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Research Article

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Effect of patient bladder voiding on radiation dose rates measured around patients undergoing PET/CT imaging using ^{18}F-FDG

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Abstract

Accurate dose rate estimates is important for radiation protection specialists conducting risk assessments and performing dose reconstruction in cases of accidental exposures.

Objectives: The objectives of this work was to experimentally evaluate the bladder voiding factor effect on the dose rate measured from patients undergoing PET/CT imaging studies using ^{18}F-FDG by directly measuring the dose rate immediately before and after voiding, and compare the results with the current scientific literature.

Results: The bladder voiding effect had a dose rate reduction factor of about 12% between dose rates measured before and after voiding. This measured reduction factor agreed with the 15% reported by the AAPM Task Group 108. We have also measured dose rates at one meter from 50 patients and found an average dose rate per unit activity of 93.7 μSv/hr/GBq. Our dose rate results were in excellent agreement with the results of current published data (92 μSv/hr/GBq, AAPM Task Group 108).

Conclusions: The presented data can be applied in radiation protection optimization procedures, especially for the protection of the care givers from patients undergoing 18F-FDG PET/CT imaging when they are considered as external radiation source or hazard to others.

The provided information will benefit medical physicist working in nuclear medicine and radiation safety policy makers.

Keywords: ^{18}F-FDG; Measured dose rate; Patient voiding factor; PET/CT

Introduction

The estimated dose rate at certain distance from a radioactive source depends on the dose rate constant, the source activity and the distance between the source and the measurement point. Once the radioactivity is incorporated into the patient it will additionally depend on patient's body tissues attenuation properties. ^{18}F-FDG is a non-specific tracer mainly used for metabolic activity and concentrates in metabolically active tumors and accumulates in areas with high metabolism such as brain, heart and active muscles. When ^{18}F-FDG is injected in patients the non-metabolized ^{18}F-FDG is eliminated from the body by glomerular filtration without being resorbed by the renal proximal tubules. Then the eliminated ^{18}F-FDG remained and accumulated in the bladder.

Voiding the bladder is recommended to patients by nuclear medicine staff and clinical protocols since it will reduce the patients' bladder dose by eliminating the unused activity of ^{18}F-FDG by the patient body; avoid signal interference due to gamma emissions from the bladder and reduce the exposure rate measured from the patient by a certain percentage. Therefore patients are asked to void at the end of the uptake time and before scanning.

In most cases the patient will void prior to imaging, removing approximately 15%-20% [1] of the administered activity and thereby decreasing the dose rate by a factor of 0.85 [1].

The objectives of this work was to quantify the effect of patients' bladder emptying on the measured dose rate value by directly measuring the dose rate from the patients immediately before and after voiding, then calculating the ratio of after to before in order to represent the reduction factor in percentage form as described below in the text.

Materials and Methods

The measured dose rate at voiding time divided by the activity calculated at the voiding time and corrected for radioactive decay was used for each patient to calculate the dose rate per unit activity constant.

Radiation dose measurements were done immediately before and after voiding, in order to calculate the dose rate reduction factor using equation 3 below. We have excluded from this analysis the patients with measured dose rate after voiding that were slightly higher than before voiding due to some mild urine contamination on their clothes. The total number of patients measurements reported in this study is 50, details are in Table 1.

Parameter	Average	Standard deviation	Coefficient of variation (%)	Minimum	Maximum
Weight in [kg]	76	27	36	15	171
Body Mass Index (BMI)	29	9	31	11	58
Injected activity in [MBq]	326	86	26	147	485
Time before voiding in [min]	39	8	21	17	68
Dose reduction due to voiding in [%]	12	6	50	2	30
Measured Dose rate per unit activity in[μSv/hr/GBq]	93.7	14	15	65	136

Table 1: Patient data, we have 50 patients in this study. Coefficient of variation is the ratio of the standard deviation over the average.

The radiation dose rate was measured using a calibrated ionisation chamber (SmartIon Type: 2120G; thermo Franklin, Massachusetts, USA). The ^{18}F-FDG dose was administered using an automatic dose injector (Intego, by MedRad Inc, Indianola, PA, USA).

The measurements were taken at one meter from the patient body surface to the entrance of the ionization chamber type radiation detector by marking the floor to show the exact standing positions to be able to reproduce the measurement geometry with ease and accuracy. The patient and the nuclear medicine technologist performing the measurements are in standing position and the radiation detector was aimed at waist level of the patient as illustrated in Figure 1.

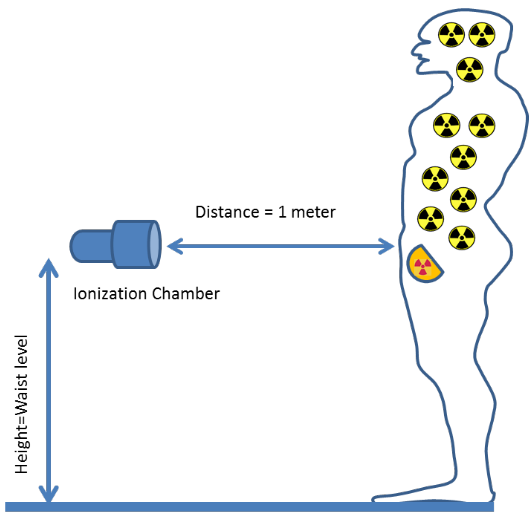

Figure 1: Setup of measurements.

Uptake time correction factor

The activity measured at the uptake time was calculated using the following relation:

$A(t_{up}) = A_0 e^{-\lambda t_{up}}$ (1)

Where (t_{up}) is the uptake time in minutes, and (λ) is equal to ln (2)/$T_{½}$.

T½ is the half-life of ^{18}F = 110 minutes.

Dose rate reduction due to voiding

We have calculated the patient voiding factor (R) as the ratio of the dose rate measured after voiding (D_{after}) over the dose rate measured before voiding (D_{before}):

$R = D_{after} / D_{before}$ (2)

The percentage of dose reduction due to voiding is then given by ($D_{reduction}$):

$D_{reduction}$ (%) = (1-R)* 100% (3)

This work was approved by the hospital medical research ethics committee.

Results

The measured dose rates from the patients were reduced by 12% ± 6% with a range of (2%-30%) due to voiding. We have found a wide variation for the first void time, our average time measured before the first void was 39 ± 8 minutes with a range of 17-68 minutes (Table 1). The ratio of the measured dose rates before and after voiding is shown in Figure 2.

It is also worth to mention that we have excluded certain number of patient data from our study because the measured dose rate after voiding was higher than the one measured before. We concluded that these patients had accidentally contaminated their clothes with radioactive urine during voiding, which caused the dose rate after voiding to be higher.

The measured dose rate per unit activity measured from 50 patients included in this study was 93.7 ± 14 (μSv/hr/GBq) (Table 1), this value is in close agreement with the value proposed by the AAPM Task Group (92 μSv/hr/GBq) [1].

Figure 3 shows the measured dose rates before and after voiding from the 50 patients in this study as a function of the time corrected injected activity.

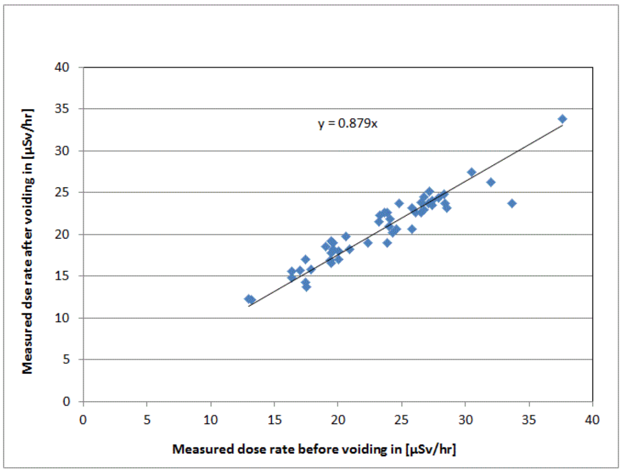

Figure 2: Measured dose rate after voiding as a function of the dose rate before voiding.

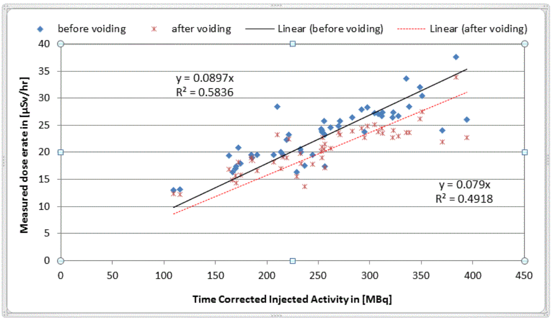

Figure 3: The measured dose rate in [µSv/hr] before and after voiding as a function of the time corrected injected ^{18}F-FDG activity in [MBq].

Discussion

The American association of physicist in medicine (AAPM) recommends the value of 15% of dose reduction due to bladder voiding and uses this percentage in their shielding calculations for imaging and uptake rooms design of the PET/CT suite in clinical environment [1].

Our results are in agreement with the study by Bach-Gansmo et al. they found that urinary FDG excretion to be highly variable with a range of 5.7% to 15.2% of the injected dose. They measured the urine radioactivity collected from 20 patients undergoing PET/CT imaging [2].

Hays and segall reports that bladder radiation dose will be much reduced if the patient voids early after FDG administration. They recommend that, when feasible high fluid intake and early and frequent voiding after FDG administration be encouraged [3].

The hydrated patients had a higher excretion of FDG than dehydrated patients 16.98% versus 14.27%, and the volume of urine voided was significantly higher ($p<0.020$) [4].

The amount of voided activity will contribute to the dose reduction in the bladder of the patient. Jones et al. reports reduction in the order of 15% of the injected activity for the first 2 hours post injection of the FDG [5].

Mejia et al. reports a mean percentage of injected activity excreted to the bladder at 2 hours void time of 21.2% and after 1 hour to be around 13.3% [6].

The initial voiding time seems to play a role in the dose calculations to the bladder wall; the optimum initial voiding time to deliver the lowest dose according to the traditional MIRD static bladder model is 40 minutes [7].

In a study by Dowd et al. on 302 adult subjects in five-year period indicate that when the bladder is large at the time of injection, the dose to the bladder is greatly reduced. And the optimal voiding time using the dynamic bladder model is 80 minutes [8].

Conclusion

Patient bladder voiding before scanning reduced the measured dose rate at one meter from the patient by about 12% for the patients' population under study, which is an agreement with other published studies (AAPM Task Group 108).

The presented information will benefit medical physicist working in nuclear medicine, radiation safety policy makers and regulators.

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Conflict of Interest

There is no conflict of interest.

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