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Reducing the Rates of Public Exposure to External Radiation Emanating from ^{18}F-FDG PET/CT Patients.

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INTRODUCTION:

Nowadays; we notice a dramatic increase in the use of 18F-fluorodeoxyglucose (18F-FDG) radiopharmaceutical agents in PET/CT imaging, especially for oncology purposes. The F-18 radioisotope is a cyclotron produced; with 110 minutes' half-life that achieves an ideal isotope used in nuclear medicine. Despite having much higher photon energy than other radioisotopes used regularly in nuclear medicine practice [(1)].

Trending in the use of diagnostic imaging throughout the world raises the possibility of cancer risks and using un preferable media coverage PET/CT is a gold standard technique for stage and restage various malignancy types, and the number of studies being conducted is steadily increasing [(2,3)].

There are many Nuclear Regulatory Commission guidelines about the release of the patients undergoing therapeutic procedures by using of public's maximum permitted exposure from the material source 20 mSv/h (2 mR/h) which is a standard point for minimizing the radiation exposure rate to as low as reasonably achievable. Nevertheless, no clear guidelines for releasing diagnostic nuclear medicine or PET/CT patients. So, Medical practitioners are attempting to lower the radiation exposure levels of the general public and patients [(4,5)].

Despite the shortness of the 18F-FDG half-life (110 min), the time frame immediately after a scan should be taken into consideration. There are many studies of major priority for reduction of the radiation exposure dose to patients and imaging employees. However, few attempts were made to search for the efficacy of lessening the radiation exposure emitted from 18F-FDG PET/CT patients to the general population [(5,6)].

Aims of the Work: To **Determine** the utility of urinary voiding after 18F-FDG PET/CT scan time, hydration and their impact on radiation exposure in relation to the external radiation dose rate.

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PATIENTS and METHODS:

Randomized Clinical trial on 60 patients over the age of 18 who came to the nuclear medicine unit, National Cancer Institute, Cairo University to undergo 18F-FDG PET/CT for different indications and were involved to participate in this study.

Medical history, age, vital and physical parameters, random blood glucose, patient’s weight, height, and age were taken.

Inclusion criteria: Patients above the age of 18 underwent 18F-FDG PET/CT study.

Exclusion criteria: Patients under the age of 18’ physically disabled patients or with renal impairment، Patients with blood glucose levels >200،

Patients’ randomization:

- Patients are divided into two groups
- The radiation dose rate will be measured in all patients enrolled in the study directly after PET/CT exam (pre-void).
- **Group 1** Will void and then re-measure the radiation dose 30 minutes later then after one hour (post-void).
- **Group 2** Will void then the patient is encouraged to take fluids (one liter of water) and then re-measuring after 30 minutes one hour.
- Radiation exposure measurement will be compared between the 2 groups.

Patient preparation:

- 4-6 hours fasting before the study, avoid severe muscle exercise for 24 hours earlier than the study and blood glucose level before the F18 FDG administration should be below 160 mg/dl.

Imaging procedure:

- Patients received a weight-calculated dose of F-18 FDG injected, approximately 0.14 mCi/kg body weight of 18-F FDG.
- A dedicated PET/CT scanner (GE Medical System) was used for the FDG-PET/CT study. Injection was followed by approximately 60 minutes of uptake and clearance time in which patients were instructed to stay in the resting area and avoid muscular activity. Immediately before PET/CT scan patients were instructed to void (pre-scan voiding). Acquisition time was approximately 13 minutes.

External radiation dose rate measurement:

- The guidelines for releasing patients after undergoing a PET/CT scan are not clear.

We use 20 µSv/h external radiation dose (the public's maximum permitted exposure from a material source) [4,5]. This study aimed to examine the difference between the patients who received hydration and those who did not receive any hydration to determine the effect of hydration on external radiation dose.

- 4 times measurement of the radiation dose rate was done for each patient, every time consisting of 3 consecutive measurements, 10 seconds each, using a GM tube (inspector USB Handheld Digital Radiation Alert® Detector from SEI with a reported accuracy of ± 15%) placed at a distance of 1 m to the patient's mid-chest and the average of the three readings was taken and recorded in µSv/h [7].

A dedicated isolated room was used for that purpose, away from the resting area of other patients and the hot lab with no other patients around.

- Measurement 1 pre-voiding.
- Measurement 2 post voiding.
- Measurement 3 after 30 minutes.
- Measurement 4 after 60 minutes later.
- All those measurements were at the end of the PET/CT scan.

Statistical methods:

SPSS version 28 was used for data management and analysis. For numerical data, means and standard deviations, or medians and/or ranges, were used as appropriate. For categorical data, numbers and percentages were used as a summary and frequency estimates were made using the numbers and percentages.

Numerical data were examined for normality using the Shapiro-Wilk and **Kolmogrov-Smirnov** tests. When comparing the independent groups with regard to categorical data, chi-square or Fisher's tests were utilized.

The student's t-test was used to compare two groups of normally distributed numerical variables, while the Mann-Whitney test was used to compare non-normally distributed numerical variables.

to calculate the degree of correlation between the measurements, which are normally distributed. The correlation coefficient, or Pearson's correlation coefficient, is called r, and it has a range of -1 to +1. The correlation coefficient, or r, is as follows: 0 to 0.25 (-0.25) indicates little to no correlation; 0.25 to 0.50 (-0.25 to 0.50) indicates a fair degree of correlation; 0.50 to 0.75 (-0.50 to -0.75) indicates moderate to good correlation; and greater than 0.75 (or -0.75) indicates very good to excellent correlation. Every test had two tails, and a probability (p-value) of less than 0.05 is regarded as significant [8].

RESULTS:

Patients Characteristics:

The radiation dose rate was assessed in 60 patients enrolled in the study directly after the PET/CT exam (pre-void), Then divided into 2 groups: Group 1 voided then re-measure the radiation dose 30 minutes later then after one hour (post-void). Group 2 will void patient and encourage him to take fluids (one liter of water) then re-measure after 30 minutes, & one hour. Radiation exposure measurement will be compared between the 2 groups. Of the 60 patients, 33 were females (55%). 27 patients were males (45%) with mean age is 36±9. **(Table 1)**.

Table (1): Characteristics of the 60 patients in study group

	Mean ± SD
Age	36±9 (y-old)
Sex	**n=60 (%)**
Female	33 (55)
Male	27 (45)
Weight	74 ±16 (kg)
FDG Dose	7.5 ±1.8 (mCi)
Glucose	109 ±24 (mg/dl)

Radiation exposure dose: Mean external radiation dose in the whole group of study was pre-voiding 29± 8 µSv/h which decreased after voiding to 25±7 µSv/h. Also, further drop at 30 min and 60 min with a mean value of 20±6 and 16±6 respectively **(Table 2)**.

Table (2): Radiation dose of the 60 patients of the study group:

	Mean ± SD (µSv/h)
Pre voiding	29 ± 8
Post voiding	25 ± 7
30 min later	20 ± 6
60 min later	16 ± 6

Correlation between weight and dose: External radiation dose rate decreased in relation to the dose injected between pre-voiding and post voiding which is adjusted according to body weight with significant difference (P valu0.001); whereas no significant correlation of radiation dose at 30 or 60 minutes **(Table 3)**.

Table (3): Correlation between on radiation exposure rate and the weight

	Weight		
	r	**P value**	**Degree of correlation**
Dose	0.78	<0.001	A Significant good positive correlation
Pre voiding	0.33	0.011	A significant fair positive correlation
Post voiding	0.27	0.039	A significant fair positive correlation
30 min later	0.14	0.288	Non-significant correlation
60 min later	0.06	0.658	Non-significant correlation

r= correlation coefficient and it ranges from -1 to +1.

Correlation between external radiation dose measurements between two groups:

There was no significant difference in groups 1,2 in pre-voiding and post-voiding. However, a significant difference is seen between both groups at 30 and 60 minutes following hydration **(Table 4 and Fig 1).**

Table (4): Radiation exposure dose in both groups

	Group 1	**Group 2**	**P value**
	Mean ± SD (µSv/h)	**Mean ± SD (µSv/h)**	
Pre voiding	28 ± 7	30 ± 8	0.322
Post voiding	24 ± 7	25 ± 8	0.672
30 min later	21 ± 7	18 ± 6	0.057
60 min later	19 ± 7	14 ± 5	0.002

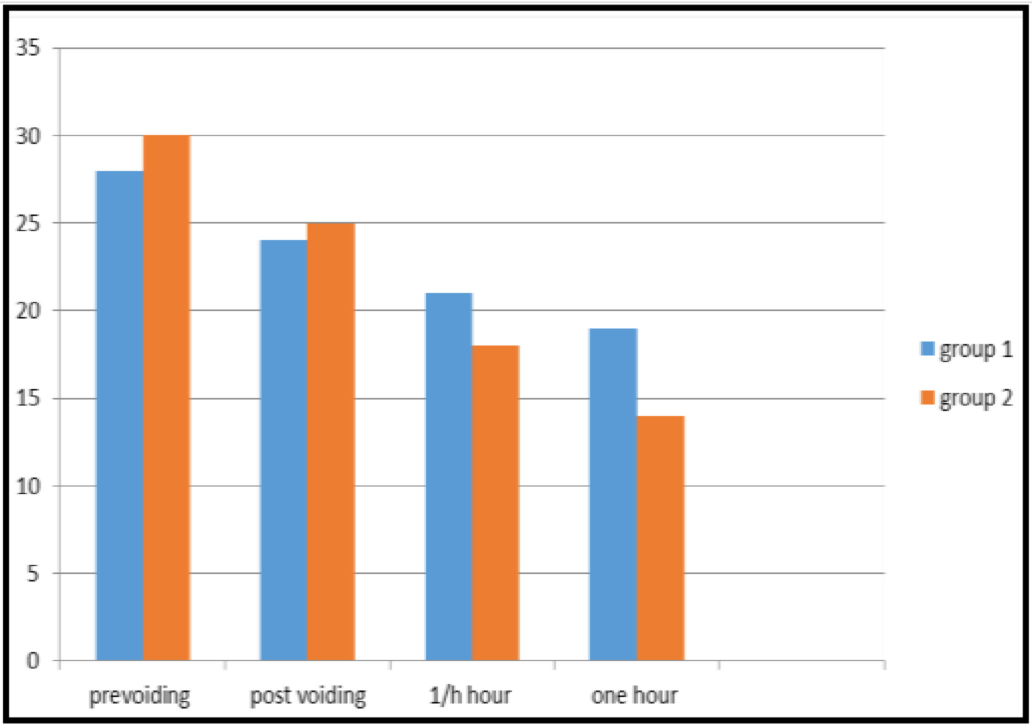

Figure (1): Mean external radiation dose among two groups at different measurements

Percent change of radiation dose in relation to voiding of the 60 patients of the study:

Pre-voiding and post-voiding external radiation dose rate measurements to all patients were compared (post-voiding – providing) with a percentage change of 12.4%. While the comparison between pre-voiding and 30 min measurements (30 min – pre-voiding) percentage change decreased to 27.1%, with further decrease after 60 min later (1 hour –pre voiding) to 41.1% (Fig 2).

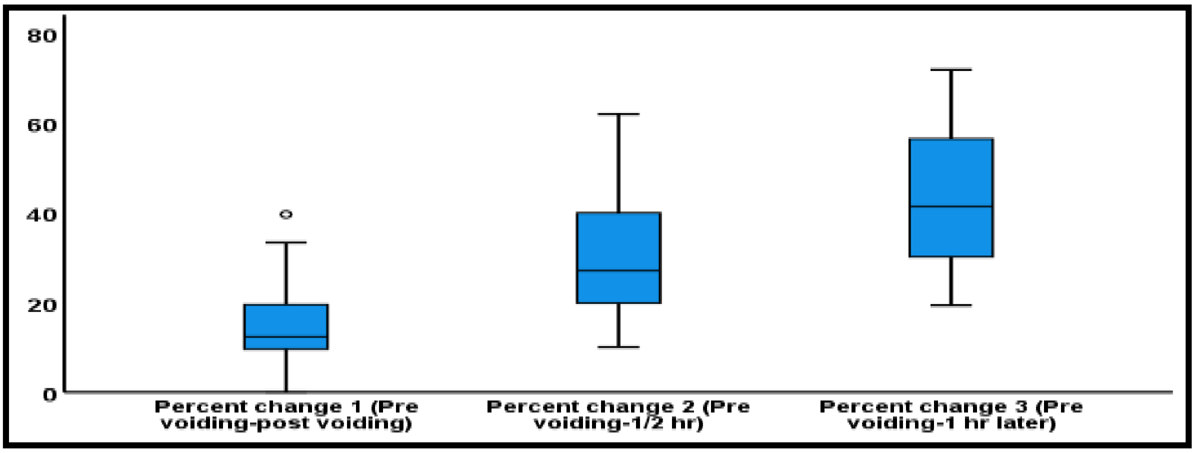

Figure (2): Percentage change in all groups in relation to time of voiding.

Percent change of radiation dose in relation to voiding between two groups of the study:

In group 1, the percentage change in relation to time factor is less remarkable with 11.7% in pre-voiding and decreased to 20% percentage decrease after 30 minutes and 30.7% after 60 minutes. On the other hand, in group 2 the change of pre-voiding changed by 13.2% with a higher change to 39.1%, and 54.8% at 30 and 60 minutes respectively.

The effect of hydration between the two groups showed a significant decrease in radiation exposure rate after 30 min (20% in group 1 & 39.1% in group 2) (p-value <0.001). Patients in group 2 with hydration showed a further significant decrease in radiation exposure rate to 54.8 % at 60 minutes (P value <0.001) **(Table 5).**

Table (5): Correlation between time and voiding effect on radiation exposure rate between two groups

	Group 1 Median (range)	Group 2 Median (range)	P value
Percent change 2 (Pre voiding-30min)	20 % (12.8-46.5)	39.1% (10-62.1)	<0.001
Percent change 3 (Pre voiding-60 min later)	30.7% (19.4-61.2)	54.8% (30-72)	<0.001

DISCUSSION:

As there is an increase in the use of PET/CT for both oncological and non-oncological reasons, major concerns regarding radiation exposure and the risk it carries for the public and medical personnel in direct contact with the patient after the PET/CT exam. Despite the advancement, techniques, and successive guidelines addressing the issue of radiation exposure of the patients who underwent PET/CT scans, issue of radiation exposure of the public and medical staff is not available [(7)].

The present study investigates this issue with attempts to decrease the public's overall radiation exposure without incurring additional costs. Just a further 60 min waiting before releasing the patients after imaging with or without hydration.

In our study, we found a strong correlation between body weight and external radiation dose rate (r=0.78 & P value < 0.001). Since the injected tracer dose was calculated based on body weight, patients with increased body weight received a higher dosage that resulted in a higher external radiation dose exposure rate. Hence, it is wise to apply the lowest dose feasible to lower the external radiation dose rate as long as it doesn't degrade the image quality.

Contrary to our study, the **Kim and Han et al** study showed that the radiation exposure dose rate was higher in patients with low body weight which might be a result of injecting a fixed tracer dose regardless of the body weight instead of weight calculated dose might result in higher external radiation dose rate in patients with lower body weight especially with less tissue attenuation (8). In order to maintain a low external radiation dose rate, a strategy involving the use of radiopharmaceuticals with adjusted amounts needed for each patient is required. It appears necessary to use the reduced dose of these radiopharmaceuticals in a range that does not affect the quality of the images (9).

Mithun et al. study found reduction in the exposure rates with 0.011 ± 0.0028 mSv/h 1 h post-injection from the patients who injected with the half-recommended dose (3–4 MBq/kg body weight 18F-FDG) at 100-cm distance compared to the radiation exposure rates about 0.021 ± 0.011 mSv/h from patients who administrated the recommended 18F-FDG dose (7–8 MBq/kg body weight) at 100-cm distance 1 h post-injection (10).

In the present study, 12.4% percentage decrease in radiation exposure dose rate of all patients enrolled with no significance between both groups between the pre-voiding and post-voiding measurement [group (1) 11.7%, group (2) 13.2%)]. There was no significant difference between the percentage decrease in radiation exposure dose rate between the pre-voiding and post-voiding measurements (P-value = 0.191).

Similarly, **Muzaffar et al.** a randomized clinical trial study published in 2020, sought to develop simple methods to reduce external radiation dose rate. They showed a more significant decrease in external radiation dose rate after the post-scan voiding step. The mean dose rate decreased by 20.0% (from 23 to 18.3 mSv/h) from the post-scan measurement, with 12 of 36 (33%) of patients remained at or above the 20mSv/h. Such finding might be due to incomplete urination and improper emptying of bladder by the patients (11).

Furthermore, **Berberoglua et al.** a randomized clinical trial published in 2019 was intended to quantify the radiation emission rate from patients undergoing 18FDG PET/CT examination for oncological conditions, two hours after imaging found that mean pre-urination activity ranged between 0.9 and 8.2mSv/h. Activity significantly decreased after urination at 3.4 ± 1.8 mSv/h, which might be due to urination and proper emptying of the bladder by the patients [13].

These highlight how crucial it is for patients to urinate more frequently in order to keep their exposure to external radiation at a minimum before departing the department.

Our study showed that throughout the 4 measurements, patients who received hydration showed an external radiation dose rate lower than patients who did not receive hydration (P-value <0.05).

Also, Kim and Han et al. a cross-sectional study published in 2012 investigated the elements influencing the rate of external radiation dose in patients underwent PET/CT scans, showed similar results with patients who received hydration post-injection elicited lower external radiation dose rate than patients who did not receive hydration after the tracer injection. Hence, encouraging patients to drink more water before and after the tracer might be advised as a simple cheap method to reduce external radiation exposure dose rate. [8].

Moreover, **Dannoon et al.**, measured the external emission radiation rates of 63 18F-FDG patients from 1-m distance at four different time points after PET image acquisition: pre-void 1 (immediate after acquisition), post-void 1 (after voiding), pre-void 2 (after waiting 30 min while drinking 500 mL of water) then re-voided (post-void 2). They found a reduction in the external radiation rates that emitted from 18F-FDG patients, following drinking water and voiding from pre-void 1 measurement at 13.65 ± 3.42 mSv/h to post-void 2 measurement at 10.48 ± 2.37 mSv/h with an average of 22.49% ± 7.48% (P-value= 0.001) 2022 [12].

The present study showed that time following imaging is an important factor in reducing external radiation dose rate, as a 27.1% decrease in external radiation dose rate, after 30 min and up to 41. 4% after 60 min are seen.

Similarly, **Berberoglua et al.** measured the rate of radiation emitted from patients that who underwent 18FDG PET/CT examinations two hours after the procedure and revealed a significant decrease in dose rate from patients which is significantly lower than the recommended limits for public and further decreases following urination. Releasing patients 2 hours after urination would have no radiation risk for relatives, the public, or other hospital employees [13].

Thus, the frequency of urination, the amount of water consumed after imaging, the amount of radiopharmaceutical dose, and the time of patient discharge all influence the rate of external radiation dose after PET/CT imaging.

Limitations

The relatively small number of patients was available for the study. The study with or without hydration should be with a comparable population regarding weight.

CONCLUSIONS:

The present study showed the importance of reduced radiation exposure dose in relation to time following imaging. The addition of hydration is necessary to reduce the external radiation dose of patients to the public.

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