Nuclear Medicine, Radiation Protection.

Finger Radiation Doses Received By Different Nuclear Medicine Working Professions in Three PET/ CT Centers.

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In the present study, we have investigated the finger radiation doses received by nuclear medicine staff involved in dispensing, administration of 18F-FDG and interacting with radioactive patients during imaging procedures in PET/ CT facility within three different diagnostic centers. **Materials and methods:** Using finger ring dosimeters delivered to physicists, technicians, and nurses, the readings were collected after one month of working. Each with his own assigned job task that varies according to the center's policy. **Results:** Finger doses were found to be within the permissible limits. The mean prospective annual finger dose measurements, across the three centers show that the physicist group has the highest received prospective annual dose 440.01 mSv/year. The mean technician's prospective annual finger dose measurements, across the three centers, appeared to be the lowest scoring 94.83 mSv/year and nurses measured 115.8 mSv/year. Finally, there was no recorded significance for the studied categories across the three centers between their prospective annual finger dose measurements. The highest finger dose was recorded for the physicists who are likely exposed from the handling of the 18F-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- intravenous time before and during administration. Also, the technicians spent the maximal time per study; however, they have the lowest finger dose because they are not exposed directly to handle the radioactive material.

Conclusions: Finger doses are important indicator for the personal exposure especially for those workers who use their hands in dealing with radioactive materials. The study revealed that the physicists are exposed higher than nurses and technologists in PET-CT facilities.

Keywords: Finger Doses, PET-CT.

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INTRODUCTION:

Radiation safety for radiation worker, the general public, and the environment is a matter of concern in any Nuclear Medicine facility. Exposure to the patient and the public and occupational exposure cannot be avoided within nuclear medicine practice (1). Radiation workers are aware that they may receive additional doses at work (2), for that reason they are trained in radiation protection (3). Also, they are under higher medical surveillance than most workers in other clinical fields, (4) where open sources of radiation are handled and radioisotope is administered to the patients in the form of radiopharmaceuticals within the patient himself who will be a moving source of radiation (5).

There are many professions where workers use radiation sources or come into contact with radiation while performing their normal daily duties. In most cases, the doses received are very low or they are received only occasionally, but there are also occupations where workers acquire small doses during their routine jobs (e.g., physicists, radiographers, nurses etc.) (6). The radiation exposure surveillance for the staff of PET-CT centers depends on different factors such as their professional behavior during their work, the working duration, the radiation doses recommended for each patient, the number of patients scanned during the work duration as well as the protection measures in their work environment. This may vary from center to center and also from country to country (7). The high number of patients in PET-CT is considered as a point of concern as it may increase the radiation exposure to staff members. Also, the high specific gamma ray constant of the 511-keV photons leads to a higher radiation exposure for staff if not properly protected (8). The 140-keV photons from Tc99m have a half value layer of 0.28 mm of lead. On the other hand for 511-keV photons of the F^{18} photons it is 4.1 mm under narrow beam geometry (9).

The lead required for shielding those high energy emissions is therefore proportionately increased. The specific gamma-ray constant for F^{18} is about six times greater than that for Tc99m [(8)]. Radiation protection monitoring in a PET facility has, therefore, to be addressed properly. Finger doses is an important indicator for radiation dosimetry for workers as it evolves information about handling radioactive materials by hand so it can give different results than that of the whole body dosimeters. **The aim of the study:** The aim of the present study is to investigate the finger radiation doses for different working professions among three different PET-CT centers.

MATERILAS AND METHODS:

Three centers were investigated, the finger radiation doses for each group of workers (physicists, technicians and nurses) The ring dosimeter were distributed among all workers under the study's surveillance, then collected, measured and then recorded, the study groups were instructed to wear it during all 18F-FDG PET/CT procedure (preparation tracer, transportation, and injection radiopharmaceutical, escorting and positioning injected patient) for one months' duration.

The TLD in the ring dosimeter were of two types either (Photon or Photon and Beta) we choose the double variant as the workers will be exposed to either beta emitter from the F18 doses before injection to the patient or from the patient's emissions of gamma radiation after injection. The measurements were done for one hand only due to shortage of dosimeters, the workers by default wears the rubber gloves during the handling of radioactive materials throughout their work and the dosimeters were kept with the workers during the whole study period. The model is finger ring Hp (0.07) from (RAD pro international GmbH, Germany).The technical specifications of the ring dosimeter are illustrated in ***table (1).***

Table (1): The technical specifications of the ring dosimeter.

Parameter	Specifications for Type BG
Dose	Sv
Dose range	0.1 mSv to 10 Sv
Lower limit of detection	0.1 mSv
Upper limit of detection	50 Sv
Beta energy	> 50 keV (Type BG)
Photon energy	10keV to 1.4MeV (Type G) 7.6keV to 1.4MeV (Type BG)
Required TL Detector	Ø 4.5mm x 0.9 mm or 3.2 mm x 3.2 mm x 0.9 mm

- The reader used is model Harshaw 6600 reader, the crystals were annealed up to 3000C and the dose- response curve was adjusted to measure in Micro- Sieverts.

The three centers differ from each other in several issues, such as the basic design, the radiation protection measures used, the skill of the workers and their professional behavior with radiopharmaceuticals during their work period. This explained as follows:

a) Center (1):

This center is operated by three workers (physicists, technician, and nurse) who perform all 18F-FDG PET/CT Scans.

Nuclear Medicine procedures require patient interaction relating to patient's preparation administration of radioactive medication or parental route, explaining the procedure comforting and reassuring the patients. The workers were assigned to cover a workday from 8:00 AM to 4:00 PM for six days per week, on an average day; the PET/CT scanner will image (4–6) patients who received (300-350) MBq with average activity (~ 325 MBq) of 18F-FDG each.

The center consists of a hot laboratory, injection room, Scanner room, control room, two hot toilets and dressing room, as well as some other facilities.

b) Center (2)

This center is operated by three workers (physicists, technician, and nurse) who perform all 18F-FDG PET/CT Scans .They are assigned to cover a workday from 8:00 AM to 5:00 PM for six days per week, on an average day, the PET/CT scanner performs 8-12 patients receiving 275- 315 MBq with average activity (~ 298 MBq) of 18F-FDG each. The center consists of a hot laboratory, injection room, uptake room, scanner room, control room, two hot toilets and dressing room, as well as some other facilities attached to the facility.

c) Center (3)

This center is operated by two groups, each group consisting of one nurse, one medical physicist and one technician operating 18F-FDG PET/CT scanning procedures. They are assigned to cover a workday from 8:00 AM to 5:00 PM for three days per week, on an average day; the PET/CT scanner perform 13–15 patients receiving 333-355 MBq with average activity (~ 345 MBq) of 18F-FDG each. The center consists of a hot laboratory, two injection room, scanner room, control room, two hot toilets and two dressing rooms, as well as some other facilities attached to the center.

The working group's job descriptions were as follows according to the actual not ideal working environment:

The Role of Medical Physicist:

Medical physicist performs many steps of task in the preparation of 18F-FDG dose:

A. Receiving the total activity of the 18F-FDG multi-dose vial from the cyclotron and stored into (5 cm) thick lead container.

B. Measurement of the total activity of the 18F-FDG.

C. Withdrawing the dose prescribed to each patient from (18F-FDG) in a syringe based on the weight of the patient (~1mCi to 10 Kgm)

D. Put the syringe loaded with tracer in a dose calibrator to assay the activity (add or subtract)

E. Transferred the syringe loaded with tracer manually to shielded transported box for the nurse to take it and inject the patient.

The dose withdrawal is always performed within hot laboratory, being drawn up behind a bench-mounted lead shield with a lead equivalent glass insert.

In addition to the supervision of the all imaging procedures in the PET/CT Facility during daily work.

The Role of Nurse: The nurses performs many steps in the administration of radiopharmaceutical, prior the nurse receives the patient and checks blood glucose) should not exceed 200mgm/dl) and Make pre- canalized intravenous (IV) line for patient (to reduce the exposure time). prior the nurse receives the patient and checks blood glucose) should not exceed 200mgm/dl).

A. Transportation of 18F-FDG dose from the hot laboratory to the injection room.

B. Injection of prescribed dose of (18F-FDG) to each patient.

C. Flushing of normal saline into the intravenous line (IV).

D. Removal of IV line after end the 18F-FDG PET/CT scan.

After injection of the prescribed dose, the nurse leave immediately the patient's injection room and The patient will normally recline in a comfortable lounge chair for (30-45) minutes in injection room or uptake room (So that the body's cells absorb the tracer) .

All the injection procedure is done under supervision of the responsible physician of each center.

The Role of Technician:

The Technician performs all PET/CT imaging tasks, these include:

A. Escorting the patient to the scanner room after voiding in a reserved bathroom.

B. Positioning the patient on the PET-CT scanner for the 18F-FDG PET/CT scan.

C. Acquiring images.

D. 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.

Statistical methods: ANOVA F-test is used within the context of one-way and factorial between-subjects' univariate designs. The ANOVA F-test was the method of choice for examining the study groups mean differences, despite its reliance on the stringent assumptions of normality and variance homogeneity. Although ANOVA F-test is relatively insensitive to violations of the normality assumption in terms of Type I error control, it is considered a highly sensitive test for differences in population variances. This sensitivity is accentuated when group sizes are unequal, which was not the case in our study.

As a result, one Way ANOVA was used to compare means from the independent groups using the F-distribution. The null hypothesis for the test was that the group means were equal. Tukey's honest significant difference (HSD) post hoc test was used to confirm where the differences occurred between groups, and was only utilized when an overall statistically significant difference in group means is calculated (i.e., a statistically significant one-way ANOVA result).Whenever the data met the homogeneity of variances assumption and to prevent Type I error, Tukey's honest significant difference test has been chosen, otherwise, when the data did not show homogeneity, Games Howell post hoc test was considered. Moreover, Scheffe's procedure, as the most flexible and most conservative post hoc test, may be used to correct alpha for all complex comparisons of means. It is important to note that, Scheffe's test complex comparisons involve contrasts of more than two means at a time. Finally, SPSS software, version 23 (SPSS Inc., Chicago, Illinois, USA) was used for data entry and analysis. All analyses were carried out at a significance level of 0.05.

RESULTS:

a) Ring Dosimeter Measurements of the Center (1):

Finger radiation doses for staff in center (1) are reported in **Table (2). T**he readings were extracted for all medical physicists, technicians, and nurses for one-month duration.

Table (2): Average finger doses per study and the prospective annual finger dose for center (1).

	Work Group	No. of Procedures	Handled Activities (MBq)/ study	Average finger Dose (μSv/study)	Prospective annual finger dose (mSv)
Center 1	**Physicist**	124	325±25	290.6±29.4	432.4
	Technician	124	325±25	55.12±8.69	82.02
	Nurse	124	325±25	29.57±4.87	44.0

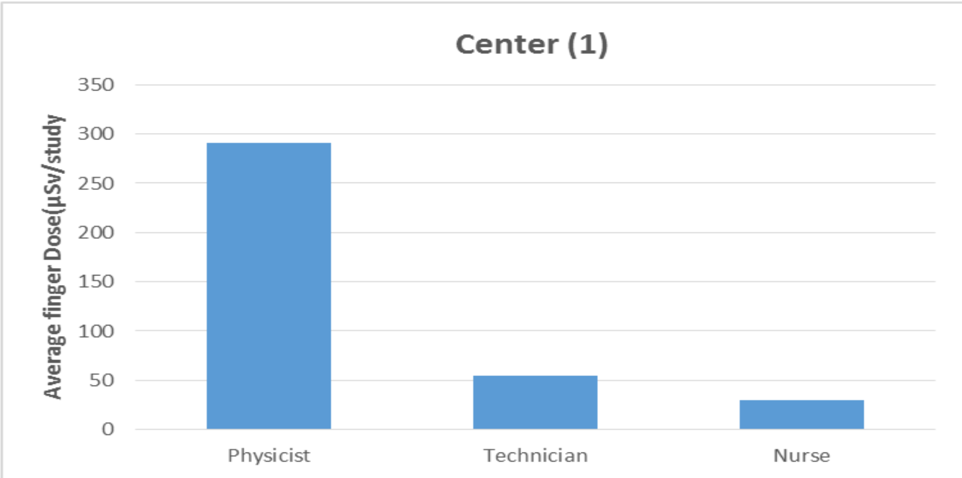

Figure (1): Average finger dose per study for workers in center (1)

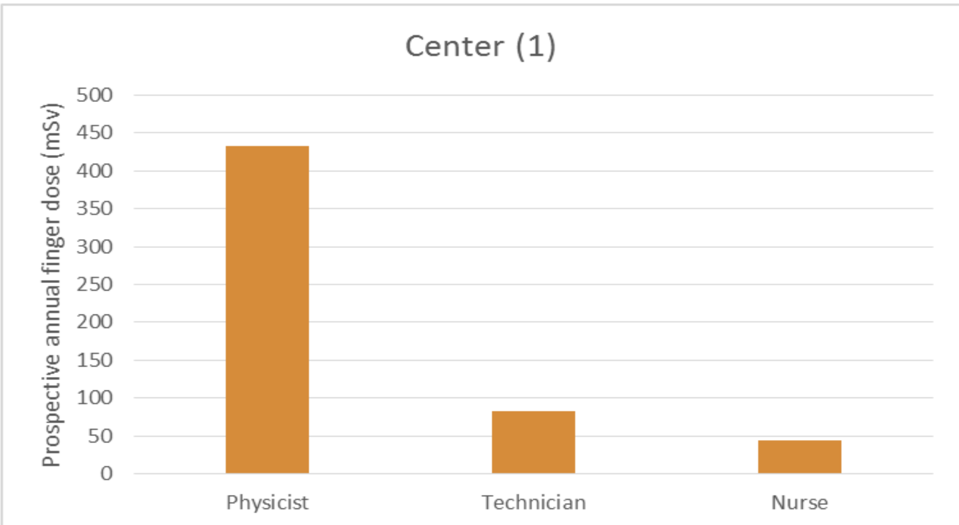

Figure (2): Prospective annual finger dose for workers in center (1).

b) Ring Dosimeter Measurements of the Center (2):

Finger radiation doses for staff in center (2) were reported in **Table (3)** the readings were extracted for all medical physicists, technicians, and nurses for a one-month duration.

Table (3): Average finger doses per study and the prospective annual finger dose for center (2).

	Work Group	No. of Procedures	Handled Activities (MBq)/ study	Average Finger Dose (μSv/study)	Prospective annual finger dose (mSv)
Center (2)	Physicist	240	295±20	168.3±17.22	484.7
	Technician	240	295±20	43.65±9.31	125.71
	Nurse	240	295±20	64.35±13.87	185.33

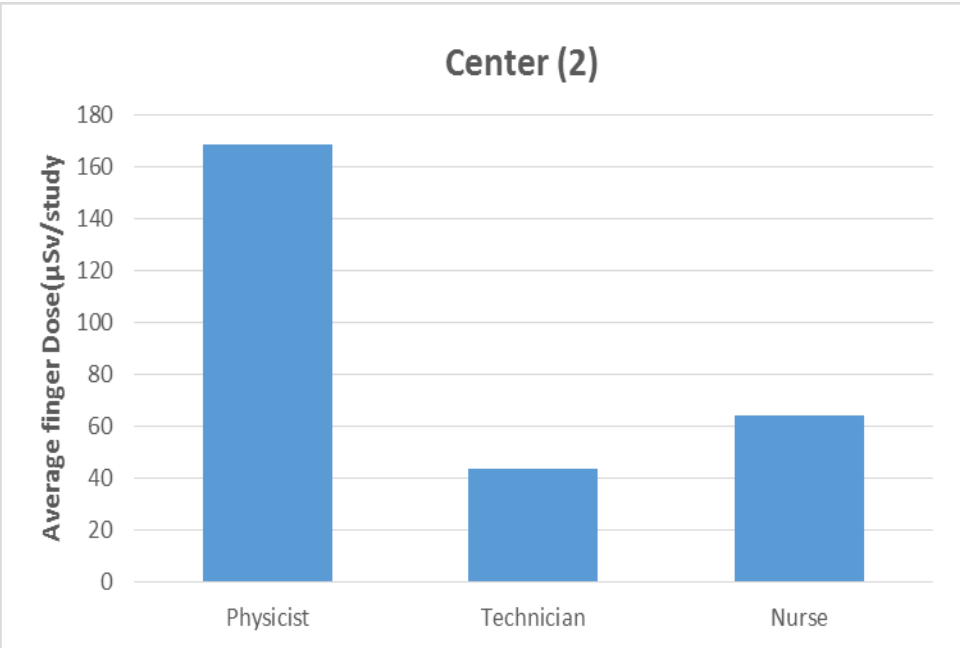

Figure (3): Average finger dose per study for workers in center (2)

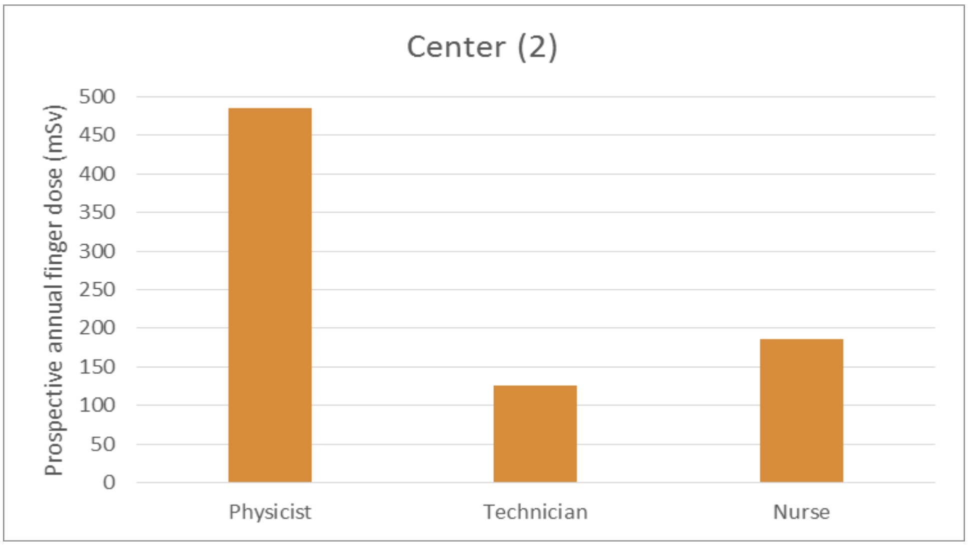

Figure (4). Prospective annual finger dose for workers in center (2).

c) Ring Dosimeter Measurements of the Center (3):

Finger radiation doses for staff in center (3) were reported in **Table (4)** the readings were extracted for all medical physicists, technicians, and nurses for a one-month duration.

Table (4): Average finger doses per study and the prospective annual finger dose for center (3).

	Work Group	No. of Procedures	Handled Activities (MBq)/ study	Average Finger Dose (µSv/study)	Prospective annual finger dose (mSv)
Center (3)	**Physicists**	165	344±11	203.5±17.74	402.93
	Technicians	165	344±11	38.77±7.33	76.76
	Nurses	165	344±11	59.6±6.33	118.08

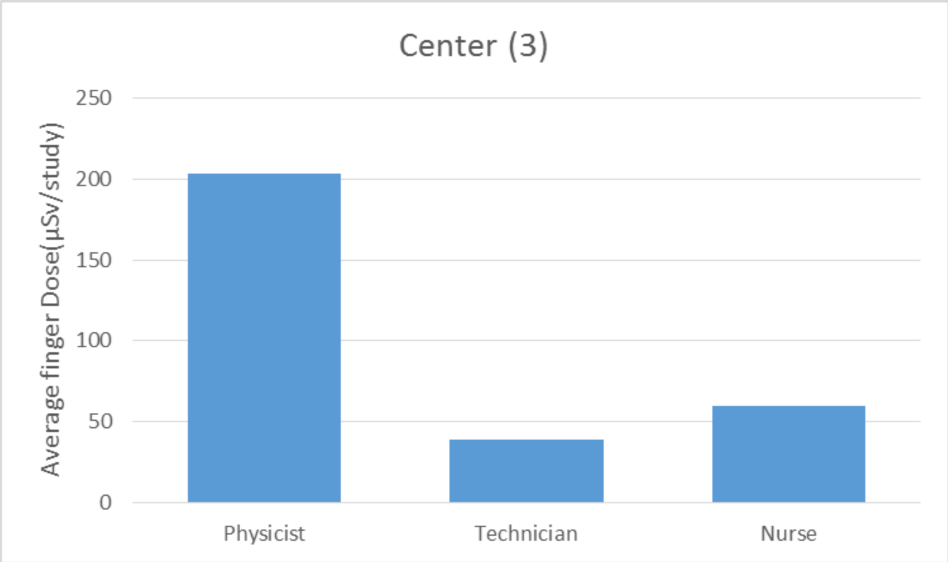

Figure (5): Average finger dose per study for workers in center (3)

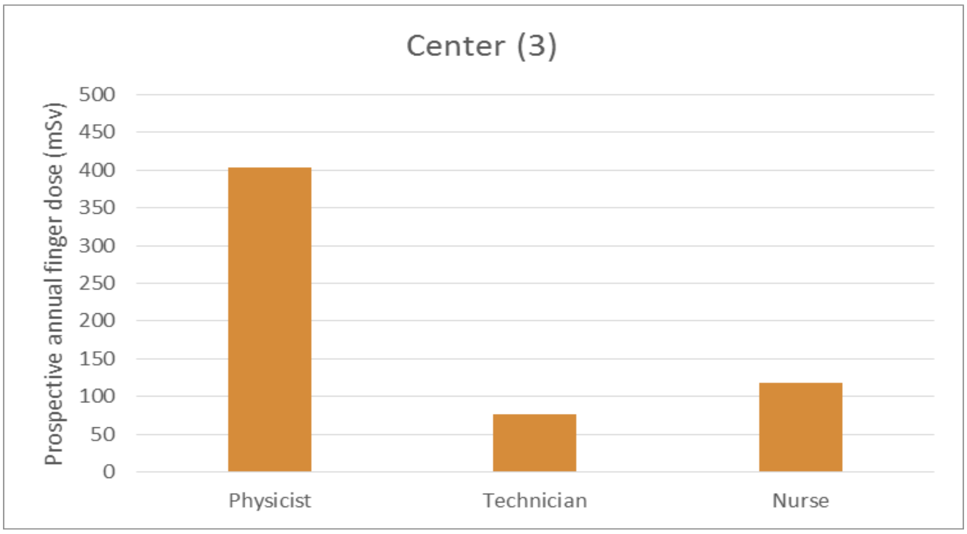

Figure (6): Prospective annual finger dose for workers in center (3).

Regarding the finger doses measurements done in the three studied centers among the studied three groups of professions, one-way ANOVA test results have shown that there were statistically significant differences between group means (p = 0.015). Tukey's honest significant difference (HSD) test revealed a significant difference between nurses group and physicists group on one side (p = 0.001) and between physicist group and technicians group on the other (p = 0.001). There were no statistically significant difference between technicians group and nurses group (p = 0.32).

The results show that the physicist group has the highest received prospective annual dose 440.01 mSv/year. The mean technician's prospective annual finger dose measurements, across the three centers, appeared to be the lowest scoring 94.83 mSv/year and nurses measured 115.8 mSv/year. Finally, there was no recorded significance for the studied categories across the three centers between their prospective annual finger dose measurements (p-value = 0.072).

DISCUSSIONS:

The evolution of the usage of positron emitters will continue to increase in nuclear medicine due to the increasing of PET and PET-CT imaging facilities [10, 11]. It is mandatory to monitor the dose received by the staff to check whether they are following the strict regulations of handling the radiation doses or not. Finger doses are one of the important indicators of the exposure for the critical group of professions handling the positron emitters specially radio pharmacists, physicist, technicians, and nurses.

The critical groups that get exposure from a radioactive patient in a PET facility are the nurses and technicians performing the injection and scanning respectively. While in most centers the physicist is responsible for dose fractionation and dispensing.

In the current study, we have estimated the annual prospective finger dose to three different groups of professions among three different PET-CT centers. There were a few studies available in the literature comparing the dose received by the staff in conventional nuclear medicine and PET imaging [12, 13]. The average whole body dose per procedure to the staff in conventional nuclear medicine has been reported to be lower than that in PET facility [9]. This is understandable due to penetrating annihilation photons and higher exposure rate constant for positron emitting radiopharmaceuticals.

A study by ***G.S. Pant et.al*** [14] studied the doses received to different categories in PET facility including the wrist dose and it indicated that they overestimated the wrist dose of the physicians and this estimated cumulative wrist dose would be less than 15 mSv.

Another study was done ***by Mustafa Demir, et.al*** [15] studied the radiation doses to technologists in their PET-CT facility including the finger doses with and without shielding precautions comparing the left and right hand measurements, their results show that the annual finger radiation doses of five technologists before shielding precautions were 210.36 and 293.72 mSv for the left and right hand, respectively, After shielding precautions were 158.16 and 217.58 mSv for the left and right hand, respectively. As they expected, the radiation doses received by the right hand was obviously significantly higher than for the left hand, because the right hand was in closer contact with the 18F-FDG vial and syringe.

In the present study, the finger doses were measured using the ring dosimeter for different working professions and a comparison was done between three different PET-CT centers. Our results show that the physicist group has the highest received prospective annual dose 440.01 mSv/year. The mean technician's prospective annual finger dose measurements, across the three centers, appeared to be the lowest scoring 94.83 mSv/year and nurses measured 115.8 mSv/year. There was no recorded significance for the studied categories across the three centers between their prospective annual finger dose measurements.

Comparing the highest finger dose which was recorded for the physicists' group to the dose limits for the extremities by the ICRP occupational dose limits report which is 500mSv/Year. [16] It was found that their finger doses are near to the maximum acceptable dose limit but still within the acceptable range.

This finding raises the issue of having more than one physicist per center in order to distribute the workload and exposure among more than one physicist. Also the principles of time, distance and shielding should be followed for any procedure involving radioactive administration, particularly while working with the PET radiopharmaceuticals. Keeping distance is the most economical method for reducing their exposure to radioactive sources. Continuing education on radiation protection is crucial for all the staff for a safe working environment.

CONCLUSIONS:

Finger doses are an important indicator for the personal exposure especially for those workers who use their hands in dealing with radioactive materials. The study revealed that the physicists are exposed higher than nurses and technicians in PET-CT facilities. There were no recorded significant differences for the studied categories across the three centers between the prospective annual finger dose measurements of the studied working professions. When comparing the highest finger dose which was recorded for the physicists' group to the dose limits for the extremities by the ICRP occupational dose limits, it was found that their finger doses are near to the maximum acceptable dose limit but still within the acceptable range.

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