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Awareness of Patients Who Will Undergo ^{18}F-FDG PET/CT Imaging About Ionizing Radiation Exposure

^{18}F-FDG PET/BT Çekimi Yapılacak Hastaların İyonize Radyasyon Maruziyeti Hakkındaki Farkındalığı

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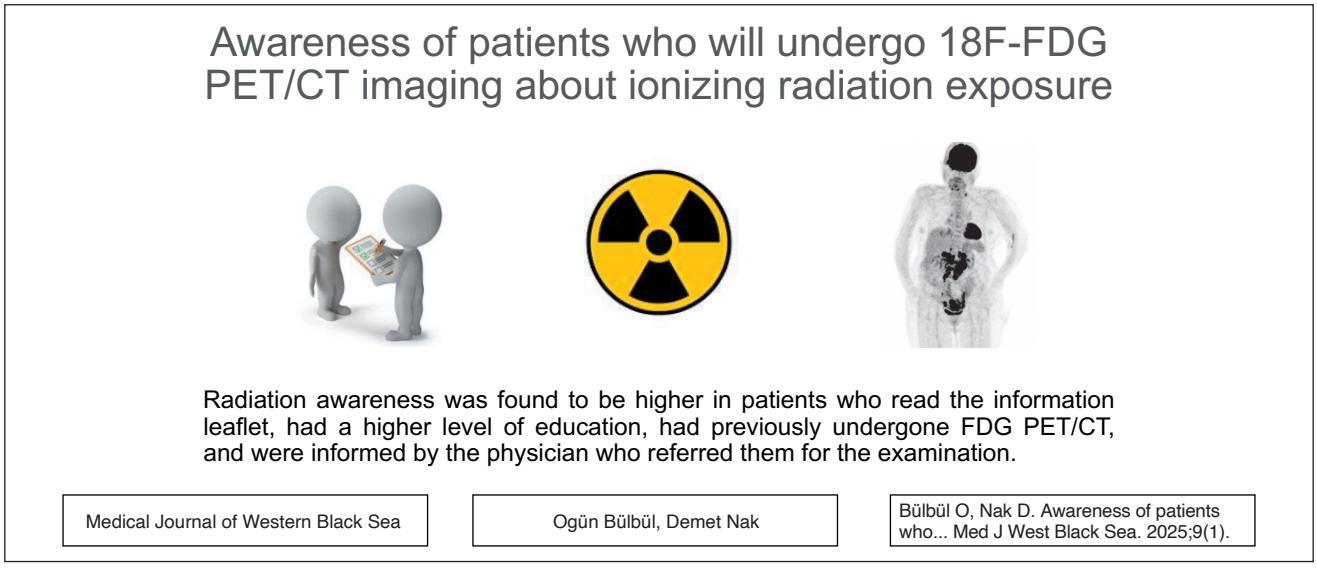
GRAPHICAL ABSTRACT



ABSTRACT

Aim: The use of ^{18}F-fluorodeoxyglucose positron emission tomography/computed tomography (FDG PET/CT) is rising. This study aimed to investigate the awareness of patients undergoing FDG PET/CT about the ionizing radiation exposure related to the examination.

Material and Methods: One hundred and eleven patients who applied to our department for FDG PET/CT were asked the survey questions before FDG injection. Patients were asked to choose the most appropriate answer among the options. The effect of some factors on the patient's responses was investigated. Chi-square and Fisher's exact test were used for statistical analysis.

Results: Approximately eighty-one percent of the patients who read the information leaflet (78/96) and 40% of the patients who did not (6/15) knew what radiation is (p=0.001). Eighty percent of patients with an education level of high school and above (16/20) and 42.9% of patients of secondary school and below (39/91) knew how long FDG would affect the people around them (p=0.011). Approximately 40% of

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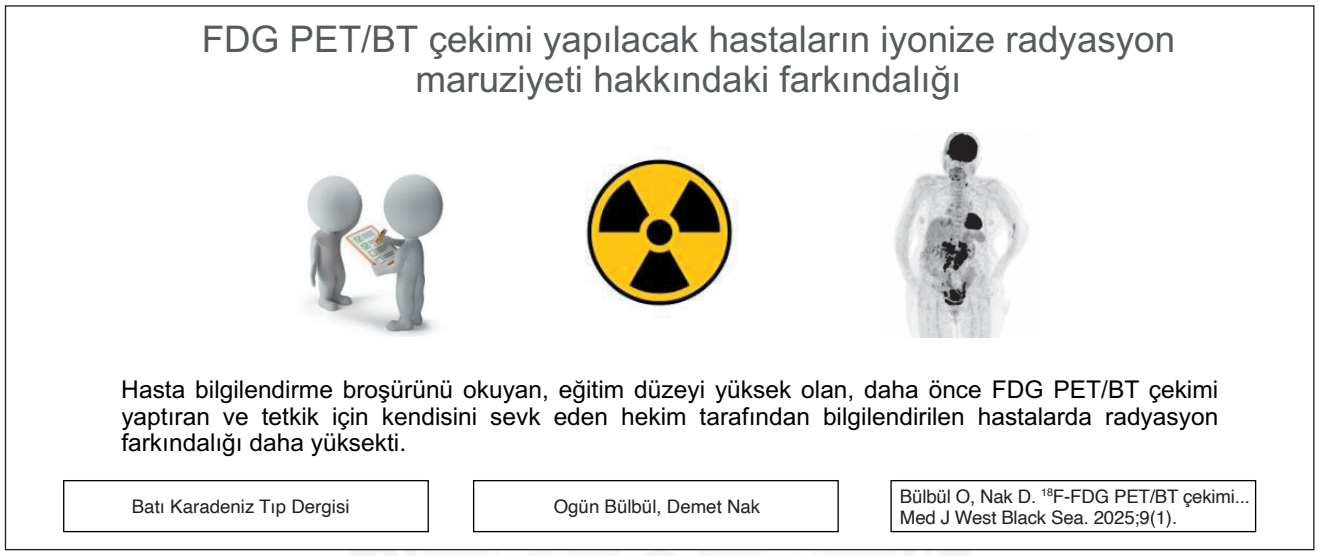
the patients who were informed about the test by their physician (21/52) and 25.5% of those who were not (12/47) were aware that repeated radiation exposure increases the risk of cancer development (p=0.021). Approximately 54% of patients (60/111) reported radiation exposure in magnetic resonance imaging, 34.2% (38/111) in ultrasonography, and 81.1% (90/111) in FDG PET/CT.

Conclusion: According to our study's results, radiation awareness was found to be higher in patients who read the information leaflet, had a higher level of education, had previously undergone FDG PET/CT, and were informed by the physician who referred them for the examination.

Keywords: Awareness, ^{18}F-fluorodeoxyglucose, ionizing radiation, positron emission tomography/computed tomography.

GRAFİKSEL ÖZET



ÖZ

Amaç: ^{18}F-florodeoksiglukoz pozitron emisyon tomografisi/bilgisayarlı tomografinin kullanımı artmaktadır. Bu çalışmadaki amacımız FDG PET/CT çekimi yapılacak hastaların tetkike bağlı iyonize radyasyon maruziyeti hakkında farkındalığını araştırmaktır.

Gereç ve Yöntemler: Departmanımıza FDG PET/CT çekimi için başvuran hastalara FDG enjeksiyonu yapılmadan önce anket soruları soruldu. Hastalardan kendilerine en uygun cevabı seçenekler arasından seçmesi söylendi. Bazı faktörlerin hastaların radyasyon hakkındaki sorulara verdikleri cevaplar üzerine etkisi araştırıldı. İstatistiksel analiz için ki-kare ve Fisher's exact test kullanıldı.

Bulgular: Bilgilendirme formunu okuyan hastaların yaklaşık %81'i (78/96), okumayanların %40'ı (6/15) radyasyonun ne olduğu hakkında bilgi sahibiydi (p=0.001). Eğitim seviyesi lise ve üstü olan hastaların %80'i (16/20), ortaokul ve altı olan hastaların ise %42.9'u (39/91) FDG'nin etraftaki insanları ne kadar süre etkileyeceğini biliyordu (p=0.011). FDG PET/CT çekim endikasyonu koyan doktorun tetkik hakkında bilgilendirdiği hastaların yaklaşık %40'ı (21/52), bilgilendirmediği hastaların ise %25.5'i (12/47) tekrarlayan radyasyon maruziyetinin kanser gelişim riskini artırdığını biliyordu (p=0.021). Hastaların yaklaşık %54'ü (60/111) manyetik rezonans görüntülemede, %34.2'si (38/111) ultrasonografide radyasyon maruziyeti olduğunu söyledi, %18.9'u (21/111) FDG PET/BT'de radyasyon maruziyeti olmadığını söyledi.

Sonuç: Çalışmamızın sonuçlarına göre bilgilendirme broşürünü okuyan, eğitim düzeyi yüksek olan, daha önce FDG PET/CT çektiren ve tetkike yönlendiren hekim tarafından bilgilendirilen hastaların radyasyon farkındalığı daha yüksek bulunmuştur.

Anahtar Sözcükler: Farkındalık, ^{18}F-florodeoksiglukoz, iyonize radyasyon, pozitron emisyon tomografisi/bilgisayarlı tomografi

INTRODUCTION

Medical imaging is widely used for the diagnosis of many diseases. Some of these imaging modalities (such as computed tomography (CT)) lead to exposure to ionizing radiation. The frequency of use of medical imaging has increased over the years (1). Medical imaging has become the primary source of artificial radiation exposure for the human body (2). The importance of this is that ionizing radiation exposure is associated with the development of malignancy (3-8). Among medical imaging, CT is the most commonly used medical imaging method, and its use is increasing mostly (9). Therefore, CT appears to be the most severe cause of artificial radiation exposure. ^{18}F-fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) is a molecular imaging modality that has been frequently used in the imaging of cancer patients in recent years (10). FDG PET/CT is a hybrid medical imaging modality with functional information about tissues provided by FDG molecule and anatomical correlation/attenuation correction provided by CT. FDG causes ionizing radiation exposure by positron decay, and CT causes X-ray exposure. Therefore, FDG PET/CT is a significant source of artificial radiation exposure in cancer patients. Since FDG PET/CT is mainly used in cancer patients, ionizing radiation exposure is not avoided, considering the benefit-harm balance. However, the ionizing radiation content of FDG PET/CT in pediatric patients and patients with prolonged survival (such as Hodgkin's lymphoma and breast cancer) deserves more attention.

Many studies in the literature have shown that patients do not have sufficient information about radiation exposure due to medical images (2,11-14). Surprisingly, some physicians consider magnetic resonance imaging (MRI) and ultrasonography (US) to contain ionising radiation (15). In addition to the developments in the field of medical imaging, the lack of awareness of patients and physicians about ionizing radiation may also be one of the reasons for the increased frequency of use of medical imaging. This study aimed to investigate the awareness of patients undergoing FDG PET/CT that this examination is a source of ionising radiation exposure.

MATERIALS and METHODS

This study was approved by the local ethics committee (Decision no: 2024/121). The ethics committee did not deem it necessary to obtain informed consent from the patients for this study. However, patients signed an informed consent form for FDG PET/CT examination.

Patients

All patients who came to our department for FDG PET/CT between 1 April 2024 and 30 June 2024 were asked whether they would like to participate in a verbal survey questioning some demographic information and the ionising radiation content of FDG PET/CT. Inclusion criteria for the study: 1- Patient's agreement to participate in the survey, 2- Patients whose medical condition was suitable for understanding and answering the questions were asked the questions. Exclusion criteria from the study: 1- Patients' unwillingness to participate in the survey, 2- Patients whose medical condition was not suitable for understanding and answering the questions. The full version of the survey is available in the supplementary material. Questions related to patients' awareness of radiation include:

- Have you had a FDG PET/CT scan before? If yes, how many FDG PET/CT scans have you had before?
- Did you read the patient information leaflet or did someone else read the patient information leaflet to you before you came for FDG PET/CT?
- Do you have information about what radiation is?
- Do you have information about the effects of radiation on the human body?
- Do you know that FDG PET/CT will cause ionizing radiation exposure to your body?
- Did the physician who referred you for FDG PET/CT explain to you that PET/CT will cause radiation exposure to your body?
- Does repeated radiation exposure increase the risk of developing cancer?
- Which examinations cause radiation exposure?
- Do you know how long the radioactive substance fluorodeoxyglucose (FDG) injected into your body for the PET/CT scan can affect the people around you?
- Do you know how long it takes for the radioactive substance fluorodeoxyglucose (FDG), which is injected into your body for the PET/CT scan, to be present in your body in such small quantities that it almost disappears?
- Are you aware of the ways in which the radioactive substance FDG (fluorodeoxyglucose) which is injected into your body for the PET/CT scan can contaminate the environment?

The patients' responses to the questions related to radiation were evaluated based on their declarations. For example, if the patient answered 'yes' to the question 'Do you have information about what radiation is?', no further questions were asked to the patient to question the reliability of this answer.

Statistical Analysis

Demographic data of the patients were presented by descriptive statistical methods. The patients' responses to the questions were described in frequency tables. The effects of nominal variables such as gender and educational status on the answers to the questions were evaluated by Pearson

chi-square analysis and Fisher's exact test. For statistical analysis, SPSS 24 software (IBM Corp., Armonk, NY, USA) was used. P<0.05 was accepted as statistically significant at a 95% confidence interval.

RESULTS

Approximately fifty-two (47%) patients were female and 59 (53%) were male in the study. The mean age of patients was 64 ± 12 years. The educational level of 82% of the patients was secondary school and below, while 18% of them were high school and above. FDG PET/CT was performed previously in 53.2% of the patients. Detailed information about the patients is given in Table 1.

The percentages of patients answering 'yes' to questions 9, 10, 11, 14, 16, 17, and 18, which asked whether radiation and its effects were known or not, were approximately 77%, 54%, 64%, 30%, 50%, 41%, and 34%, respectively.

Approximately 81% of the patients who read the information leaflet and 40% of those who did not, were aware of what radiation is (Question 9, p=0.001) (Figure 1 and Table 2). Approximately fifty-four percent of the patients who read the leaflet and 20% of those who did not know how

Table 1. Detailed patient characteristics.

	Sonuç (n=111)
Age (Years) (Mean ± standardized deviation)	64 ± 12
Gender, n (%)	
- Female	52 (46.8)
- Male	59 (53.2)
Educational level, n (%)	
- Illiterate	20 (18.0)
- Primary school	54 (48.6)
- Secondary school	16 (14.4)
- High school	15 (13.5)
- University and above	6 (5.5)
Previous FDG PET/CT imaging, n (%)	
- Yes	59 (53.2)
- No	52 (46.8)
Referring department, n (%)	
- Non-surgical departments	102 (91.9)
- Surgical departments	9 (8.1)

FDG: ^{18}F-fluorodeoxyglucose, **PET/CT:** positron emission tomography/computed tomography

Table 2. The effect of reading the patient information leaflet, educational level, and previously undergoing FDG PET/CT on patient awareness about radiation in PET/CT.

		Reading the patient information leaflet			p-value
		Yes	No	Unsure	
Knowing what radiation is, n (%)	Yes	78 (81.2)	11 (11.5)	7 (7.3)	**0.001**
	No	6 (40.0)	4 (26.7)	5 (33.3)	
		Reading the patient information leaflet			**p-value**
		Yes	No	Unsure	
Knowing how long FDG affects people around the patient, n (%)	Yes	52 (54.2)	33 (34.4)	11 (11.4)	**0.048**
	No	3 (20.0)	9 (60.0)	3 (20.0)	
		Knowing how long FDG affects people around the patient			**p-value**
		Yes	No	Unsure	
Educational level, n (%)	High school and above	16 (80.0)	3 (15.0)	1 (5.0)	0.011
	Secondary school and below	39 (42.9)	39 (42.9)	13 (14.2)	
		Knowing how long FDG affects people around the patient			**p-value**
		Yes	No	Unsure	
Previously undergoing FDG PET/CT, n (%)	Yes	39 (66.1)	16 (27.1)	4 (6.8)	0.011
	No	16 (30.8)	26 (50.0)	10 (19.2)	
		Knowing that repeated radiation exposure increases the risk of cancer development			**p-value**
		Yes	No	Unsure	
Information provided by the referring physician, n (%)	Yes	21 (40.4)	2 (3.8)	29 (55.8)	0.021
	No	12 (25.5)	6 (12.8)	29 (61.7)	
	Unsure	0 (0.0)	3 (25.0)	9 (75.0)	

FDG: ^{18}F-fluorodeoxyglucose, **PET/CT:** positron emission tomography/computed tomography,

long FDG affects people in the neighborhood (Question 17, p=0.048) (Figure 2 and Table 2). Approximately 39% of the patients younger than 75 years and 50% of the older patients knew the approximate time after which FDG would be almost non-existent in the body (Question 10, p=0.040). Eighty percent of patients with an education level of high school and above and 42.9% of patients with an education level of secondary school and below knew how long FDG would affect the people around them (Question 9, p=0.011) (Figure 3 and Table 2). Approximately 65% of patients with high school education and above and 35% of patients with secondary school education and below knew approximately how long it would take for the FDG to disappear from the body (Question 10, p=0.048). Approximately 7% of patients who had undergone FDG PET/CT and six percent who had not had FDG PET/CT had correct knowledge about the radiation doses of FDG PET/CT and thoracoabdominopelvic CT (The radiation doses of both examinations are close to each other (16)). Approximately 66% of patients who had previously undergone FDG PET/CT and 31% of those who had not had FDG PET/CT knew how long FDG would affect people around them (Question 9, p=0.001) (Figure 4

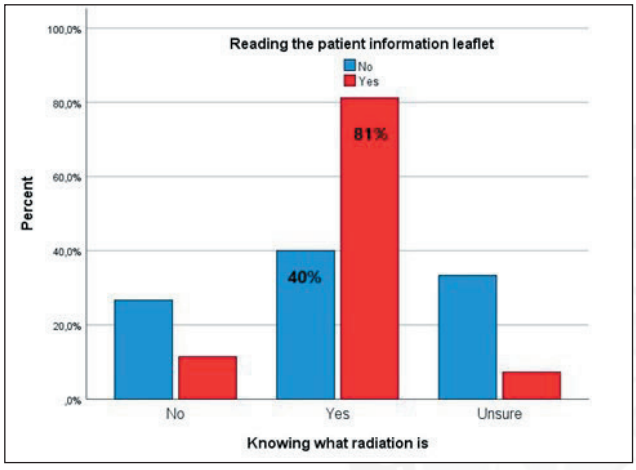


Figure 1: The effect of reading the patient information leaflet on knowing what radiation is. Eighty-one percent of the patients who read the information leaflet and 40% of those who did not were aware of what radiation is (p=0.001).

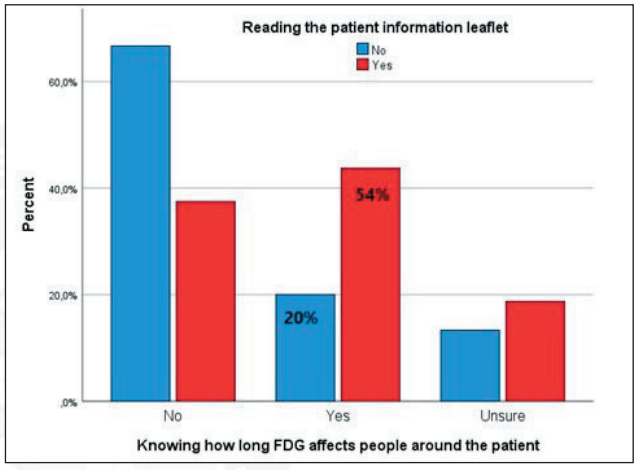


Figure 2: The effect of reading the patient information leaflet on knowing how long FDG affects people around the patient. Fifty-four percent of the patients who read the leaflet and 20% of those who did not know how long FDG affects people in the neighborhood (p=0.048).

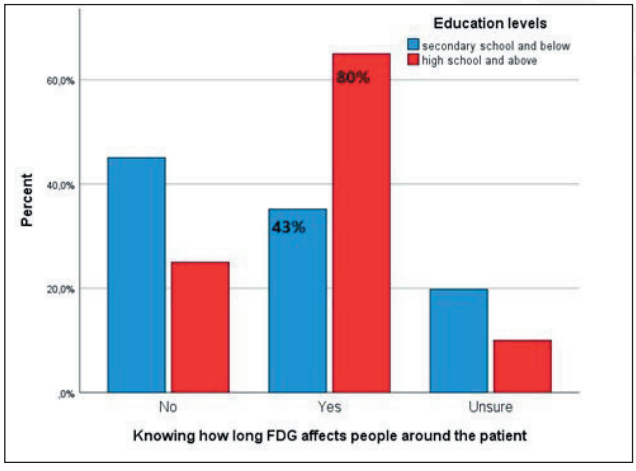


Figure 3: The effect of educational levels on knowing how long FDG affects people around the patient. Eighty percent of patients with an education level of high school and above and 43% of patients with an education level of secondary school and below knew how long FDG would affect the people around them (p=0.011).

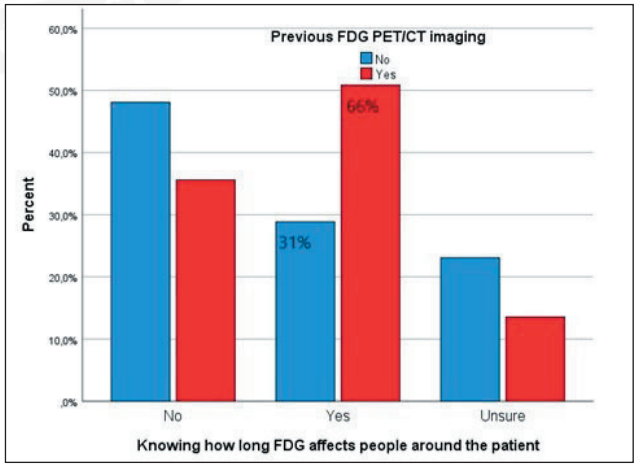


Figure 4: The effect of previously undergoing FDG PET/CT on knowing how long FDG affects people around the patient. Sixty-six percent of patients who had previously undergone FDG PET/CT and 31% of those who had not had FDG PET/CT knew how long FDG would affect people around them (p=0.001).

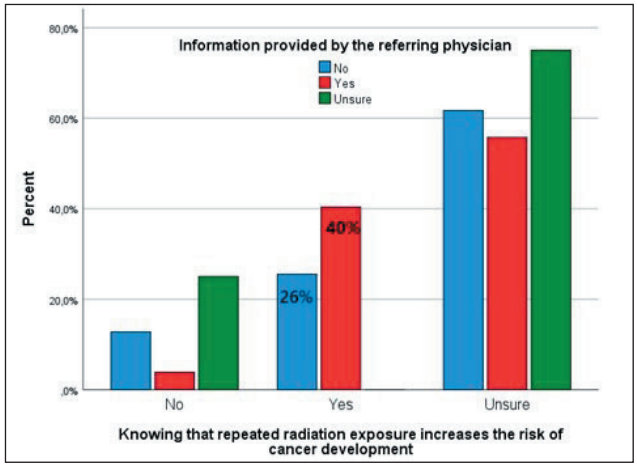


Figure 5: The effect of being informed by the referring physician on knowing that repeated radiation exposure increases the risk of cancer development. Forty percent of the patients who were informed about the test by the physician indicating FDG PET/CT, and 26% of the patients who were not informed knew that repeated radiation exposure increases the risk of cancer development (p=0.021).

and Table 2). Approximately 40% of the patients who were informed about the test by the physician indicating FDG PET/CT, and 25.5% of the patients who were not informed knew that repeated radiation exposure increases the risk of cancer development (Question 6, p=0.021) (Figure 5 and Table 2). Patients informed by the physician had a higher percentage of correct answers to Question 16 and Question 17 (Question 16, approximately 66% vs. 30%, p=0.011; Question 17, approximately 58% vs. 23%, p=0.014). Approximately 48% of patients referred for FDG PET/CT by surgical departments and approximately 33% of patients referred by nonsurgical departments reported having information about the effects of radiation on the human body, but this difference was not statistically significant. This is probably because there were 102 patients referred by internal and nine patients referred by surgical departments in our study. There was no statistically significant difference between the answers given by male and female patients to the questions in this study. Results that were not statistically significant were not presented as tables.

Approximately 47% of patients reported no radiation exposure in X-ray, 45% in CT, 19% in PET/CT, and 74% in mammography. Approximately 54% of patients reported radiation exposure in MRI, 34% in US.

DISCUSSION

Many studies have shown that patients do not have sufficient information about radiation exposure in medical imaging (2,11-14). In this study, we investigated the knowledge of patients undergoing FDG PET/CT about radiation exposure and the effects of some factors on this situation. According to the results of our study, patients who read the information leaflet, had a higher level of education, had undergone FDG PET/CT before, and were informed about the examination by the referring physician answered 'yes' with a higher percentage when asked whether they knew the questions about the radiation involvement of FDG PET/CT examination.

Schuster et al. asked 101 patients who underwent abdominopelvic CT in the emergency department and health care providers, including physicians practicing in the hospital, to compare the radiation dose of the examination with chest X-ray (12). Of the 61 patients who answered the comparison question, 14 (23%) gave the correct answer (the radiation exposure from 1 CT is approximately the same as from 100-250 chest X-rays). Patients who had discussed the radiation dose of the examination with their physician were more likely to estimate the correct radiation dose. In our study, patients who were informed by the referring physician were better aware of how long FDG affects the environment and how long FDG remains in the body in undetectable amounts than those who were not informed.

Singh et al. analysed patients' knowledge about radiation in medical imaging and its risks (13). Only 30.6% of the patients included in the study knew that PET/CT caused radiation exposure. In the same study, 48.3% of the patients reported that MRI, and 9.9% reported that US caused radiation exposure. In addition, only 34.2% of the patients knew that CT caused more radiation exposure than X-ray. Sin et al. conducted a survey study with 173 patients and measured their knowledge about radiation in medical imaging and its effects (14). 60.7% of patients did not know that MRI is a radiation-free medical imaging modality, and 32.7% did not know that US is a radiation-free modality. Only 17.8% of patients had correct information about the risk of developing fatal cancer due to CT. In our study, 81.1% of the patients knew that FDG PET/CT includes radiation. However, our study aims to measure the radiation awareness of patients undergoing FDG PET/CT. The higher rate of our patients knowing that FDG PET/CT contains radiation may be associated with 'bias.' However, in our study, the percentage of patients who thought that MRI and US contained radiation was similar to the literature (54% and 34%, respectively).

Ribeiro et al. investigated whether 50 patients undergoing bone scintigraphy and 52 patients undergoing FDG PET/CT were informed about the radiation content of these examinations and whether patient information leaflets provided sufficient information (11). Thirty-seven percent of patients reported not having sufficient knowledge about nuclear medicine. Only 6.7% of the questions about the ionizing radiation content of FDG PET/CT were answered correctly by the patients, and 66.8% were answered with 'I do not know.' Interestingly, 75.6% of the patients who received informa-

tion leaflets from the nuclear medicine department thought that these leaflets provided sufficient information. Patients who had previously undergone FDG PET/CT and patients with better educational status were more likely to answer the questions correctly. In our study, patients who had previously undergone FDG PET/CT answered question 9 as 'yes' in a higher percentage, and patients with higher educational levels answered question 9 and question 10 as 'yes' in a higher percentage.

The knowledge of the referrers about the radiation content of medical imaging methods and cancer formation due to this radiation is not sufficient. Uri et al. assessed the knowledge of patients' referrers about medical images' radiation content (15). Thirty-seven percent of the participants correctly ranked the radiation doses of radiological imaging techniques. Fifteen percent of the participants stated that US and MRI contain radiation, and 11% stated that radionuclide studies do not contain radiation. Also, in clinics working under heavy working conditions, it may not be possible to ensure that the referrers inform the patients adequately. Therefore, adequate information of the patients by the departments performing medical imaging will increase the awareness of the patients about radiation. Patient information leaflets should contain more satisfying information about the radiation content of the examinations and potential cancer formation due to this radiation. These information leaflets should be enriched with attention-grabbing content (visuals, etc.) and made more readable.

This study has some limitations. This survey-based study is a single-center study conducted in a clinic where approximately 12 patients per day undergo FDG PET/CT. Therefore, the number of patients participating in the study was limited. When analysing the results of our study, readers should be aware that the generalisability of these results to patient populations in different countries is limited. Studies involving larger centers with more PET/CT scans may be more representative of the population. The patients' responses to the questions related to radiation were evaluated based on their declarations. For example, if the patient answered 'yes' to the question 'Do you have information about what radiation is?', no further questions were asked to the patient to question the reliability of this answer. The educational status of the patients participating in the study is heterogeneous. Since the number of patients with low educational status was high in this study, their radiation awareness may be lower than the radiation awareness of patients in developed countries. However, we recommend paying attention to the difference between the radiation awareness of patients with and without low educational status when interpreting the results of our study.

According to our study's results, radiation awareness was found to be higher in patients who read the information leaflet, had a higher level of education, had previously undergone FDG PET/CT, and were informed by the physician who referred them for the examination. To increase patients' awareness of radiation exposure, it would be useful to ensure that their referring physicians adequately inform patients and that the information leaflets given to patients for examinations in diagnostic medicine departments are carefully prepared.

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None.

Author Contributions

Concept: **Ogün Bülbül,** Design: **Ogün Bülbül, Demet Nak,** Data collection and processing: **Ogün Bülbül, Demet Nak,** Analysis and interpretation: **Ogün Bülbül, Demet Nak,** Literature search: **Ogün Bülbül,** Writing: **Ogün Bülbül,** Approval: **Ogün Bülbül, Demet Nak.**

Conflicts of Interest

The authors declare no conflict of interest.

Financial Support

The authors declare that no financial support received by authors for this research.

Ethical Approval

This study was approved by Ethics Committee and conducted according to the principles of the Declaration of Helsinki (Decision date: 13.06.2024, approval number: 2024/155). The ethical committee waived the requirement for informed consent.

Review Process

Extremely and externally peer-reviewed.

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