doi.org/10.15392/2319-0612.2025.2796
Braz. J. Radiat. Sci., Rio de Janeiro
2025, 13(2) | 01-15 | e2796
Editor: Prof. Dr. Bernardo Maranhão Dantas
Editor: Prof. Dr. Alfredo Lopes Ferreira Filho
Submitted: 2024-10-13
Accepted: 2025-03-14

Adressing Operational Changes in time and radioactive activity administered following the introduction of PET-CT Equipment with New Technologies: A Retrospective Analysis

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Abstract: Decreased radioactive activity to be injected in individuals for diagnostic exams performed on Positrons emission Tomography associated with Computed Tomography is becoming mandatory since the patient protection is one of the pillars for Radiation Protection. The technological advance opens the possibility to demonstrate this activity reduction as well as time reduction during the exam, which allow a better convinience to population, and still maintaining the quality of the diagnose. This study investigates operational changes observed after the introduction of a new PET-CT scanner (PET2), focusing on reductions in administered radioactive activity and acquisition time. The results show significant decreases in these parameters compared to a prior system (PET1). The scope of the study is limited to describing these operational impacts, based on the manteinance of diagnostic image quality support by the physician criteria.

Keywords: time reduction, activity reduction, PET-CT, new technology

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Abordando mudanças operacionais no tempo e na atividade radioativa administrada após a introdução de equipamentos PET-CT com novas tecnologias: Uma análise retrospectiva

Resumo: A redução da atividade radioativa a ser injetada em indivíduos para exames diagnósticos realizados em Tomografia por Emissão de Pósitrons associada à Tomografia Computadorizada está se tornando obrigatória, uma vez que a proteção do paciente é um dos pilares da Proteção Radiológica. O avanço tecnológico abre a possibilidade de demonstrar essa redução de atividade, bem como a redução do tempo durante o exame, o que permite uma melhor conveniência à população, e ainda mantendo a qualidade do diagnóstico. Este estudo investiga as mudanças operacionais observadas após a introdução de um novo scanner PET-CT (PET2), com foco nas reduções na atividade radioativa administrada e no tempo de aquisição. Os resultados mostram reduções significativas nesses parâmetros em comparação com um sistema anterior (PET1). O escopo do estudo se limita a descrever esses impactos operacionais, com base na manutenção do suporte da qualidade da imagem diagnóstica pelos critérios do médico.

Palavras-chave: Redução de tempo, redução de atividade, PET-CT, novas tecnologias

1. INTRODUCTION

Nuclear Medicine (NM) procedures constitute 1.9% of the total medical imaging procedures, yet they contribute 8.6% to the collective effective dose, resulting in an average effective dose of 0.12 mSv per capita (1). NM plays a crucial role in clinical practice, driven by the increasing number of procedures and advancements in radiopharmaceuticals and multimodality imaging technologies (2). This expansion highlights the importance of implementing exposure optimization processes and establishing Diagnostic Reference Levels (DRLs) in accordance with international recommendations (3–6).

The advent of digital technology in PET/CT imaging has brought about significant advancements, particularly in enhancing image quality, reducing radiation exposure, and improving operational efficiency (7). For that reason, it is important to demonstrate with retrospective collected data from a Nuclear Medicine Service the time and activity reduction administrated to individuals, during diagnostic exams made on Positron emission Tomography associated with Computed Tomography (PET-CT), assessing the impact of new technology. In order to make the exam a radiopharmaceutical called Fludesoxiglicose (18F)(8) was administred to patients. Based on technological advances from the machine purchased by a Northeast region Hospital in Brazil, this decrease made on the diagnostic exam presented no loss in quality whatsoever. Therefore, this procedure indirectly contributes to the radiological protection of patients and workers (Ocupationally exposed individuals – OIE). This project was approved by the CEP of the institute.

2. MATERIALS AND METHODS

Encrypted data collection from 175 individual exams performed between July and August, 2022, and another 175 individual exams performed between May to July, 2024, from a Nuclear Medicine service in the Northeast region of Brazil.

There were 2 machines from Siemens manufacturer. A Biograph TruPoint16 (PET1) (9) released in 2009, and a Biograph Vision-450 (PET2) (10) released in 2018.

Both machines presented the *Lutetium Oxyorthosilicate* (LSO) crystals on the PET side. The technological diferences between the machines were presented in the featured photomultiplier (PMT). PET1 has a vacum glass tube with a photocathode inside, a series of electrodes with increasing voltage called dynodes, and an anode for each crystal block. PET2 presented a Silicon Photomultiplier solid state detector system (SiPM) (11), with a whole crystal coverage, which presented a better use for signal and detected radiation.

PET1 presented a total of 24336 crystals with 4,0x4,0x20mm dimensions, while PET2 presented a total of 45600 crystals with 3,2x3,2x20mm, double of detectors from 1.

PET 1 has a coincidence time of 495,00 picoseconds (ps), and PET2, with time of fly technology (TOF), the value is 212,75 ps. TOF provides an improvement in the signal-to-noise ratio, with consequent better use of the generated coincidences.

The exams were carried out in PET1 by "Bed" (static bed positions) with determined time, which moved and stopped moving according to the configuration applied by the operator. In PET2, the technological advance of the "Flow Motion" system, the bed moves in constant velocity (also with the configuration applied by the operator), but with no stopping on each determined time.

For individuals' registration a standard table data was used with the following information: date of exam (dd/mm/year), gender, weight (Kg), height (m), acquisition time (min) and administered activity (MBq).

2.1. Data Analysis

Descriptive and comparative statistical analyses were performed using IBM SPSS version 20 (12), ensuring data confidentiality and anonymity. Descriptive statistics of the data utilized frequency, percentage, mean, standard deviation, minimum, maximum, and median to summarize results of continuous variables, while categorical variables were summarized using number and percent. The assumption of normal distribution was evaluated using the Kolmogorov-Smirnov test. To evaluate differences in demographic contínuos data between different technologies, the non-parametric t-test for independent samples was applied, with a 95% confidence interval and a significance level of 0.05. Only in the sex statistical correspondence between samples was analyses using a Chi-square test. Wilcoxon signed-rank tests were used to compare the dosimetry variables between the two machines.

3. RESULTS:

The table 1 shows the results of the descriptive and comparative statistical analyses of demographyc variables and activity per equipment. Demographic variables show no significant diferences between both groups, meanwhile acquisition time and activity were statistically diferent. All the studies were informed with diagnostic quality by the nuclear medicine physicians, addressing there is not impact on overall clinical image parameters. The average results found in PET1 for 175 individuals were 91 females (52%) and 84 males (48%), average measured weight of 68,47 ± 13,52 kg, height of 1,65 ± 0,09m and administered activity of 270,10 ± 55,59 MBq. The average injected activity by weight in PET1 was 3,93 MBq/kg. The figure 1 shows the distribution of activity per weight, meanwhile the figure 2 and the figure 3 show the same for female and male respectively. The average results found in PET1 for female gender have the measured weight of 64,74 ± 13,16 kg, height of 1,59 ± 0,07 m and administered activity of 257,78 ± 54,67 MBq. For male gender, the average measured weight is of 72,51 ± 12,78 kg, height of 1,70 ± 0,07 m and administered activity of 280,80 ± 54,39 MBq.

The results from PET2 for 175 individuals, on which 108 are female (61,37%) and 67 are male (38,3%), with average measured weight of 69,53 ± 13,59 kg, height of 1,63 ± 0,10 m and administered activity of 171,19 ± 47,87 MBq. The figure 4 shows the distribution of activity per weight, while the figure 5 and the figure 6 show the same for female and male respectively. The observed results in P2 for female gender have the measured weight of 66,52±13,11 kg, height of 1,59 ± 0,07 m and administered activity of 164,92 ± 47,90 MBq. In the male gender, we have the average measured weight of 71,78 ± 13,44 kg, height of 1,68 ± 0,11 m and administered activity of 181,31 ± 45,58 MBq.

In terms of acquisition time, PET1 presented an average acquisition time of 30 ± 10min per patient and PET2 of 15 ± 5min. When using PET2 there was a reduction of 36,4% for injected activity in the exams, associated with reduction of 50% in the acquisition time (patient permanence time in the machine).

Table 1 : Descriptive and comparative statistical analyses of demographyc variables and activity per equipment

Variable	PET 1 (Media ± SD)	PET 2 (Media ± SD)	Valor p
Weight (kg)	68,5 ± 13,5	69,53 ± 13,59	0,335
Height (m)	1,7 ± 0,1m	1,63 ± 0,10	0,069
BMI	25,9 ± 4,9	25,2± 4,4	0,181
Activity (MBq)	270,1 ± 55,6	171,2 ± 47,9	0,003
Acquisition time (min)	30 ± 10	15 ± 5	0,012
	PET 1 (n, %)	PET 2 (n, %)	Valor p
Sex	91 females (52%) 84 males (48%),	108 females (61,37%) 67 males (38,3%)	0.12

Figure 1 : Administered activity by weight (PET1)

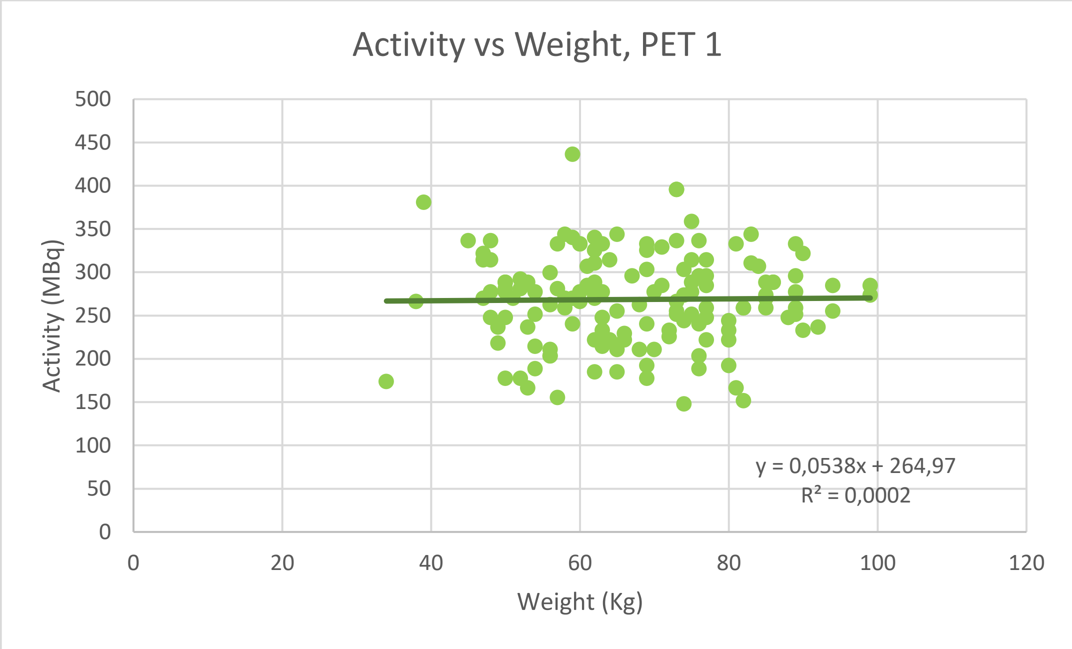


Figure 1 : Administered activity by weight (PET1 Female)

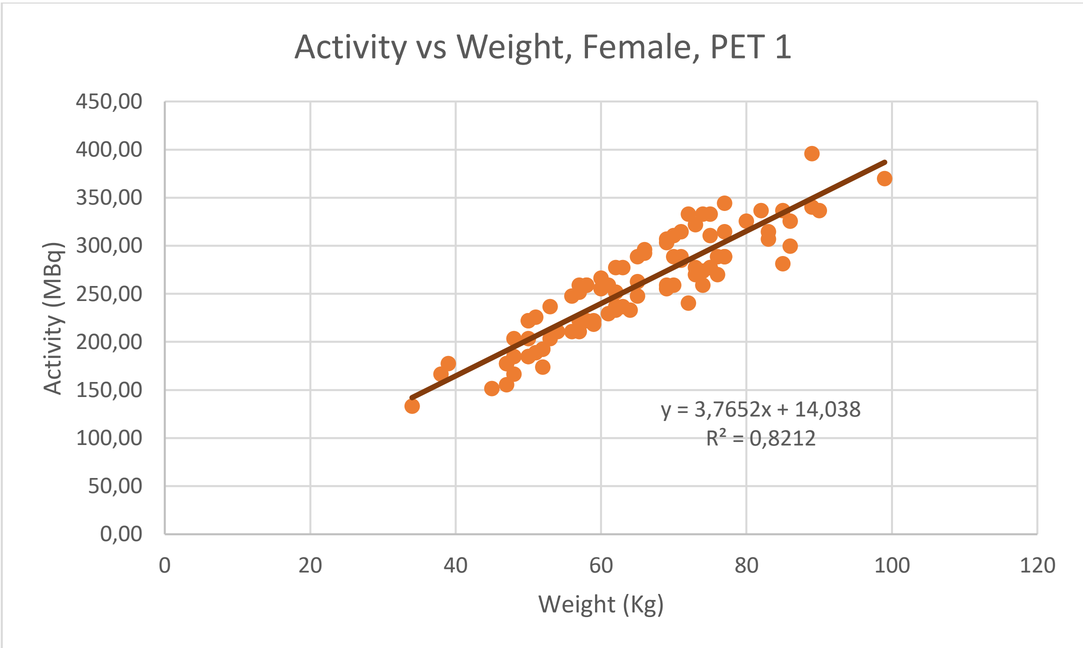


Figure 2 : Administered activity by weight (PET1 Male)

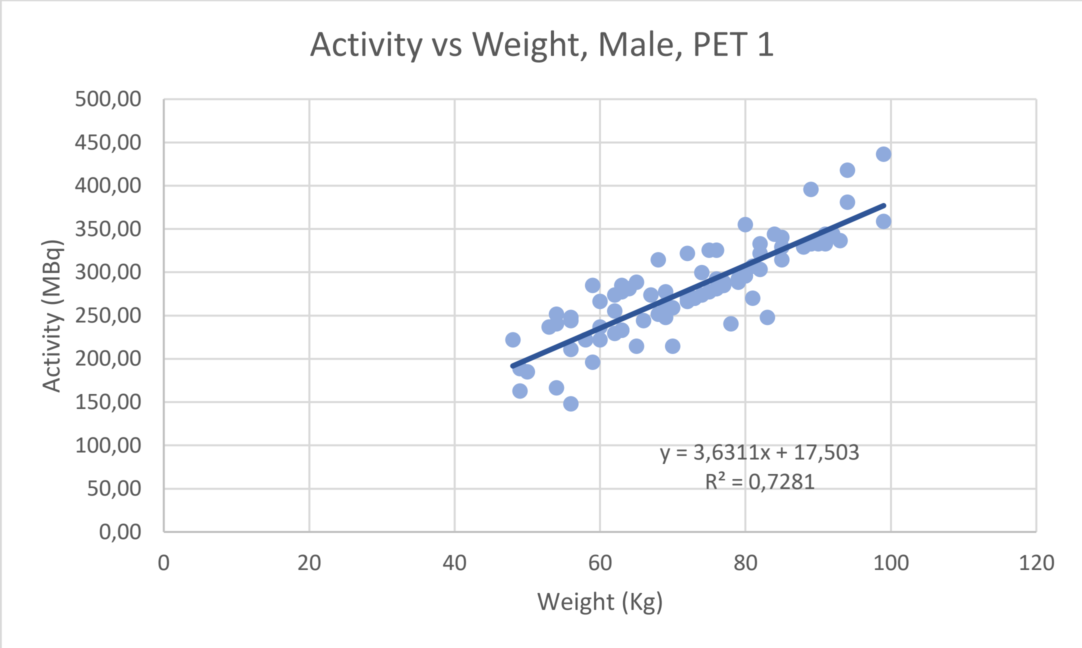


Figure 3 : Administered activity by weight (PET2 Total): n=175

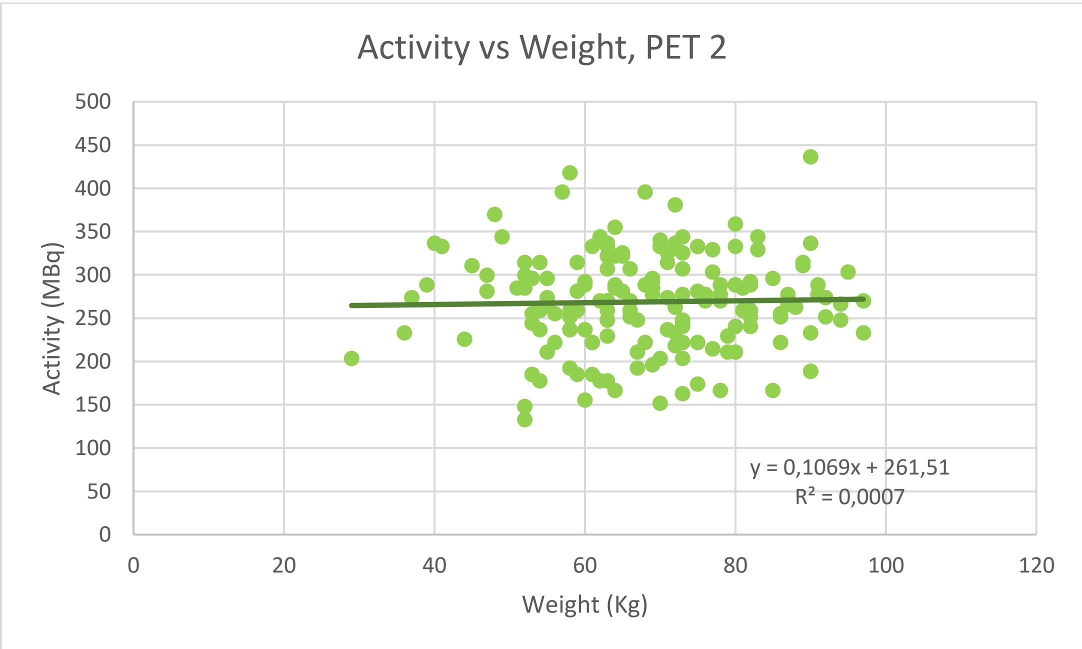


Figure 4 : Administered activity by weight (PET2 Female)

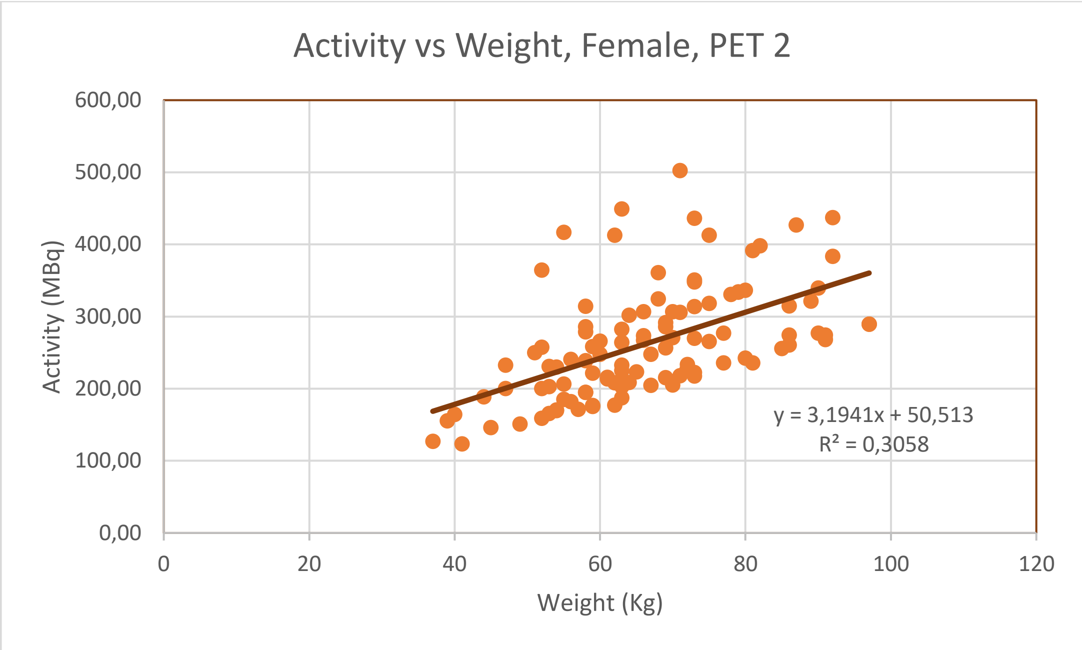
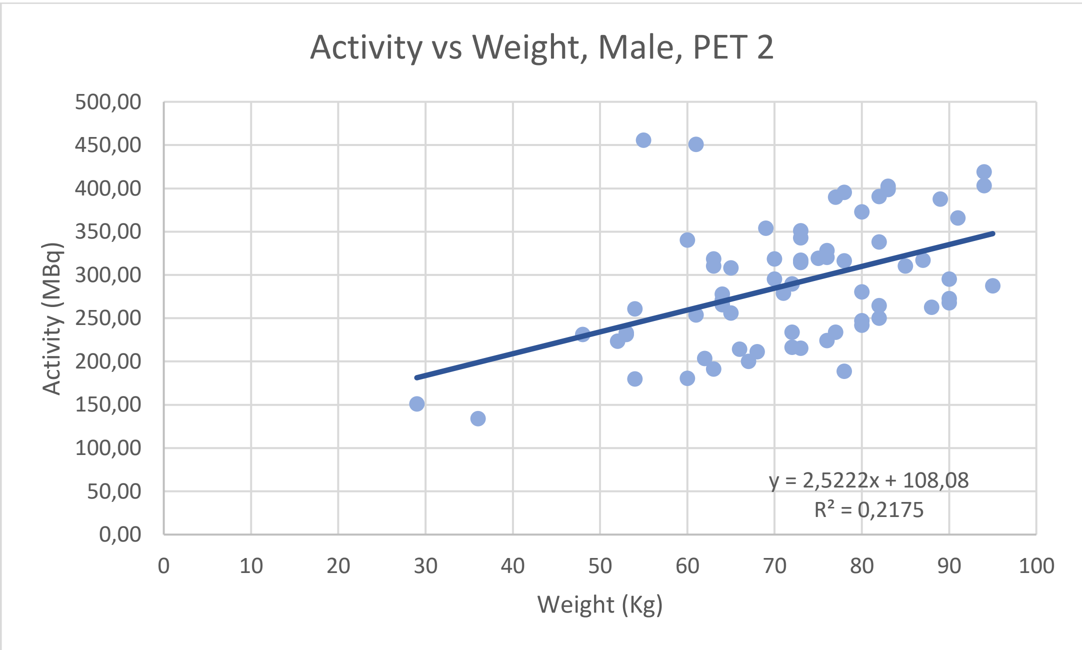


Figure 5 : Administered activity by weight (PET2 Male)



4. DISCUSSION

In the Brazilian Nuclear Medicine Society (SBMN) (13) Guideline the recommendation for activity to be injected is around 4,44 to 5,18 MBq/kg and acquisition time of 30-40 minutes depending on the stature of the patient.

The Society of Nuclear Medicine & Molecular Imaging (SNMMI) (14) recommends the dose to be injected to be around 3,7-5,2 MBq/kg, and the acquisition time of the image around 25 to 30 minutes, depending on the stature of the patient.

If we observe the distributions of activity by weight in both sexes, a dispersion is evident without a discernible trend line. Interpreting differences in FDG uptake between males and females in PET scans requires careful consideration of various biological and methodological factors. The guidelines emphasize the importance of standardizing uptake values and recognizing the influence of sex on metabolic processes (15–17). Considering the differences in weight and size between sexes, the analysis was performed independently, showing clearer trend lines in both cases, where higher administered activity corresponds to higher weight. Notably, in PET1, there is a clear trend that should align better for the PET2 system once the optimization process is completed. For this reason, it is important to study exposure levels and establish typical values that reflect actual clinical practice and enable the development of better practices, including the management of sex differences (18,19).

Digital PET systems, which leverage silicon photomultipliers (SiPMs), have revolutionized PET imaging by optimizing performance parameters and enhancing diagnostic capabilities. These systems demonstrate improved spatial resolution through optimized scintillation crystal sizes, resulting in better lesion detectability (20). Additionally, the integration of SiPM technology enables a larger axial field of view (AFOV), contributing to dynamic imaging and superior signal-to-noise ratios (20,21). In terms of radiation dose, digital PET has significantly reduced the injected activity of radiopharmaceuticals, with reports of reductions from 350 MBq to 190 MBq, equating to a 54% decrease (7). Moreover, digital systems present lower dose length product (DLP) values, particularly benefiting obese patients by minimizing radiation exposure (22). Operationally, digital PET scanners enable shorter scan times and improved patient throughput, critical for clinical efficiency (22). Furthermore, the stability of time-of-flight (TOF) resolution across varying count rates ensures consistent image quality, even under high activity conditions (21). However, transitioning from analog to digital PET/CT systems presents challenges, including high initial costs and the need for personnel training, which can be particularly burdensome for facilities with limited budgets or resources.

In this approach we have had a reduction around 36,4% of 18F-FDG administered activitity to the patients, compared to Brazilian and American guidelines. Therefore, there was a significant improvement of patients radiation protection (less radiopharmaceutical recieved) and OIEs (less radiation material to be handled, less external radiation exposure during patient attention), as confirm others authors (7,23).

Ida et al. (24) highlights the possibility of acquisition time reduction on similar technology machines as PET2, but it does not evaluate the possibility of injected activity.

When compared to Brazilian and American guidelines, the acquisition time for this kind of exam have shown a 50% reduction, which means less time for patient to lie down during procedure. As a result, patient will be more comfortable, and in some cases the decreasing of the claustrophobic sensation reported by some patients in the research.

Therefore, we were able to perform faster studies, using less 18F-FDG material injected in patients. It´s important to emphasize this is the first research of this nature, since PET2 is the first of its kind to be installed in Brazilian territory, and it's been installed in less than six months.

5. CONCLUSIONS

As a conclusion we can highlight the injected activity reduction on PET2 with less permanence time of patient during acquisition. The injected activity reduction in the patient contributes for the exposure decrease of the Workers in the service (OIEs) and the patient itself, following the basic Radiation Protection principles. The shorter time of acquisition benefit the claustrophobic sensation or even the discomfort of patients for liying down in the dorsal decubitus position for longer time.

New studies should be done to evaluate the decresing of both, time and activity.

ACKNOWLEDGMENT

This research was supported by Santa Casa da Bahia – Hospital Santa Izabel (Nuclear Medicine Dept.) and Programa Processos Interativos dos Orgão e Sistemas do ICS/UFBA.

FUNDING

The research was conducted with no third part funding.

CONFLICT OF INTEREST

We have no conflicts of interest to disclose.

All authors declare that they have no conflicts of interest.

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