Original Article

Measurements Of The Patient's External Dose Rate Before, During, And After F-18 Fdg During Pet/Ct Imaging

Karzan Noori Saleh [1], **Ronak Taher Ali** [2]

1-Department of Physics, College of Science, Salahaddin University, Erbil, Iraq.
2- Department of Basic sciences, College of Medicine, Hawler Medical University, Erbil, Iraq.
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Abstract

Now a days, positron emission tomography/computerized tomography is one of the most frequently used tests for screening patients having cancer. The test is done forty to sixty minutes following the intravenous injection of fluorine-18 deoxyglucose or 18F FDG, which is the most commonly used radiopharmaceutical in this imaging technique. Radiation is transferred to the atmosphere once the injection is performed; the released dose differs based on the activity of the substance being injected into the patient. The goal of this research was to evaluate the emitted radiation dose in subjects who were injected with F18-FDG intravenously and conclude a suitable discharge time following the performance of the PET/CT imaging technique for the patients. A total of fifty patients, twenty-nine females and twenty-one males participated in this study. They were sent to the department of nuclear medicine for fluorine-18 deoxyglucose positron emission tomography/computerized tomography test. The rate of the radiation doses was calculated at a distance of zero, hundred, and two-hundreds centimetres from patients using a radiation survey meter at 4 different times, including:1-Following the IV injection of fluorine-18 deoxyglucose ,2-Prior to positron emission tomography/computerized tomography imaging ,3- Right after scanning and 4-Right before the patient is discharged. To determine the differences between the measurements, a statistical analysis was done. Results presented that the patients were injected 335.21±21 megabecquerel (MBq) (range: 199.8 - 525.4 MBq) of fluorine-18 deoxyglucose intravenously. The subjects remained for 120.9±15.77 min (range: 95 min-165 min) in the nuclear medicine department following IV fluorine-18 deoxyglucose injection. When measured from one meter, the radiation dose rates were 111.48 ±19.26 μSv/h following the injection, 39.58 ±10.05 μSv/h prior to the positron emission tomography/computerized tomography imaging, and 26.62±5.02 μSv/h right before the patients were discharged.

It was determined that once the positron emission tomography/computerized tomography test was finished, measurements at a distance of one meter were suitable for discharge based on the Turkish Atomic Energy Authority regulation. Hence, after performing the fluorine-18 deoxyglucose positron emission tomography/computerized tomography and explaining the required safety measurements for radiation, patients can be discharged safe and sound.

Keywords: fluorine-18 deoxyglucose, positron emission tomography/computerized tomography, radiation safety, radiation dose rate, 18 FDG- PET/CT

Introduction

F18-FDG PET/CT is a non-invasive procedure that has been frequently used for many years in the department of nuclear medicine. This test is indicated for imaging infections, investigating foci of epilepsy, dementia's differential diagnosis, and of course, staging of many cancers, evaluating the response of treatments, re-staging, planning for radiotherapy, and inspecting the etiology of unknown fever (1, 2).

PET/CT is becoming the modality of choice for numerous oncological illnesses more and more. It presents both anatomical and physiological images of bone marrow, bones, and solid organs as well. The subject could be imaged either from the vertex to the toes or from the base of the skull to the level of the middle of the thigh. This test is also the modality of choice for the evaluation of the response to treatment following chemotherapy and radiotherapy (3). Improvements in positron emission tomography/computed tomography and the medical cyclotrons' installation in hospitals are quickly progressing (4).

Fluorine-18 is a cyclotron product radioisotope that releases positron. It has a brief half-life of about 109.7 minutes (5). In comparison to the most frequently used T-99 in nuclear medicine, with a photon energy of 140 keV, fluorine-18 has a markedly higher photon energy of about 511 keV. Fluorine-18 deoxyglucose is the most regularly used fluorine-18-labelled metabolic product. Fluorine-18 deoxyglucose is an analogue of glucose which is entering cells via glucose transporters and is used then in the glycolytic pathway. It is shown that the utilization of glucose by cells is proportional to the buildup of fluorine-18 deoxyglucose in tissues. It is significant for patients to micturate prior to the test as intravenously-injected FDG is excreted from the body from the urinary tract and the activity of the bladder needs to be decreased (5).

The slightest possible activity of F-18 deoxyglucose needed for positron emission tomography/computed tomography is based on the age and BMI of the subject, the scanning protocol and the device used for the PET/CT test (5). It is crucial to remember to use the principle of using the lowest reasonable, achievable dose possible for health workers and patients as well (6). In national and international studies, the effective dose exposure of patients themselves and people around them during the diagnostic tests in the nuclear medicine department is documented as well (7). Here, based on law number 2690 of the Turkish Atomic Energy Authority or TAEK department of radiation and safety, the tasks are implemented regarding amenities related to licensing, determining principles and regulations, and usage of radioactive materials and ionizing radiation securely (8).

Appropriate protective measures and shielding should be used to minimize and control the exposure of the staff to radiation from 18-fluorine. Besides this, the radiation dose depends on how long the patient is exposed and the quantity of activity of the source (9). From one technologist to another, the timing of the stages of positron emission tomography is different, and it is related to the condition of the individual. The dose is higher when a patient requires complete assistance than an ambulatory individual.

The objective of this research was to evaluate the external dose rates of radiation from individuals that are intravenously injected with fluoride-18 deoxyglucose and determine an appropriate time for discharge following positron emission tomography/computed tomography.

Methods

Patient Population

A total of fifty patients of various age groups who applied to the nuclear medicine department (twenty-nine females, twenty-one males; forty-four years ± eighteen years) who fulfilled the criteria and agreed to volunteer were randomly selected and participated in our study.

Study Design, Data Collection and External Dose Rate Measurement

Data collection began on January 1st 2022 and continued till July 20th 2022. For the F-18 deoxyglucose positron emission tomography/computed tomography test, after eight hours of fasting, the level of blood glucose of the patients was evaluated. Those whose fasting blood glucose was less than two-hundred mg/dL were injected with 335.21±72.43 MBq (range: 199.8 - 525.4 MBq) of fluorine-18 deoxyglucose intravenously based on the recommendations of the European Nuclear Medicine Association FDG PET/CT guideline 2nd version (5). Following the injection, the individual drinks about one litre of water.

A radiation Survey Meter (REED R8008, USA) was used to measure the dose rates, which was created in an ISO 9001 facility and calibrated at the time of the manufacturing. ±3% is the documented accuracy of the GM probe (4). For every patient, external dose rates were measured from the middle of the thorax using this detector at three different times, from zero, a hundred, and two-hundreds centimetres distance. 1st measurement was done directly following fluoride-18 deoxyglucose IV injection, 2nd one following micturition prior to scanning, 3rd measurement was done right after the scanning, and the 4th was following the positron emission tomography/computed tomography right before discharge following micturition. The individuals stayed in isolated rooms with bulletproof insulations till they were discharged. The weight of the individuals and the hours of injection, scanning, and measurements and results were all documented.

Statistical Analysis

We evaluated the standard deviation and mean values of body weight, age, external dose rates, and the time the patient stays in the nuclear medicine department following injection.

The student's t-test was used to calculate the statistical significance of the different measurements of the dose rates. A p-value of less than 0.05 was known to be significant.

Results

The age of the participants in this study was 44.46 ±18.37 years (range: 3 -78 years). 69.9±21.28 kg (range: 15-131 kilograms) was the average body weight. 120.9±15.77 min (range: 95-165 minutes) was the average length of stay from the time of injection of fluorine-18 deoxyglucose till discharge.

As shown in table 1 and in figure 3, the average dose rates were calculated using a survey meter at a distance of zero, hundred, and two-hundreds centimetres from the level of the thorax following injection, following micturating prior to scanning, right after scanning, and following micturition prior to discharge.

Table 1: Comparison of dose rates at different distances (0,100 and 200 centimetres) and times.

Distance (cm)	1Mint Post Injection		(Immediately before Scanning)		(Immediately After scanning)		(Before Discharge)	
	Dose rate (µSv/h)		Dose rate (µSv/h)		Dose rate (µSv/h)		Dose rate (µSv/h)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	251.29	23.86	119.67	20.07	88.98	11.18	73.43	10.09
100	111.48	19.26	39.58	10.05	26.62	5.02	20.63	4.48
200	30.7	5.57	14.88	2.31	10.7	2.17	8.69	1.84

In figure 1 presents the measurement of dose rated from distances of zero, a hundred, and two-hundred centimetres versus time, and figure 2 presents the association between distance and average dose rates from the very beginning until the patient is discharged from the nuclear medicine department.

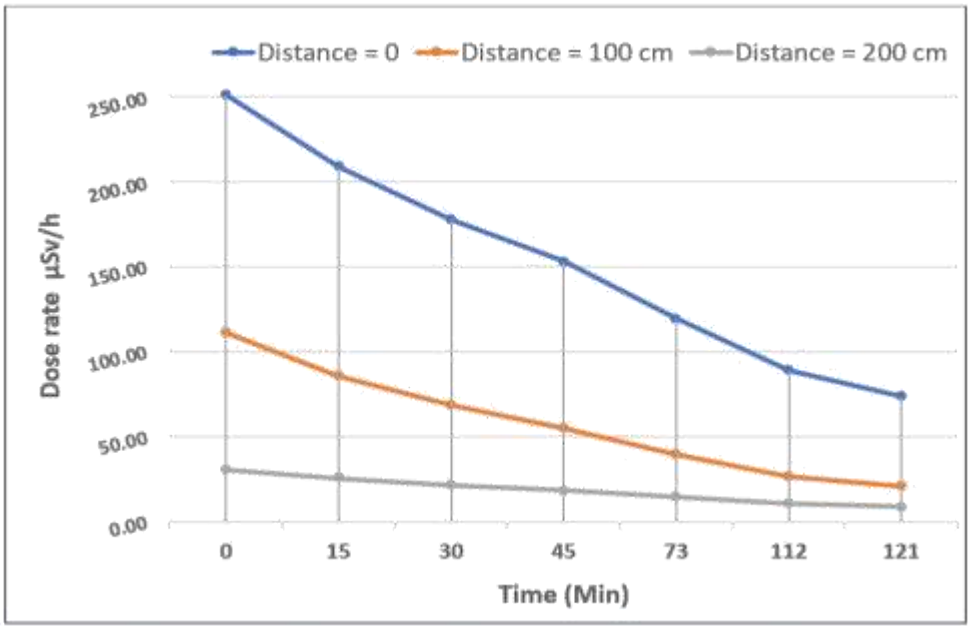

Figure 1: Dose rate measurements from a distance of zero, a hundred, and two-hundreds centimetres versus time

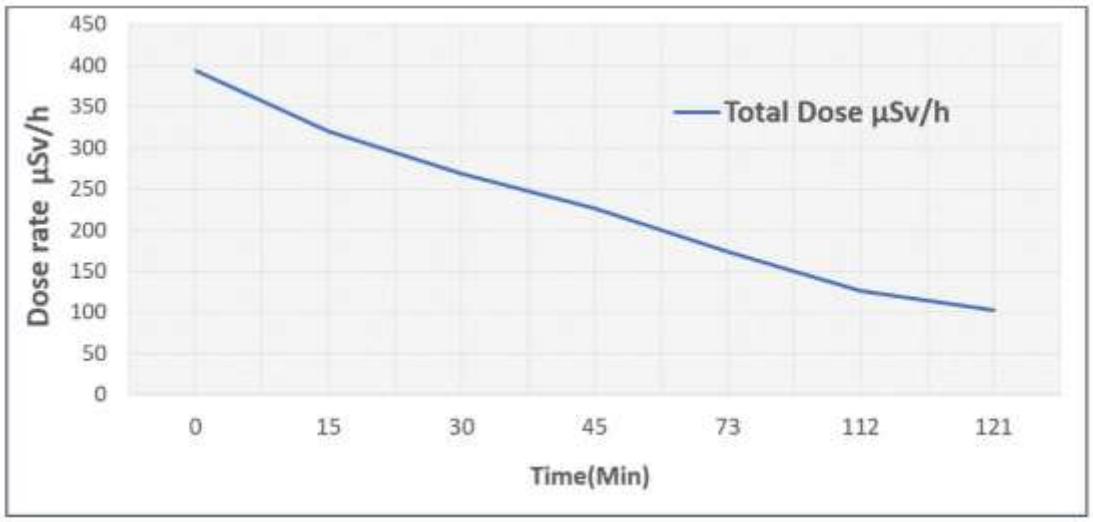

Figure 2: Relation between distance and mean dose rates from the beginning until leaving the positron emission tomography/computed tomography department.

A significant difference between dose rates was seen at a distance of zero, one, and two metres with a P value of ($p<0.05$), as well as at different times of measurement done at the same distances ($p<0.05$). Even though TAEK has no data about fluorine-18-bound pharmaceuticals' external dose rates at the time of discharge, the discharge limit for I-131 was determined as a safety limit dose rate of fewer than thirty µSv per hour in annex-5 of the Radiation Safety Regulation (10). At the end of the positron emission tomography/computed tomography imaging technique, every patient who participated in this study was discharged with a safe dose rate with an external dose rate of 20.63±4.48 µSv/h (range: 9 - 29 µSv/h) at a distance of one meter.

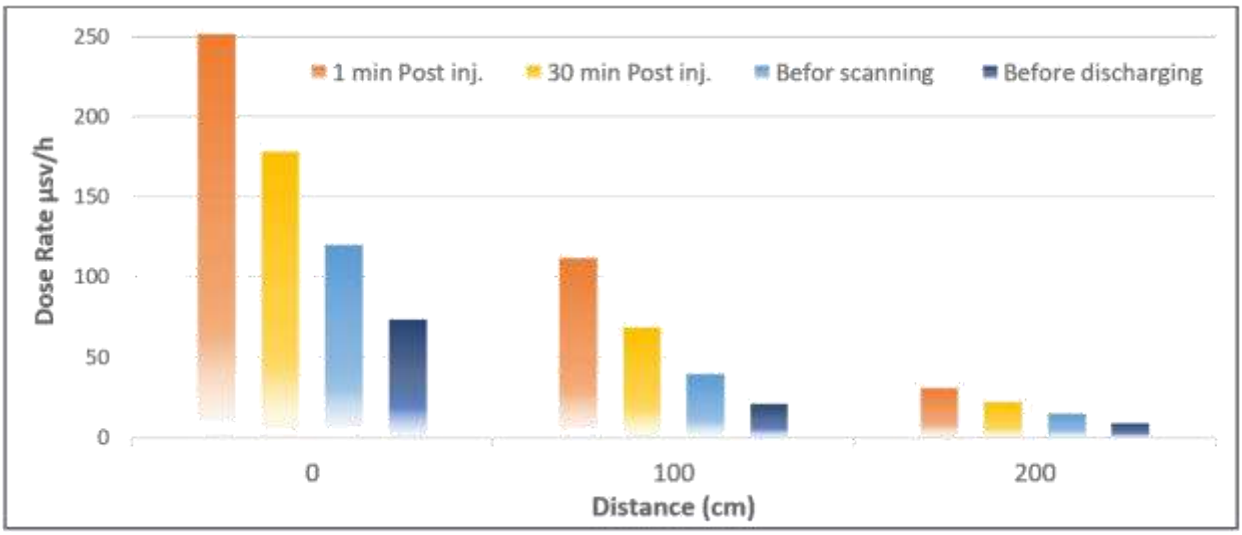

Figure 3: Comparison of dose rates at different distances (0, 1 and 2 metres) with 1, 30 minutes following injection, times, prior to scanning and following scanning.

Discussion

Individuals who are receiving radionuclide treatment in our city based on the regulation of TAEK are isolated in private rooms until the level of radiation dose rate is decreased to less than 30 µSv/h. In the USA, the external dose rate limits at the time of discharge are less than fifty 50 µSv/h and less than twenty µSv/h in countries of the European Union (11). Even though clear values are determined for radionuclide treatments, it is seen that discharge rate limits accomplished in this country and countries of the European Union in the department of nuclear medicine at the time of positron emission tomography/computed tomography imaging about short half-lives of fluorine-18 isotope, quite a low level of radioactivity in comparison to treating and biologically eliminating fluorine-18 isotope used for diagnosing in this research, but with increased photon energy.

It is documented by the International Commission on Radiological Protection that the acceptable yearly internal/external radiation exposure dose for subjects in the community is one mSv (12). Higher exposure dose limits than what we just mentioned are acceptable in individuals that are aware of the exposure and are near patients receiving radioactive substances for either therapeutic or diagnostic reasons, as is published in a manual by TAEK. Subjects that come by for a patient visit or caregivers' effective dose at the time of diagnosis and treatment shall not be more than five mSv. It is also described that dose exposure for children and pregnant ladies, which is patient-induced, shall not be more than one mSv (7).

It is essential in our research to avoid unnecessary radiation exposure to people and the society around the subject receiving radioactive material, which becomes a temporary source of radiation even though the external dose limits of patients at the time of discharge are quite below the criteria determined according to legal regulations (7). This is crucial for the staff working in the service of the patients in the hospital and those working in the nuclear medicine department as well. It is also documented that the personnel will be exposed to 0.1 mSv of radiation every month if the patient transfers are done with the same personnel, as the distance between the patient and the staff who are in charge of transporting the patients to significant services is very little (7). In other research, it is advised that 50 centimetres shall be between the patients and their relatives or the staff accompanying them two hours following the injection of fluorine-18 deoxyglucose (13). Myocardial perfusion scintigraphy or PET imaging studies are the reason for the highest reported radiation dose of nurses working in the ICU (14). Exposure of the personnel who works outside

the department is associated with the time the patient needs to reach the relevant services following their injection. Even though radionuclide materials and their application doses are different from the doses administered to the patients, the exposure of the personnel and the external dose rate are reduced due to the time needed for the patient to be delivered from the department to the services (14) (15). In research performed by Cronin et al. (15), it was demonstrated that it is not required for inpatients who have done fluorine-18 deoxyglucose positron emission tomography and stay in the nuclear department for two hours following injection to be severely restricted. But we should be cautious not to let any close contact between them and children or pregnant ladies for a minimum of six hours following injection (13).

The annual exposure of technicians to radiation in the nuclear medicine department is below twenty mSv (16); about forty percent of this exposure is said to be the result of contact with patients and sixty percent because of contact with radioactive material (16). In that case, as it is mentioned in our study, the radiation dose can be significantly decreased by radiation safety personnel by being cautious about the distance of the injected patient during their stay in the clinic and making the time of contact with the radionuclide agent as short as possible (13, 17). The least activity of fluorine-18 deoxyglucose needed for positron emission tomography/computed tomography is based on the body weight of the individual and the user device (18). The maximum applicable dose is also documented in some countries (5). As we previously mentioned, during daily practice, we inject patients with fluorine-18 deoxyglucose and discharge them based on guidelines of the European Association of Nuclear Medicine and the International Commission on Radiological Protection recommendations (5, 19, 20). Hydration and micturition are very significant for patients both prior to and following injection and imaging, as the organ that receives the maximum dose of radiation during the procedure is the bladder. Therefore we shall encourage patients to drink water during the injection and following the scanning as well to decrease the radiation dose of the bladder and hence reduce the external dose rates (17).

Conclusion

Based on the results of our research, in spite of a half-life of 109.8 minutes, it is defined that greater than 50% of fluorine-18 isotope is excreted in about sixty minutes by micturition, hydration and biological elimination. It is determined that individuals can leave the department safely once all the required radiation safety measures are explained to them following their examination since at a distance of one meter from patients, external dose rates do not cause any risk to the environmental radiation safety following the procedure.

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