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Effect of urinary excretion on radiation dose in patients having PET/CT scans

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ABSTRACT

Objectives: ^{18}Fluorine-fluorodeoxyglucose (^{18}F-FDG) positron emission tomography/ computed tomography (PET/CT) is commonly used for diagnosis, staging and re-staging of cancers and for determining the effectiveness of treatment. Because of renal, ureteral and urinary involvement of ^{18}F-FDG radiopharmaceutical after its injection, patients subject to radioactivity during its effective half-life. The aim of the present study was to determine the degree of association between effective dose levels of patients and bladder emptying of patients having PET/CT scans.

Methods: The present retrospective study included 108 patients (43 females and 65 males, average age: 60.9 ± 12.7 years). Effective dose level as mSv/h was determined from a distance of 1 m in all patients before and after bladder emptying at the first hour following ^{18}F-FDG injection. Radioactivity excretion amounts were compared based on gender, age, body mass index, fasting blood sugar level and clinical diagnosis.

Results: Amount of radioactivity decreased by 22.75% ± 14.77% after bladder emptying. No association was found between urinary excretion level and age, gender, fasting blood sugar and body mass index ($p > 0.05$).

Conclusions: Active emptying of bladder in patients having PET/CT scans where ^{18}F-FDG radiopharmaceutical is involved is an effective method for the radiation safety of both health workers and patients.

Keywords: ^{18}Fluorine-fluorodeoxyglucose, positron emission tomography, computed tomography, urinary excretion, effective dose

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Nuclear medicine imaging procedures has been increasingly used over the past 20 years, and theyprovided considerable reductions in morbidity and increases in longevity [1]. ^{18}Fluorine-fluorodeoxyglucose (18F-FDG) positron emission tomography/ computed tomography (PET/CT) is a molecular imaging technique used to differentiate tumor cells from normal cells. It is especially useful for pre- and post-treatment evaluation of oncology patients [2, 3]. PET radiopharmaceuticals are positron emitting agents which emit 511 keV annihilation photons [4]. PET imaging commonly uses maximum standardized uptake value (SUV) as a criterion for malignancy in clinical practice [5].

PET/CT has proven useful in management of several tumors. Since urinary excretion of ^{18}F-FDG radiotracer masks the presence of lesions, diagnostic power of PET/CT scanning is lower in urologic tract tumors and prostate cancer [6]. It was reported that PET/CT scanning has a high frequency of false-negatives in

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urologic tumors [7]. Absorption of ^{18}F-FDG in both benign and malignant lesions may often result in misinterpretation. A glucose analogue, ^{18}F-FDG accumulates in malignant lesions because of their elevated glucose metabolism. Nevertheless, ^{18}F-FDG can also accumulate in normal tissues, benign tumors of the pelvic area and other non-neoplastic occurrences of pelvis. ^{18}F-FDG is commonly excreted into urinary system and diagnostic evaluation may difficult in the bladder, prostate, uterus and ovarian cancer. ^{18}F-FDG accumulation in the urinary tract can be lowered by administration of diuretics, and patients are requested to empty their bladder completely before PET/CT imaging [8].

There is an increasing movement to minimize exposure to ionizing radiation especially from medical imaging involving X-rays and from internal radiation due to the use of radionuclides. Radiation from PET radiopharmaceuticals originates from positron and annihilation photons. General principles of radiation protection from the hazard of ionizing radiation are summarized as three key words; justification, optimization, and dose limit. Because medical exposure of radiation has unique considerations, diagnostic reference level is generally used as a reference value, instead of dose limits. The principle of justification and optimization are source-related and apply in all exposure situations. The principle of application of dose limits is individual-related and applies in planned exposure situations [9].

Patients are exposed to radioactivity due to physiological involvement of ^{18}F-FDG in kidneys, ureter and bladder during its effective half-life after injection. Health care workers andpatients are exposed to radiation during the PET/CT scan.The aim of the present study was to determine the association between urinary excretion and total effective dose level of ^{18}F-FDG in patients receiving PET/CT scans.

METHODS

This retrospective study included 108 patients. The patients had been referred to nuclear medicine department for staging of previously diagnosed cancer using ^{18}F-FDG PET/CT imaging. Forty-three patients were females (40%) and 65 males (60%), and average age was 60.9 ± 12.7 years. Patients who had histories of bladder operation, kidney failure, urethra stenosis, urinary incontinence and hyper-dynamic bladder were excluded. PET imaging was performed prior to any treatment and images were obtained using a combined PET/CT scanner (Biograph 2, USA). Each patient had fasted for at least six hours before imaging. After blood glucose level dropped below 170 mg/dl, 370 MBq ^{18}F-FDG was administered intravenously, patients were rested and image was taken one hour after injection. PET images were attenuation-corrected using CT images (70 mA, 120 kV, axial slice thickness of 3.75 mm).

All patients were given oral hydration with 800-1,000 ml of water. One hour after ^{18}F-FDG injection, effective dose levels (millisievert/hour, mSv/h) were determined at a distance of 1 meter in each patient before and after emptying bladder using aradiation survey meter (Dose-Rate Meter NEB.211, ÇNAEM, Turkey). Radioactivity excretion percentage was calculated using the formula *"[Full Bladder (mSv/h) – Empty Bladder (mSv/h) / Full Bladder (mSv/h)] x 100"* Radioactive excretion percentages of gender, age, body mass index, fasting blood sugar level and clinical diagnosis groups were compared.

Statistical Analysis

Data were analyzed using SPSS software (version 14.0; SPSS Inc.) and expressed as mean ± standard deviation. Statistical significance of the parameters was evaluated based on frequencies test. Pre-urinary and post-urinary excretion values were compared through paired t-test. Correlations of total effective dose with gender, age, body mass index, fasting blood sugar level and clinical diagnosis groups were studied using Mann-Whitney U test and Pearson correlation test. Significance levels were presented as *p* values. $P < 0.05$ was considered statistically significant.

RESULTS

Cancer diagnoses of 108 patients who had ^{18}F-FDG PET/CT scans were as follows: lung (26.8%), colorectal (16.6%), breast (12.9%), head and neck (8.3%), lymphoma (8.3%), male genitalia (5.5%), endometrium (2.7%), liver and bile ducts (2.7%), malignant melanoma (2.7%), stomach (2.7%), gastrointestinal stromal (1.8%), mediastinum and

Table 1. Total effective dose classification of study patients (n = 108)

Type of cancer	n	Radioactivity excretion (%)
Lung	29	18.9 ± 13.1
Colorectal	18	29.2 ± 18.1
Breast	14	17.4 ± 10.6
Head and neck	9	26.2 ± 17.2
Lymphoma	9	23.2 ± 18.6
Male genitalia	6	13.9 ± 4.9
Endometrium	3	28.9 ± 11.1
Liver and bile ducts	3	37.2 ± 12.3
Malignant melanoma	3	20.8 ± 5.3
Stomach	3	21.6 ± 12.6
Gastrointestinal stromal	2	27.3 ± 5.7
Mediastinum and thymus	2	15.4 ± 0.7
Ovarian	2	44.5 ± 22.5
Brain	1	19.1
Esophagus	1	10.4
Pancreas	1	46.4
Unknown primary	1	14.5
Sarcoma	1	14.9

thymus (1.8%), ovarian (1.8%) and others (5.4%). Cancer type and urinary excretion values of all patients were given in Table 1.

Effective dose levels of patients as mSv/h were measured at a distance of 1 m before and after bladder emptying. Comparisons were made between gender, age, body mass index and clinical diagnosis groups. Results showed that bladder emptying decreased radioactivity level by 22.75% ± 14.77%.

When the age groups were compared, the percentage of radioactivity excretion was higher in 41-60 years age group compared to 20-40 and over 61 age

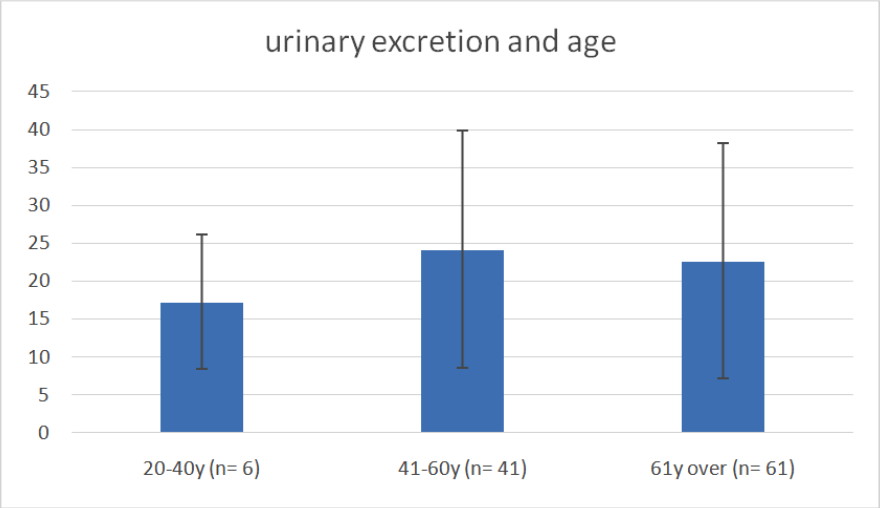

Figure 1. Urinary excretion of radioactivity in different age groups.

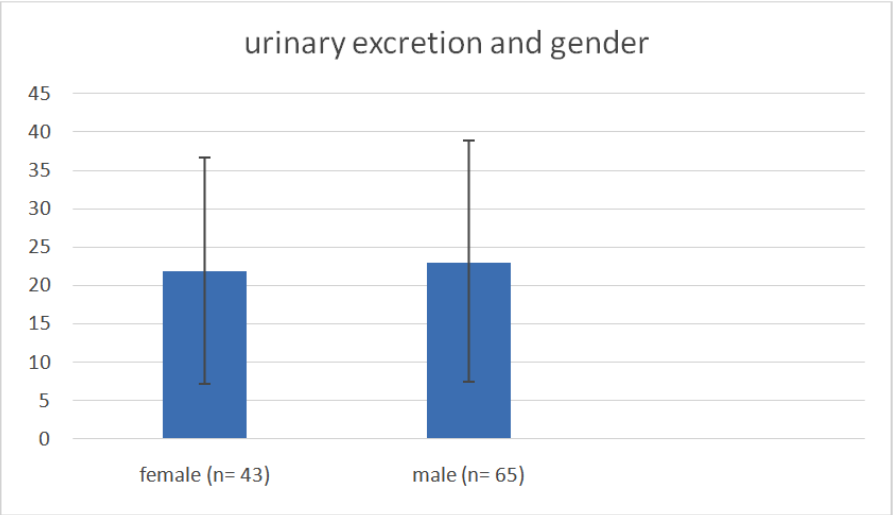

Figure 2. Urinary excretion of radioactivity in different gender groups.

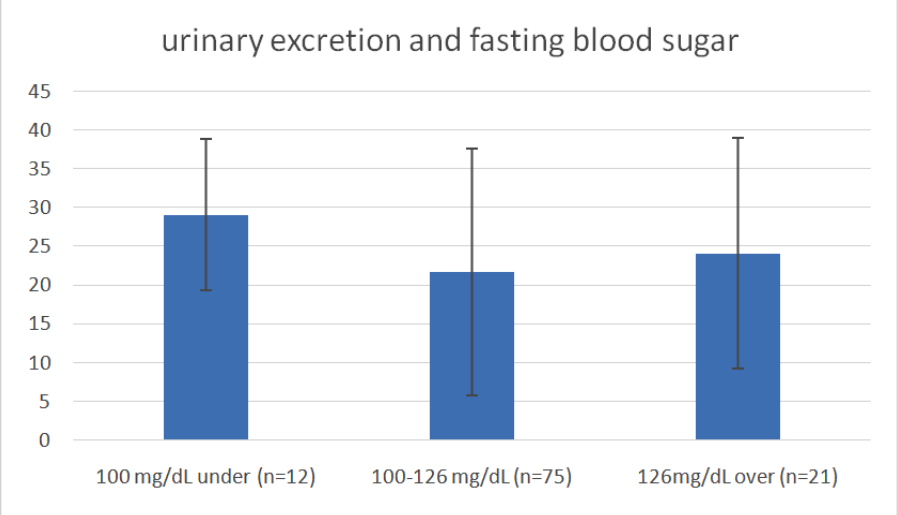

Figure 3. Urinary excretion of radioactivity in different fasting blood sugar groups.

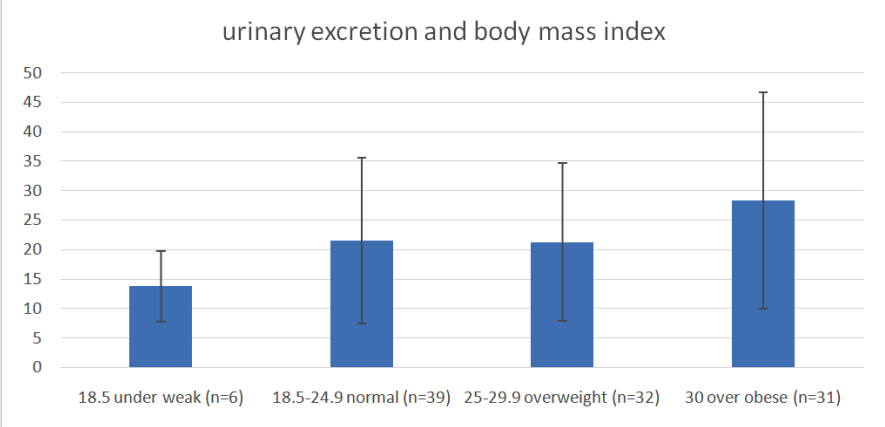

Figure 4. Urinary excretion of radioactivity in body mass index groups.

groups (Figure 1), but the difference was not significant ($p = 0.123$).

In terms of gender, urinary excretion was higher in male group compared to female group, but the difference was not significant ($p = 0.578$) (Figure 2). Radioactivity excretion did not change in different fasting blood sugar groups, despite a slight, but not significant, increase in group with less than 100 mg/dl ($p = 0.534$) (Figure 3).

In spite of a small increase in > 30 body mass index group, radioactivity excretion was not significantly different in body mass index groups ($p = 0.069$) (Figure 4).

^{18}F-FDG PET/CT images of a patient with lung cancer diagnosis were shown in Figure 5. Decrease change was observed in the amount of 18F-FDG radiopharmaceutical in the bladder before and after urinary excretion.

DISCUSSION

^{18}F-FDG PET/CT is widely used throughout the world for primary diagnosis, staging, restaging, evaluation of treatment effectiveness and radiotherapy planning in lung cancer [10]. PET/CT has the power to differentiate tumor and non-malignant tissue [11]. Maximum standardized uptake value is a commonly used malignancy criterion in clinical practice and is defined as ratio of activity in tissue per milliliter to the activity in the injected dose per kilogram body weight [12]. The present study was conducted to determine the effect of urinary excretion on total effective dose level in patients having PET/CT scans.

^{18}F-FDG in circulation undergoes glomerular filtration and is not reabsorbed as glucose. Thus, it is predominantly excreted in urine, which results in a problem in imaging of renal, ureteral, bladder, and prostate tumors. Poor ^{18}F-FDG uptake by some malignant neoplasms such as renal, prostate, and hepatocellular carcinomas is another drawback of ^{18}F-FDG. Therefore, ^{18}F-FDG PET has been considered useless to detect bladder cancer and perivesical lymph nodes [13]. In pelvis, increased physiological ^{18}F-FDG uptake may occur in bowel, uterus, ovary, bone marrow, bone, and urinary system [8].

PET/CT is typically acquired in the caudal to cranial direction to further reduce urinary bladder ^{18}F-FDG accumulation. Bladder catheterization or continuous bladder irrigation may also be used to reduce bladder radiopharmaceutical activity in patients who cannot urinate well [14]. Delayed ^{18}F-FDG PET/CT scans after a diuretic and oral hydration can dramatically improve detection of local recurrent or residual bladder tumors [13, 15]. In the present study, effective radiation level was lowered by 22.7% through urinary secretion in patients having ^{18}F-FDG PET/CT.

FDG is an^{18}F radionuclide-labelled analogue of glucose. It is the most widely used radiopharmaceutical in PET/CT technique. FDG is a typical short-lived radionuclide and has a half-life of 1.8 hours [16]. Studies have shown that ^{18}F-FDG urine excretion is highly variable. The results of the present study showed that FDG excretion varied between 5% and 15% during the hour between FDG administration and imaging in patients with normal kidney function and blood glucose levels for performing PET. Urinary FDG excretion was between 5.7% and 15.2% of decay-corrected injected dose. This variation is another problem for the accuracy of SUV. Urinary excretion relies upon hydration of patients along with various other factors influencing standardized uptake value. FDG excreted through kidneys is not absorbed by cells and is not accumulated intracellularly [17]. It was observed in the present study that age, gender, fasting blood sugar and body mass index did not affect urinary excretion of FDG.

Several strategies have been introduced to reduce radiation level exposed by patients and health care providers. The first and foremost strategy is proper use of ionizing radiation based on ALARA (As Low As Reasonably Achievable) principle. This principle aims to reduce exposed radiation level through reducing exposure time and using correct distance management (source-patient-detector, and source-patient-healthcare staff distances) and appropriate shielding. It was shown that adherence to this principle reduces radiation exposure. These precautions to reduce radiation exposure can compromise the efficiency and reliability of the procedure itself. Image fusion technology, for example, can further reduce radiation exposure [18]. Based on ALARA principle, the present study investigated minimal radioactivity level and corresponding imaging time required for reliable semi-quantification in PET/CT imaging [19]. The

cumulative 18F-FDG dose was calculated in milli-Curies during treatment and surveillance of all patients who received PET/CT scans. Calculated 18F-FDG PET/CT dose was converted to effective dose from milli-Curies to Becquerels and then from Becquerels to milli-Sieverts using a conversion factor of 0.019 mSv/MBq [20].

It is hypothesized that patients with renal failure may require a greater uptake time during an 18F-FDG PET/CT scan than patients with normal kidney function due to the impaired distribution and clearance of ^{18}F-FDG. Since urine production has such a drastic impact on the amount of dosage excreted, it can be associated with the rates of delayed urine production between renal failure [21]. It is may be decreased radioactivity dose in patients with renal failure during PET/CT scan.

Pain, loss of appetite, nausea, vomiting, cachexia, fatigue, dyspnea, acidity, liquid and electrolyte imbalances, anxiety, agitation, delirium and confusion are among the most common findings and symptoms in oncology patients [22, 23]. These patients frequently visit emergency services with these complaints. Therefore, emergency service employees are under a continuous radiation exposure risk. In addition to radiation protection measures for patients having PET/CT, effective urinary excretion practice would contribute to radiation safety of patients and emergency service workers. In the present study, it was shown that removal of ^{18}F-FDG from bladder through urinary excretion after PET/CT scan could protect patients and health care providers.

CONCLUSION

Active emptying of bladder, physiological area of involvement for ^{18}F-FDG, is an effective method in radiation safety of health care providers and patients in PET/CT use. Especially in cases where functional capacity of bladder is impaired, urinary catheter use could lower radiation exposure level.

Authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors, and all authors are in agreement with the manuscript.

Conflict of interest

The author disclosed no conflict of interest during the preparation or publication of this manuscript.

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REFERENCES

[1] Siegel JA, Stabin MG. Medical imaging: the challenges of radiation risk assessment. J Nucl Med 2014;55:16-7.
[2] Grigsby PW. The prognostic value of PET and PET/CT in cervical cancer. Cancer Imaging 2008;8:146-55.
[3] Anderson C, Koshy M, Staley C, Esiashvili N, Ghavidel S, Fowler Z, et al. PET-CT fusion in radiation management of patients with anorectal tumors. Int J Radiat Oncol Biol Phys 2007;69:155-62.
[4] Jha AK, Zade A, Rangarajan V. Estimation of radiation dose received by the radiation worker during F-18 FDG injection process. Indian J Nucl Med 2011;26:11-3.
[5] Hasbek Z, Doğan ÖT, Sarı İ, Yücel B, Şeker MM, Turgut B, et al. The diagnostic value of the correlation between serum anti-p53 antibody and positron emission tomography parameters in lung cancer. Mol Imaging Radionucl Ther 2016;25:107-13.
[6] Delgado Bolton RC, MucientesRasilla J, Perez Castejon MJ, Carreras Delgado JL. [Positron emission tomography (PET) and PET-CT in renal, bladder and prostate cancer: update]. Actas Urol Esp 2009;33:11-23. [Article in Spanish]
[7] Hoilund-Carlsen PF, Poulsen MH, Petersen H, Hess S, Lund L. FDG in urologic malignancies. PET Clin 2014;9:457-68.
[8] Khiewvan B, Torigian DA, Emamzadehfard S, Paydary K, Salavati A, Houshmand S, et al. Update of the role of PET/CT and PET/MRI in the management of patients with cervical cancer. Hell J Nucl Med 2016;19:254-68.
[9] Do KH. General principles of radiation protection in fields of diagnostic medical exposure. J Korean Med Sci. 2016;31:6-9.
[10] Börksüz MF, Erselcan T, Hasbek Z, Yücel B, Turgut B. Morphologic and metabolic comparison of treatment responsiveness with 18fludeoxyglucose-positron emission tomography/ computed tomography according to lung cancer type. Mol Imaging Radionucl Ther 2016;25:63-9.
[11] Shyn PB. Interventional positron emission tomography/computed tomography: state-of-the-art. Tech Vasc Interv Radiol 2013;6:182-90.
[12] Hasbek Z, Yucel B, Salk I, Turgut B, Erselcan T, Babacan NA, et al. Potential impact of atelectasis and primary tumor glycolysis on F-18 FDG PET/CT on survival in lung cancer patients. Asian Pac J Cancer Prev 2014;15:4085-9.
[13] Anjos DA, Etchebehere EC, Ramos CD, Santos AO, Albertotti C, Camargo EE. 18F-FDG PET/CT delayed images after diuretic for restaging invasive bladder cancer. J Nucl Med 2007;48:764-70.
[14] Gorospe L, Jover-Diaz R, Vicente-Bartulos A. Spectrum of

PET-CT pelvic pitfalls in patients with gynecologic malignancies. Abdom Imaging 2012;37:1041-65.
[15] Yildirim-Poyraz N, Ozdemir E, Uzun B, Turkolmez S. Dual phase 18F-fluorodeoxyglucose positron emission tomography/computed tomography with forced diuresis in diagnostic imaging evaluation of bladder cancer. Rev Esp Med Nucl Imagen Mol 2013;32:214-21.
[16] Noh S, Jeong S, An M, Jang HK, Kwon TE, Lee JI, et al. Internal dosimetry for intake of 18FDG using spot urine sample. Radiat Prot Dosimetry 2016;168:343-9.
[17] Bach-Gansmo T, Dybvik J, Adamsen T, Naum A. Variation in urinary excretion of FDG, yet another uncertainty in quantitative PET. Acta Radiol Short Rep 2012;1(8). pii: arsr.2012.120038.
[18] Stangenberg L, Shuja F, van der Bom IMJ, van Alfen MHG, Hamdan AD, Wyers MC, et al. Modern fixed imaging systems reduce radiation exposure to patients and providers. Vasc Endovascular Surg 2018;52:52-8.
[19] Chen MK, Menard DH, Cheng DW. Determining the minimal required radioactivity of 18F-FDG for reliable semiquantification in PET/CT imaging: a phantom study. J Nucl Med Technol 2016;44:26-30.
[20] ICRP. Radiation dose to patients from radiopharmaceuticals. Addendum 3 to ICRP Publication 53. ICRP Publication 106. Approved by the Commission in October 2007. Ann ICRP 2008;38:1-197.
[21] Kode V, Karsch H, Osman MM, Muzaffar R. Impact of renal failure on F18-FDG PET/CT scans. Front Oncol 2017;7:155.
[22] Aydoğan F, Uygun K. Kanser hastalarında palyatif tedaviler. Klinik Gelişim 2011;24:4-9.
[23] Elçigil A. [Palliative care nursing]. Gülhane Tıp Derg 2012;54:329-34. [Article in Turkish]