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Impact on dosimetry of occupationally exposed individuals on the patient management for PET/MRI studies: a comparison study with dosimetry on PET/CT

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ABSTRACT

PET/MRI technology has expanded the boundaries of investigation in nuclear medicine, supported by the high sensitivity of solid-state PET detectors. Nonetheless, the coil positioning might lead to an increased exposure period of the worker to the injected patient. This procedure does not occur on PET/CT and, therefore, exposure period is reduced on such scanner. The aim of our study was to evaluate the dosimetry of two occupationally exposed individuals (OEI) working at the Center of Nuclear Medicine of Hospital das Clínicas of the University of Sao Paulo. We used thermoluminescent (TLD) dosimeters in pulse, whole-body and crystalline for PET/MRI and PET/CT procedures during five months of clinical and research routine. We also monitored the time for positioning/removing the patient on both scanners. For this study, OEI1 performed 76 PET/MRI studies and 102 PET/CT studies while OEI2 performed 26 and 56 PET/MRI and PET/CT studies, respectively. We found no evidence of differences for the whole-body dose values between both scanners (*p *= 0.22). The average time of patient management (positioning/removing the patient) was 14.38, and 3.81 minutes for PET/MRI and PET/CT, respectively. When the normalization by the number of PET/CT studies was applied, we found no statistical difference for effective and equivalent dose values. Our study encourages future investigations on nursing staff, which is a critical population that is exposed to ionizing radiation, mainly on dynamic studies, due to the synchronized injection with the protocol starting.

Keywords: **Dosimeter, Exposure, Medical Physics, TLD.**

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1. INTRODUCTION

The Positron Emission Tomography (PET) is an imaging approach to evaluate the metabolism of structures of interest such as bones, muscles, brain, lungs and liver, among other organs [1-5]. The advent of PET/MRI (PET/magnetic resonance imaging) provided new horizons in the study of hybrid imaging in Nuclear Medicine. The new equipment provided physiological and anatomical images unparalleled quality images, as the PET detectors are digital and provide functional images with great spatial resolution, that could be related to the anatomical MR images with high contrast resolution [6].

The PET/CT (PET/Computed Tomography), is more widespread among Nuclear Medicine services in Brazil and worldwide. This hybrid technology also allows to fuse metabolic and anatomical images but it is rather affordable, compared to the PET/MRI [7]. In this sense, the PET/CT is suggested for several pathologies and, especially in oncology, is used in detecting and staging tumors and metastasis that could be correlated with the structural information from CT [8]. Such synergy provides for details than both examinations performed separately. The post-processing allows the identification and differentiation between benign and malign nodules through the radiotracer uptake. Thus, PET/CT studies are shown to be more sensitive to very small lesion detection, which most of the times are not seen by any other image modality [9].

The radiopharmaceuticals such as ^{18}F-FDG, ^{18}F-NaF, among other beta-emitters are necessary to perform the PET studies to show the tissue-of-interest's uptake. In the so-called pair annihilation process, two high-energy photons (511 keV each) are emitted from the patient's tissue-of-interest in opposite direction, reaching the PET detectors. During this period, the patient is under care of the clinic workers, i.e., the occupationally exposed individuals (OEI): nurses and biomedical staff and nuclear medicine physicians, which are exposed to the emitted radiation.

The concern about the absorbed radiation by the OEI always encouraged studies and specialists in radioprotection [10] as the low amounts of radiation that might harm the worker's health in the future still are not quite determined. To regulate the exposure of workers and the public, two dose quantities are suggested by the International Commission on Radiological Protection (ICRP) [11]: the equivalent and effective doses, both expressed in sievert (Sv) to distinguish them from the absorbed dose in gray (Gy). In fact, the annual dose limit (for OEI) preconized by the National

Commission of Nuclear Energy (CNEN) is 20 mSv for the whole body, 20 mSv for the lens of the eyes and 500 mSv for body extremities (hands and feet). The field of physics that provides advances in the frontier of knowledge regarding the absorbed radiation from both patient and OEI is dosimetry [12]. In the scope of this study, we were interested in the specific dosimetry of the biomedical staff as, in general, they have a higher amount of time dealing with the injected patient during the exam's explanation and their positioning in the scanners. Furthermore, the biomedical staff that works on PET scanners might receive a higher equivalent dose than those working only with conventional nuclear medicine due to the fact that 511 keV photons from positron annihilation is much higher than the 140 keV photons from ^{99m}Tc (Technetium). Such scenario together with infrastructure matters, i.e., availability of shielding, radiopharmacy good practices, dedicated rooms to injected patients have posed an impact for radiation protection to the staff working in nuclear medicine, specifically PET scanners [13]. The motivation of our study relied on the fact that PET/MRI scanners need to place coils over the patient to perform the MRI sequences. This step takes more exposure time by the OEI to the injected patient, laid on the bed scanner. Such step is absent in the PET/CT as there is no need to place scanner devices over the patients.

The aim of this study was to evaluate whether the OEI's dosimetry working on PET/MRI is higher than PET/CT as positioning the coils on the patient lead to a higher dose on the former one for the biomedical staff in a Nuclear Medicine facility in São Paulo, Brazil.

2. MATERIALS AND METHODS

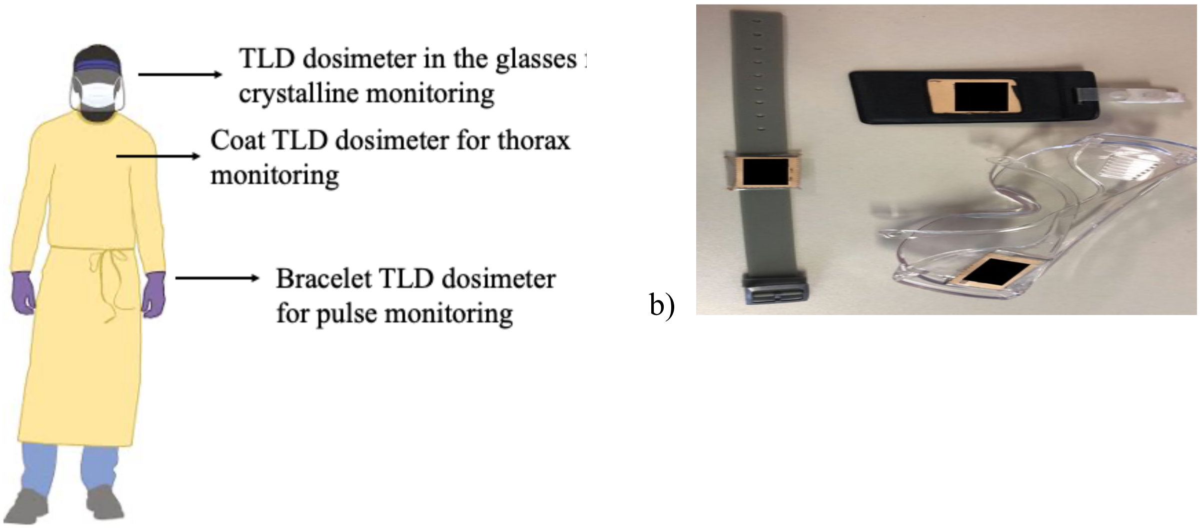
This study was approved by the institutional board of the Institute of Radiology of the Hospital das Clínicas de São Paulo (process number: 19491919.9.0000.0068).

2.1. Dosimetry measurement and reading

The dosimetry of two OEIs (biomedical staff) was measured during a period of five months. Both of them used two sets of TLD (thermoluminescent dosimeters) for pulse, whole-body and crystalline: one set for PET/MRI, and the other set for PET/CT studies, respectively (see Figure 1).

The set of dosimeters were monthly renewed and the TLD reading was performed at the Institute of Physics of the University of São Paulo. The dose units for each TLD dosimeter were showed in mSv (miliSievert).

Figure 1: a) crystalline, whole-body and pulse TLD dosimeter monitoring and b) TLD dosimeters used by the OEI for this study.



a)

The time of patient management during the PET/MRI and PET/CT studies were recorded by the OEIs during the procedure, and it included only the time of positioning and removing the patient from each bed scanner.

2.2. Statistics

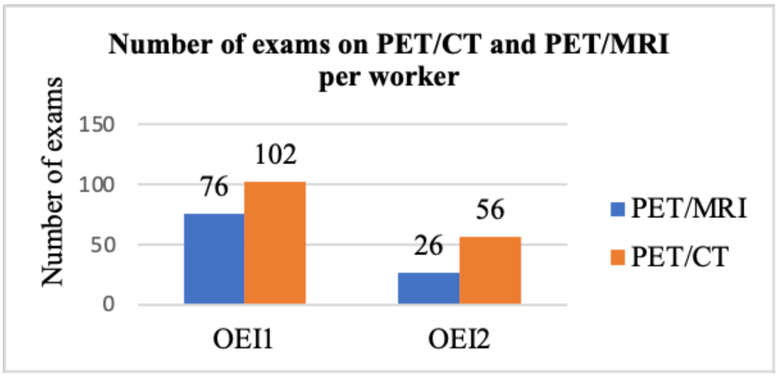
To evaluate the normality distribution of our data, we applied the Shapiro-Wilk test. Posteriorly, we used the One-way ANOVA to test the difference of effective and equivalent doses between the workers for both PET/MRI and PET/CT, and the difference of time management for placing and removing the patient from each bed scanner. Statistics calculation were performed using Microsoft® Excel. A significance level of $\alpha = 0.05$ was adopted.

3. RESULTS AND DISCUSSION

We evaluated the dosimetry of two OEIs through TLD dosimeters for pulse, whole-body and crystalline for procedures on PET/CT and PET/MRI. The injected activities for the studies performed in both scanners were 185 – 370 MBq for ^{18}F studies, 111 – 185 MBq for ^{68}Ga studies, 370 – 740 MBq for ^{11}C studies. Activities varied due to the different acquisition protocols.

Several studies were performed on both scanners such as ^{18}F-FDG, ^{68}Ga-PSMA, ^{11}C-PIB, ^{11}C-PK11195. The most frequent study procedure on the PET/MRI was brain scans using ^{18}F and ^{11}C-labeled pharmaceuticals, and head-to-thighs standard oncologic procedure with ^{18}F-FDG on the PET/CT. Overall, one-hundred two studies were performed on the PET/MRI while one-hundred fifty-eight studies were performed on PET/CT during the period of this study. The Figure 2 show the number of examinations performed on the PET/MRI and PET/CT scanners by each worker.

Figure 2: studies performed on the scanners by each OEI



The number of examinations retrieved of each scanner represent the common clinical routine in the Nuclear Medicine facility, since this study was performed before the pandemic. Furthermore, the number of examinations on PET/CT represent the clinical demand, while almost all studies on PET/MRI was demanded by medical studies. This explains the higher number of PET/CT studies, compared to those of PET/MRI. The OEI2 performed a smaller number of examinations than OEI1 during our study because he had a schedule period on the conventional nuclear medicine as well.

The Table 1 shows the estimation of dose for whole-body, pulse and lens of the eyes of both workers. In such evaluation, we found no statistical difference neither for whole-body (p = 0.22), pulse (p = 0.08) or lens of the eyes (p = 0.09) between the working time on PET/MRI and PET/CT.

The value of dose for whole-body during the PET/MRI examinations ranged from (0.05 mSv– 0.32 mSv), while the dose for lens of the eye and pulse ranged from (0.05 mSv– 0.19 mSv). For PET/CT examinations the dose values ranged from (0.05 mSv– 0.66 mSv) and (0.05 mSv– 0.93 mSv), respectively. These range values do not necessarily belong to the same worker, as they are the overall absolute maximum and minimum values reached during the period of this study.

Table 1: Whole-body, pulse and crystalline dose values between PET/MRI and PET/CT

	PET/MRI		**PET/CT**		***p*-value**
	Mean (mSv)	**CI (95%)**	**Mean**	**CI (95%)**	
Whole-body	0.09	0.03 – 0.15	0.18	0.03 – 0.32	*P = 0.22*
Pulse	0.10	0.06 – 0.13	0.28	0.06 – 0.51	*p* = 0.08
Lens of the eye	0.08	0.05 – 0.12	0.25	0.04 – 0.45	*p* = 0.09

CI: Confidence interval

The following Table 2 shows the mean dose for whole-body, pulse and lens of the eyes normalized by the number of exams performed on each scanner (102 PET/MRI and 158 PET/CT studies) over the whole period. We also found no difference for PET/CT when comparing to the normalized number of PET/MRI examinations as shown in the referred table.

Table 2: Mean dose values normalized by the number of PET/MRI and PET/CT studies.

	PET/MRI		**PET/CT**		***p*-value**
	Mean (mSv/exam)	**CI (95%)**	**Mean (mSv/exam)**	**CI (95%)**	
Whole-body	0.0009	0.0003 – 0.0015	0.0011	0.0002 – 0.0021	
Pulse	0.0009	0.0006 – 0.0013	0.0018	0.0004 – 0.0033	*p>0.05*
Lens of the eye	0.0008	0.0005 – 0.0011	0.0016	0.0003 – 0.0029	

CI: Confidence interval; mSv: miliSievert

We evaluated the doses for whole-body, pulse and crystalline of two workers on PET/MRI and PET/CT for clinical and research routine using TLD dosimeters. As we hypothesized that those body parts could show higher dose values due to the patient management while placing the MR coil, the pulse and lens of the eyes TLD readings could provide proper information about the protocol of handling the patients. Such evaluation is shown on Table 1, where the mean dose values are explicit for the three TLD dosimeters, as well as the statistics. Despite the mean dose values were about 2-fold for PET/CT, we found no statistical difference. When normalizing the readings of whole-body, pulse and lens of the eyes by the number of examinations for each scanner, we also found no statistical difference, as shown in the Table 2. Finally, we tracked the time spent on the patient management (shown in Table 3) during their placement/adjustment and removal from the bed scanner by the workers.

Table 3: Mean time management on PET/MRI and PET/CT

	PET/MRI		**PET/CT**		***p*-value**
	Mean (min)	**CI (95%)**	**Mean (min)**	**CI (95%)**	
Management time	14.38	11.92 – 16.85	3.81	3.48 – 4.13	$p < 0.001$

CI: Confidence interval

As expected, the PET/MRI procedures took longer than those from the PET/CT ($p < 0.001$) due to the positioning of the body coils over the patient. Also, a specific medical study protocol usually took about 30 to 40 minutes to correctly adjust a dedicated coil to the patient's kneel in the PET/MRI bed.

4. CONCLUSION

We found no difference on the management of patients by OEIs working on PET/MRI and PET/CT. We found no difference on the evaluation of whole-body, pulse and lens of the eyes TLD readings between both scanners. When the normalization by the number of examinations on both PET scanners was applied, the differences were also not statically significant. Also, none of the workers who contributed to the study have reached the investigation limit according to Brazilian recommendations for workers with ionizing radiation. Despite the longer period of patient management on the PET/MRI, our results showed the effect of the safety and good practice at our Nuclear Medicine facility. One limitation of our study was the lack of the dosimetry monitoring of the nursing staff. The high demand on the injected patient care during the clinical routine (either for regular or medical study patients) would mitigate the annotation of exposure time by the nurse themselves. Our study encourages future investigations on the nursing staff, which is a critical population that is also exposed to ionizing radiation, mainly on dynamic studies due to the synchronized injection that must be performed in the exam room, aside from the injected patient.

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