not detectable
Nurse 2	36	1.22 ± 0.24	Not detectable
Mean ± SD		1.21 ± 0.02	Not detectable
Technologist 1	20	38.45 ± 7.63	1.87 ± 1.05
Technologist 2	8	35.75 ± 8.65	1.31 ± 0.75
Technologist 3	25	39.28 ± 8.95	1.94 ± 1.04
Technologist 4	13	38.54 ± 8.13	1.92 ± 0.83
Technologist 5	25	39.52 ± 8.86	2.20 ± 1.25

Technologist 6	6	42.50 ± 13.52	1.73 ± 0.54
Technologist 7	10	37.40 ± 7.09	1.35 ± 0.99
Technologist 8	12	39.75 ± 6.76	1.13 ± 0.82
Technologist 9	21	40.38 ± 9.32	2.58 ± 1.66
Mean ± SD		39.06 ± 1.89	1.77 ± 0.46

3.2 Finger doses

Finger radiation doses were reported in Table 2. The measurement was performed in all radiopharmacists and nurses similar to the whole-body measurement. However, we were able to measure finger doses from only 2 technologists who rotated to PET/CT center in the last month. The mean finger doses per study were 265.65±107.55, 19.22±2.59 and 4.84±1.08 µSv, for radiopharmacists, nurses and technologists, respectively.

Table 2. Finger doses [$H_p(0.07)$] to nuclear medicine staffs while performing duties with ^{18}F-FDG PET/CT procedures.

Medical staff	N	Time spent minutes/study	Finger dose, µSv/study	
			Right hand	Left hand
Radiopharmacist 1	30	5.90 ± 2.88	229.10	511.30
Radiopharmacist 2	40	5.85 ± 2.60	150.09	172.05
Mean ± SD		5.88 ± 0.03	189.59 ± 55.87	341.70 ± 239.92
Nurse 1	34	1.20 ± 0.29	17.06	11.31
Nurse 2	36	1.22 ± 0.24	17.71	30.79
Mean ± SD		1.21 ± 0.02	17.38 ± 0.46	21.05 ± 13.76
Tech 5	25	39.52 ± 8.86	3.76	4.86
Tech 9	21	40.38 ±9.32	4.40	5.91
Mean ± SD		39.95 ± 0.61	4.08 ± 0.46	5.60 ± 0.53

4. Discussion

As shown in table 1, unsurprisingly, the mean effective whole-body dose per study received by technologist, 1.77±0.46 µSv was higher than other personnel which are likely to depend on time spent in proximity to a patient (35 to 43 minutes). High radiation doses may also imply that their patients need more attention, therefore, more contact time. The total radiation dose incurred by a technologist during a PET/CT studies is the product of dose rate and exposure time. Then, trying to spend unnecessary around the patient will minimize radiation dose. In contrast, the steps of the procedures for radiopharmacists and nurses are shorter and could be performed behind a bench mounted lead shield. Undetectable whole body dose means that radiation dose received by nurses were below the detection threshold of the ED.

In table 2, undoubtedly, the higher mean finger dose per study than other personnel received by radiopharmacist was from high amount of radioactivity being handled and from interaction with vials and syringes containing ^{18}F-FDG. Practicing dose dispensing and calibration techniques with nonradioactive materials will reduce the chance of high exposure. The experienced one would be able to reduce the time for each step of the procedure.

There were several reports on whole-body dose per study in the literature; such as 8.9 µSv by Zeff *et al*. [8], 8.5 µSv by Chiesa *et al*. [3], 6.5 by Benetar *et al*. [9], and 7.2 µSv by Biran *et al*. [10]. In our study, if one personnel was to perform all duties it can be assumed that the combined dose from 1 radiopharmacist, 1 nurse and 2 technologists, 4.6 µSv would be delivered per study. It is difficult to compare these doses between institutes because of the variability in the condition factors in each individual PET/CT facility, such as the patient doses, the procedure, the staff performance and shielding devices.

Finger doses were found to be within permissible limits. The highest finger dose to radiopharmacists are likely from handing of the ^{18}F-FDG multi-dose syringe, transferring the dose to the injection room and measuring the post-injection residual dose in the syringe. The nurse performed shorter part with ready-made individual radiopharmaceutical syringe and pre-canalized IV line for administration. Although, technologists spent the maximal time per study, however, they have the lowest finger dose because they did not directly handle the radioactive material.

In addition, our study reported the left hand majorly received higher dose than the right hand except one nurse while all staff is right handed. We assumed that it is an inconvenience handling anything in the non-dominant hand. Or simply, the non-dominant hand would be the one holding the radioactive material while the dominant hand would be moving, dividing, injecting etc. Therefore, the dominant hand received less finger dose than the non-dominant one. However, in order to decrease the finger dose, especially high volume PET/CT center, an automatic dose dispenser would be incorporated in the hot laboratory to draw ^{18}F-FDG multi-dose.

When compared to the ICRP occupational dose limits [6], 20 mSv per year for whole-body and 500 mSv per year for fingers. If each of our staffs continues to work with their maximum capacity e.g. 1,200 PET/CT studies during a whole year, the whole body doses would be about 1.28, and 2.12 mSv for radiopharmacists and technologists, respectively. The finger doses would be about 410.04, 25.26 and 6.72 mSv for radiopharmacists, nurses and technologists, respectively. All would be very minimal and far below the limit.

5. Conclusion

This study confirmed that our staff can work safety within recommended safety levels of occupational radiation doses to which they are routinely exposed.

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