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An occupational dose distribution study in a positron emission tomography service

Estudo da distribuição de dose ocupacional em um Serviço de Tomografia por Emissão de pósitrons

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Abstract

Positron emission tomography (PET) is a powerful diagnostic tool, especially for Oncology. In PET procedures, the hands exposition of the workers is potentially higher than the thorax exposition due to the direct handling of the high-energy photons radionuclide. As the dose distribution in the extremities is non-uniform, the conventional monitoring methods (dosimetric ring and bracelet) may underestimate the skin dose equivalent in the most exposed part of the hand, which usually are the fingertips. In this study, two PET services had their workers monitored during the tasks of preparation and injection of the radiopharmaceutical ^{18}F-fluorodeoxyglucose (^{18}F-FDG) in patients, using chips of LiF:Mg,Cu,P thermoluminescent dosimeters (TLD-100H). Each employee worn TLD sets attached on the wrist and fingers of the dominant hand, and on the thorax. The highest dose values were measured on the index finger, which received doses up to 0.4 mSv in a single procedure of ^{18}F-FDG dose preparation and 0.27 mSv in one injection. In a potential annual dose extrapolation, assuming that this technician performs 840 PET scans (preparation and injection), with these doses values, in one year, his skin dose equivalent on the index finger would be 564 mSv, exceeding the annual skin dose equivalent limit of 500 mSv. Despite the hands dose distribution is very sensitive of how to hold the syringe, the dose near to the index fingertip are always the highest, can be, respectively, 4 and 12 times greater than in the position where dosimetric rings and bracelets are commonly used for routine individual monitoring. Thus, extremity individual monitoring, in addition to the mandatory whole body individual monitoring with thorax dosemeters, are important tools for occupational dose optimization and should also be mandatory for PET technician.

Keywords: positron-emission tomography, occupational exposure, dosimetry, TLD.

Resumo

A tomografia por emissão de pósitrons é uma poderosa ferramenta de diagnóstico, especialmente para a Oncologia. Nos procedimentos de tomografia por emissão de pósitron, a exposição das mãos dos trabalhadores é potencialmente maior do que a do tórax devido ao manuseio direto de radionuclídeos com fótons de alta energia. Já que a distribuição da dose nas extremidades não é uniforme, os métodos de monitoramento convencionais (anel dosimétrico e pulseira) podem subestimar a dose equivalente da pele na parte mais exposta da mão, que costuma ser a ponta dos dedos. Neste estudo, dois serviços de tomografia por emissão de pósitrons tiveram seus trabalhadores monitorados durantes as práticas de preparação e injeção do radiofármaco ^{18}F-fluordeoxiglicose (^{18}F-FDG) em pacientes, usando dosímetros termoluminescentes LiF:Mg,Cu,P (TLD-100H) em forma de pastilhas. Cada funcionário utilizou um conjunto de TLDs afixados ao punho e aos dedos da mão dominante, e no tórax. Os valores de dose mais altos foram medidos no dedo indicador, que recebeu doses de até 0,4 mSv em um único procedimento da preparação de dose de ^{18}F-FDG e 0,27 mSv em uma injeção. Numa extrapolação da potencial dose anual, considerando que este técnico realize 840 exames de tomografia por emissão de pósitron (preparação e injeção), com esses valores de doses, em um ano, seu equivalente de dose na pele do dedo indicador seria 564 mSv, ultrapassando o limite anual de dose equivalente na pele de 500 mSv. Apesar de a distribuição de dose nas mãos ser muito sensível de acordo com a forma de segurar a seringa, a dose próxima à ponta do dedo indicador será sempre a maior e pode ser, respectivamente, 12 e 4 vezes maior do que na posição em que as pulseiras e os anéis dosimétricos são comumente utilizados para monitoramento individual periódico. Desse modo, o monitoramento individual da extremidade, além do monitoramento individual de corpo inteiro obrigatório com dosímetros do tórax, são ferramentas importantes para a otimização da dose ocupacional e devem ser obrigatórias para o técnico da tomografia por emissão de pósitrons.

Palavras-chave: tomografia por emissão de pósitron, exposição ocupacional, dosimetria, TLD.

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Introduction

Positron emission tomography (PET) is a powerful diagnostic tool, particularly in Oncology, where its application is growing continuously and becoming a routine procedure in Nuclear Medicine Services. In this type of procedure, doses are transferred from vials to syringes and, then, administered to patients, resulting in non-uniform occupational dose. This dose is mainly due to high-energy photons resulting from the annihilation of positrons from the decay of the ^{18}F-fluorodeoxyglucose (^{18}F-FDG)[1], which nowadays is the unique commercially available radiopharmaceutical in Brazil for PET studies. The large and growing number of patients undergoing PET procedures and workers involved in this practice warrants continued efforts to improve the quality of diagnosis and to reduce the radiological risk associated.

The radiation dose to a technician who performs PET scans is usually greater than the dose for the same function in conventional nuclear medicine, considering the same number of procedures. However, the doses in PET can be quite variable, because in this practice professionals handle the radioactive material using syringes and vials partially shielded, making a directional radiation field, which does not occur with conventional procedures.

The routine monitoring of workers is an important part of any radiation protection program and is performed, among other reasons, to verify and demonstrate compliance with dose limits regulated, besides giving information on work practices. In Brazil, external individual monitoring with dosimeter located on the thorax is compulsory for all workers in controlled areas. Extremity dosimeters are recommended in activities where the hands dose can be much higher than on the thorax, but is not compulsory. In PET procedures, the radiation risk on the hands is much higher than on the thorax. To worsen the occupational skin dose evaluation, in this case, the dose distribution on the hands is not homogeneous. The highest doses are usually received by the fingertips[2]. The difficulty in estimating the exposure of the most exposed part of the fingers is exacerbated by the conventional method used to determine the dose received by the hands skin, using dosimetric bracelets or rings. Even rings underestimate the skin dose of the finger most exposed part. Therefore, special attention must be paid in positioning the extremity dosimeters[3].

This paper presents results of a study of occupational dose distribution in the two most critical activities of PET services: ^{18}F-FDG preparation and injection. The measurements are made with thermoluminescent dosimeters (TLDs) on all fingers of the dominated hand, on the wrist and on the thorax of each worker.

Methodology

The study of doses of occupationally exposed individuals was done in two Brazilian PET services (S1 and S2). The workers evaluated were those that performed tasks of preparation of the radiopharmaceutical for its subsequent administration in the patient, and of injection the radiopharmaceutical into the patient during PET procedures for oncologic purposes. Both practices were chosen because of the proximity of professionals with radioactive material.

In both services studied, for dose preparation, the technician uses a manual device shielded with 30 mm lead to fractionate doses. The dose is then transferred to a syringe protected by a shield with 6 mm tungsten, and the activity is measured in a dose calibrator and taken to the patient to be injected. After injection, the technician takes back the syringe in the shield to the radiopharmacy. The same worker performs the tasks of dose preparation and injection of the radiopharmaceutical.

To make the dosimetry of professionals, discs with 3.6 mm in diameter and 0.38 mm thick of Harshaw LiF:Mg,Cu,P TLD (TLD-100H) were used. The dosimeters were evaluated in a semi-automatic 5500 Harshaw reader. Individual sensitivity factors are used for the TLD in order to reduce the uncertainties. The operational quantity used for the measurements is $H_p(10)$ for thorax dosimetry and effective dose estimation, and $H_p(0.07)$ for finger and wrist dosimetry and skin dose equivalent. Calibration in $H_p(0.07)$ and $H_p(10)$ are performed, respectively, in ISO rod and slab phantoms, according to ISO 4037-3[4] and ISO 12794[5].

The dosimeters were placed in blister of pills cut into individual cavities. In S1, the dosimeters were placed, with the aid of adhesive tape, in 8 points of the right hand (Figure 1), one point in the right wrist (where the dosimetric bracelet is commonly used) and one on the thorax (trapped in the official dosimeter) of the worker in each procedure. In S2, only 5 points were measured in the right hand, corresponding to points A, B, C, D and E in the Figure 1, which are the points closer to the radioactive material during handling. TLDs were placed immediately before the beginning of each practice (preparation and injection of radiopharmaceuticals) and removed soon after it ends.

During all measurements, parameters such as service, place where the monitoring were performed, date, type of procedure (preparation or injection), number and position of each dosimeter, activity handled, exposure time, professional name (recorded in code) and any other special comments were recorded.

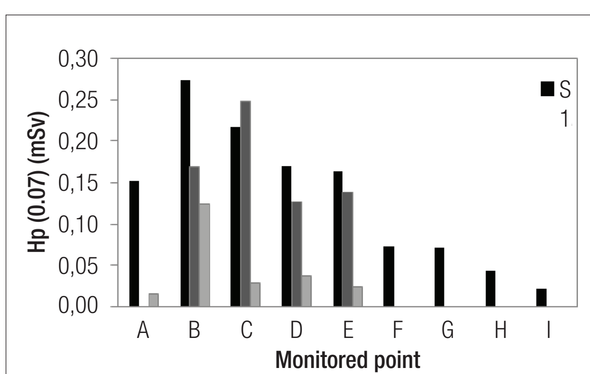

Figure 1. Location of monitored points at the workers' hand.

Results

In S1, six procedures of preparation and six of injection, all performed by one technician, were evaluated. In S2, five preparations and five injections performed by one technician and one injection performed by another technician were measured.

In S1, the mean time spent both in the dose preparation and in the injection of ^{18}F-FDG was about 50 seconds. The activity manipulated and injected in each patient was about 370 MBq. In S2, the mean time spent in the preparation was approximately 160 seconds and in the injection, 37 seconds. Each syringe was filled, in this case, with about 300 MBq.

Table 1 shows the results of the TLD measurements evaluated points. The reported values are mean values per procedure.

As expected, thorax doses, both in preparation and injection, were much lower than in the hands, because they are always closer to the source. In preparation, the thorax is additionally shielded by the bulkhead in front of the table handling, giving doses even lower than in the injection. The dose in the fingers during preparation is about two orders of magnitude higher than in the thorax and, in the injection procedure, one order higher. These results show clearly that hands routine individual monitoring, besides thorax dosimetry, is always recommended for PET technicians, but it is rarely used today in Brazil.

The doses received by the workers' fingers vary widely depending mainly on the form in which the PET service employee holds the syringe. However, all dose values measured in this work during the radiopharmaceuticals preparation is higher than in the injection process, some cases reaching values four times higher. The highest doses were obtained always on the index finger, especially at the point closest to the fingertip (B).

Taking into account both the preparation and the injection, the hands point with the highest dose evaluated (B) may received a dose four times higher than the point where the dosimetric rings are commonly worn (E) and 11 times higher than the point where dosimetric bracelets are worn (I). Then, for extremity individual monitoring of PET workers services, the use of dosimetric bracelet should be avoided and much attention should be given to the positioning of the dosimetric ring to do not underestimate the hands skin dose. Figure 2 shows the hands dose distribution of the three PET technicians.

The mean dose values on the hands depend also on the activity manipulated and on the experience of the technician. Greater experience, less time spent to perform each function, then less dose.

For preparation, at S2, even with higher times, the doses are still lower at the measured hand; this is probably due to the fact that all measurements were made only on the dominated hand, which is not always the one located closer to the source, i.e., the most exposed. Measures in both hands are now in progress.

Table 1. Mean measured dose per procedure.

Monitored point	Preparation S1	Preparation S2	Injection S1	Injection S2
Hand	$H_p(0.07)$ (mSv)			
A	0.29	0.08	0.15	0.02
B	0.40	0.16	0.27	0.15
C	0.36	0.11	0.22	0.14
D	0.26	0.10	0.17	0.08
E	0.26	0.07	0.17	0.08
F	0.20		0.07	
G	0.19		0.07	
H	0.15		0.05	
I	0.06		0.02	
Thorax	$H_p(10)$ (mSv)			
	0.001	< LID*	0.01	< LID*

*<LID = Value lower than the lower detection limit of the system.

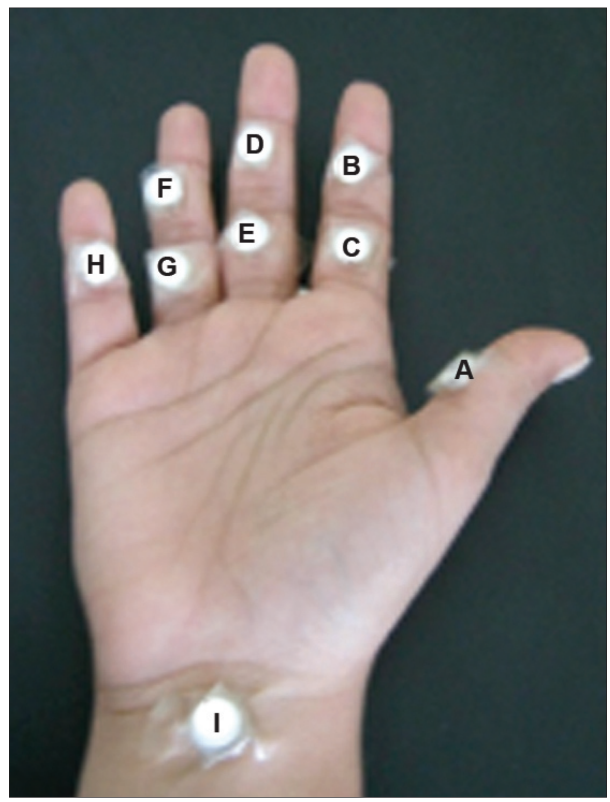

Figure 2. Dose distribution in the hands of three different technicians performing the task of injection at PET services.

Using the Table 1 data, an extrapolation of the potential annual dose received by the S1 technician was made, whereas he performs about 840 PET examinations per year, including preparation and injection. The results are presented in Table 2, showing the possibility of the skin of his index finger (point B) receiving equivalent doses (estimated by the TLD $H_p(0.07)$ measurements) higher than the extremity annual skin equivalent dose limit of 500 mSv/year[6,7]. The annual skin dose equivalents in all other points of the fingers are lower than the dose limit, but surpass the skin (and extremity) annual dose equivalent investigation level of 150 mSv/year[6,7].

Table 2. S1 technician potential annual dose on PET preparation and injection procedures.

Monitored point	Potential annual dose (mSv)		
	Preparation	Injection	Total
A	244.19	128.13	372.32
B	334.07	230.05	564.12
C	301.65	183.30	484.95
D	220.12	142.43	362.56
E	214.85	138.37	353.22
F	165.94	61.36	227.29
G	155.05	60.29	215.34
H	128.21	37.70	165.90
I	52.92	19.28	72.20
Thorax	0.88	8.67	9.55

On wrist, the dose is below the skin dose equivalent investigation level. Considering the value of $H_p(10)$ measured on the thorax as an estimate of the effective dose, this one exceeds the annual effective dose investigation level of 6 mSv/year, but not its annual limit.

Conclusions

The external radiation doses measured on the thorax and hands of workers doing procedures of ^{18}F-FDG preparation and injection for PET examinations confirm, as expected, that the values are high and not homogeneous. Thus, extremity individual monitoring, in addition to the mandatory whole body individual monitoring with thorax dosimeters, are important tools for occupational dose optimization and should also be mandatory for PET technician.

Despite the great variation in the distribution of the skin doses in the hands for different PET employees, which depends on the different way they hold the ^{18}F-FDG syringes, the point of highest exposition on the hands are normally the index fingertip (B). The highest skin dose equivalent does not happen on their wrist (I) or their middle finger base (E), where extremity dosimeters are usually worn. This work evaluated only the dominated hand, but, as observed during the measurements, sometimes the highest dose may occur on the other hand. Then, it is necessary to continue this work to better map both hands of the professionals in PET procedures to check the points that receive the highest doses, in order to aid better position of the dosimetric ring.

In PET service, constant optimization of radiation protection is essential, because it is possible that some doses surpass annual individual dose limits. Occupational exposures can be minimized through good planning, good practice, education program and patient cooperation. As the dose is directly related to exposure time and manipulated activity, it is necessary to focus on basic recommendations of radiation protection, including time, distance and shielding. Appropriated routine external individual monitoring can give very important information for dose optimization programs.

References

1. Ginjaume M, Pérez S, Duch MA, Ortega X. Comparison of TLD-100 and MCP-Ns for use as an extremity dosemeter for PET nuclear medicine staff. Radiation Measurements. 2008;43:607-10.
2. Wrzesien M, Olszewski J, Jankowski J. Hand exposure to ionising radiation of nuclear medicine workers. Radiat Prot Dosimetry. 2008;130(3):325-30.
3. European Commission. Technical recommendations for monitoring individuals occupationally exposed to external radiation - RP160; 2009.
4. International Organization for Standardization. ISO 4037-3, Part 3. X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy; 1999.
5. International Organization for Standardization. ISO 12794. Nuclear energy – Radiation protection – Individual thermoluminescence dosimeters for extremities and eyes; 2000.
6. Comissão Nacional de Energia Nuclear. Diretrizes básicas de proteção radiológica, CNEN-NN-3.01. Brasil; 2005.
7. International Commission on Radiological Protection. The 2007 recommendations of the International Commission on Radiological Protection, Publication 103. 2007;37(2-4).