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Radiation Exposure Dose of Handlers Using ^{18}F-FDG in Small Animal Image Acquisition Experiments

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Abstract This study was conducted to confirm the safety of the operator's radiation exposure in the micro PET-CT image acquisition experiment using the ^{18}F-FDG. The usage of ^{18}F-FDG and the exposure dose of handlers were measured at University B in Metropolitan City A, which uses ^{18}F-FDG for micro PET-CT image acquisition. As a result of the measurement, the exposure dose is far below the effective dose limit of radiation workers, 50 mSv per year, and the equivalent dose limit of 500 mSv per year for hands, feet, and skin. has been measured Since these exposure doses can be further increased according to the number of times of use of ^{18}F-FDG, it is judged that the exposure dose compared to the handling amount of ^{18}F-FDG shown in this study can be used as reference data. In addition, as changed environments such as the use of materials other than unopened RI are occurring in education and research environments, such as the use of ^{18}F-FDG at University B, radiation exposure with more interest in safety management by checking the factors of radiation exposure of the handler concerned We will always do our best to reduce it.

Key words: ^{18}F-FDG, PET-CT, Radiation exposure dose of handlers

1. INTRODUCTION

In order to acquire images of PET-CT (Positron Emission Tomography-Computer Tomography), which is widely used in the field of radiology diagnosis today, ^{18}F-FDG (Fluoro-Deoxy glucose) is mainly used [1,2]. Positron emission tomography (PET) is one of the nuclear medicine imaging methods. It is a state-of-the-art technique that detects the distribution of tumors by injecting drugs that combine radioisotopes that emit positrons into the body and tracking them through positron emission tomography [3]. PET has been mainly used in the field of cranial nerves in the early stages of development while imaging the distribution of various biochemical substances in the body [4]. Although it has high diagnostic value in the field of functional evaluation of the living body and oncology, the disadvantage is that the resolution of the image is relatively lower than that of diagnostic radiology using X-rays, and the anatomical location and the distinction between the surrounding tissues are not clear, which limits clinical diagnosis [5]. With the addition of a computed tomography (CT) scanner, PET-CT improves the quality of medical care by further enhancing clinical diagnosis with more accurate image information through biochemical changes in PET along with anatomical image information of CT [6]. Since the introduction and installation of PET-CT for the first time in Korea in 2003, there has been a steady increase since then [7]. In accordance with this trend, Micro PET-CT, which is a miniaturized PET-CT equipment, has been introduced and used in research to acquire diagnostic images of animals in education and research fields, and ^{18}F-FDG, a radioactive drug, is also used. The characteristic of using unopened radioisotopes in edu-

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cation and research fields is that they use a variety of nuclides, such as ^{8}H, ^{14}C, ^{32}P, ^{35}S, ^{45}Ca, and ^{125}I, but use a relatively small amount of radioactivity. The use of unopened radioactive isotopes is further decreasing compared to the past due to the improvement of performance of analysis equipment and the development of alternative test methods according to the development of science and technology. On the other hand, ^{18}F-FDG is an essential element for obtaining Micro PET-CT images. Due to its short half-life and the characteristics of the experimental method, ^{18}F-FDG is used for about 10 to 100 times more radioactive handling than other unopened radioactive isotopes at one time. It is necessary to investigate the radiation exposure characteristics of ^{18}F-FDG handlers at the research site. Therefore, in this study, in conducting an image acquisition experiment of small animals using ^{18}F-FDG at University B in Metropolitan City A, the amount of ^{18}F-FDG used during the experiment and the number of experiments were accurately identified to introduce and distribute ^{18}F-FDG During a series of procedures from the time of administration to the test subject administration of ^{18}F-FDG, image acquisition using Micro PET-CT, and the process of discarding the test subject, the exposure dose to the handler was measured at each stage of the experiment using a glass dosimeter. In addition, by measuring the exposure dose of the hand and chest, which directly control the radiation source, of the body of the ^{18}F-FDG handler, the radiation exposure characteristics of the ^{18}F-FDG handler are investigated at educational and research sites to determine the appropriateness of radiation safety management. wanted to check it out.

2. MATERIALS AND METHODS

2.1. Research subjects and materials

In this study, the exposure dose of handlers was measured according to the usage of ^{18}F-FDG at B university in A Metropolitan City, which uses ^{18}F-FDG for micro PET-CT image acquisition.

2.1.1. Micro PET-CT

PET-CT (Positron Emission Tomography-Computer Tomography) is the addition of a computed tomography (CT) scanner, which enhances clinical diagnosis with more accurate image information through biochemical changes in PET along with anatomical image information of CT.

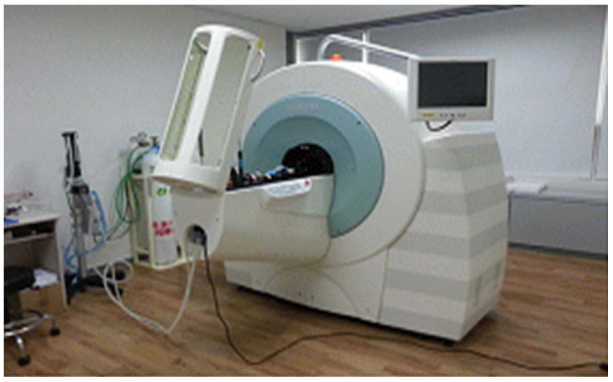

Fig. 1. Micro PET-CT.

Fig. 2. ^{18}F-FDG Transport container .

Micro PET-CT is a device that has been miniaturized and developed to be used for laboratory animals for research and development purposes [8].

2.1.2. ^{18}F-FDG

^{18}F-FDG (Fluoro-Deoxyglucose) is a glucose-like substance labeled with 18F (half-life 110 minutes, 0.511 Mev, β+), a radioactive isotope, and radiopharmaceuticals, which are tracers that reflect physiological, chemical, and functional changes, are used.

2.1.3. Laboratory animals

The animal used for the image acquisition experiment in this study is a rat with a body weight of 350 g to 500 g. A disease (stroke) model was created in this rat through arbitrary manipulation, and 3.7 to 5.55 MBq (0.1 to 0.15 mCi, 1 mCi = 3.7×10^{7} Bq) of ^{18}F-FDG was injected per 100 g of the weight of the rat in the disease model, and Micro PET-Acquire mouse images of the disease model by scanning

with CT [9].

2.1.4. Glass dosimeter

Glass dosimeter is similar in use and characteristics to thermoluminescence dosimeter, but it is used as a useful radiation dosimeter in terms of various characteristics such as uniformity of line quality, fading over time, and re-reading [10].

The glass dosimeter used in this study is GD-450, which has two types of plastic filters with different thicknesses and three types of metal filters such as Al, Cu, and Sn.

2.2. Research method

In the laboratory of B University using ^{18}F-FDG, the exposure dose of handlers was measured using a glass dosimeter for about 2 months from July 13 to September 15, 2022. During the study period, the handling date, number of experiments, and radiation dose of ^{18}F-FDG, which affect the exposure dose of handlers, were recorded each time.

In addition, from the viewpoint of radiation exposure to ^{18}F-FDG handlers, the experimental stage was divided into three stages: ^{18}F-FDG distribution, test subject administration, Micro PET-CT examination, and specimen recovery, and the exposure dose was measured.

2.2.1. Distribution of ^{18}F-FDG

The ^{18}F-FDG dispensing step is a step in which the operator receives the ^{18}F-FDG produced and delivered by the cyclotron, checks the amount of radioactivity, and distributes the ^{18}F-FDG so that it can be used for the experiment. It takes a total of 5 minutes.

2.2.2. Administered to the test subject

The ^{18}F-FDG test subject administration step is a step of directly administering an appropriate amount of ^{18}F-FDG to a rat that has completed the preparation for the experiment, and it takes less than 3 minutes for each experiment.

2.2.3. Micro PET-CT inspection and collection of specimens

Micro PET-CT test and specimen recovery step is to set the micro PET-CT for examination of the rat that has been stabilized for 30 minutes after ^{18}F-FDG is administered,

Fig. 3. Glass dosimeter.

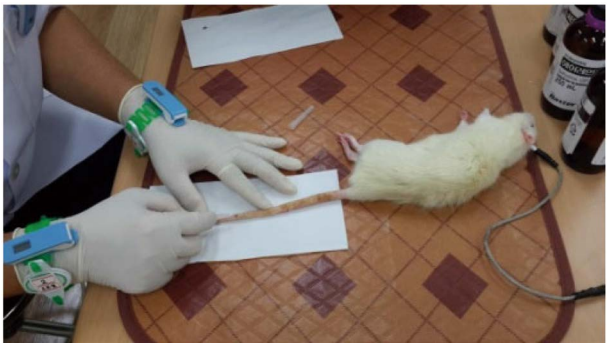

Fig. 5. Administration of ^{18}F-FDG to rat.

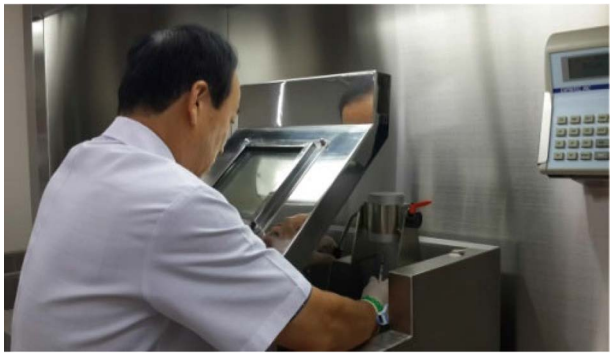

Fig. 4. Distribution of ^{18}F-FDG.

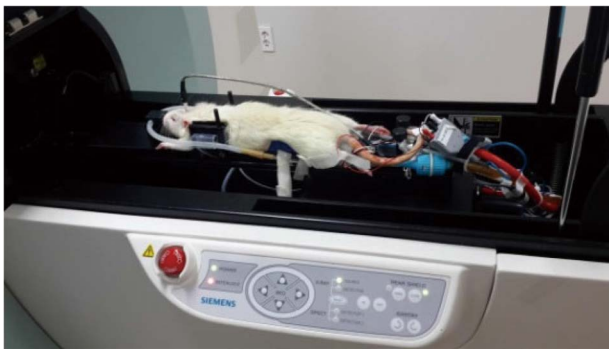

Fig. 6. Micro PET-CT Examination of the rat.

Fig. 7. Glass dosimeter location.

and collect the specimen after the test is completed. Within 5 minutes for each experiment.

2.2.4. Measurement of exposure dose

The glass dosimeter was distinguished by attaching labels for the 1st, 2nd, and 3rd steps and the wearing position for each measurement step, and it was worn by replacing them at every experiment. The nine glass dosimeters whose measurements were completed were read by a specialized reading institution.

3. RESULTS AND DISCUSSION

3.1. Image acquisition experiment details using ^{18}F-FDG

During the experiment period, ^{18}F-FDG was brought in a total of 19 times. The total radioactivity of the imported ^{18}F-FDG was 18,307.6 MBq, and an average of 963.48 MBq was imported once. The total amount of radioactivity administered to the test subject was 896.103 MBq, and an average of 47.163 MBq per day was administered to the test subject. The number of times that the imported ^{18}F-FDG was distributed and administered to the test subjects was a total of 58 times, and an average of 3.05 experiments were conducted per day on the day of the experiment.

The total amount of radioactivity of ^{18}F-FDG brought in during the experiment was 18,307.6 MBq, and the total amount of radioactivity injected into the test subject was 896.103 MBq. 963.48 MBq of ^{18}F-FDG was brought in on average per day, and the amount of radioactivity injected into the specimen was 47.163 MBq on average.

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Table 1. Summary of image acquisition experiments using ^{18}F-FDG

No.	Carry-in radioactivity (MBq)	Administered radioactivity (MBq)	Number of experiments
1	1,169.2	61.198	4
2	1,028.6	61.124	4
3	1,087.8	59.607	4
4	1,398.6	41.884	3
5	839.9	63.418	4
6	1,054.5	44.326	3
7	876.9	49.95	3
8	1,165.5	47.989	3
9	1,050.8	27.713	2
10	836.2	47.767	3
11	995.3	34.003	2
12	910.2	45.991	3
13	847.3	46.176	3
14	936.1	56.573	4
15	858.4	48.322	3
16	595.7	29.637	2
17	1,036	59.644	4
18	780.7	52.429	3
19	839.9	18.352	1
Total	18,307.6	896.103	58
Average	963.48	47.163	3.05

3.2. Result of measurement of exposure dose of ^{18}F-FDG handlers

As a result of the reading of the glass dosimeter worn by the ^{18}F-FDG handler during the experiment, the sum of exposure doses in the first stage of the experiment was 0.8 mSv, 0.71 mSv in the second stage, and 0.55 mSv in the third stage. In addition, the sum of exposure doses for each part of the operator was 0.21 mSv in the chest, 0.8 mSv in the left wrist, and 1.05 mSv in the right wrist. As a result of measuring the exposure dose in each experimental stage, the exposure dose was the highest at 0.8 mSv in the first stage, which is the stage of distributing ^{18}F-FDG. In addition, the second stage of administering ^{18}F-FDG to the test subject

Table 2. ^{18}F-FDG operator exposure dose measurement result

Experiment phase	Position	Measured dose (mSv)	Dosimeter number	Monitor
Level 1	Chest	0.04	5021043	Monitor-1
	Left	0.28	5054513	Monitor-2
	Right	0.48	5054878	Monitor-3
Level 2	Chest	0.07	5051095	Monitor-4
	Left	0.3	5011990	Monitor-5
	Right	0.34	5043640	Monitor-6
Level 3	Chest	0.1	5054181	Monitor-7
	Left	0.22	5014920	Monitor-8
	Right	0.23	5052584	Monitor-9

was 0.71 mSv, and the lowest exposure dose was measured at 0.55 mSv in the third step of Micro PET-CT examination and discarding the test subject. It is evaluated that the exposure dose gradually decreased due to the short half-life (100 minutes) of ^{18}F radioisotope.

In addition, when the exposure doses in each experimental stage were summed up by region, 0.21 mSv was measured in the chest of the ^{18}F-FDG handler, 0.8 mSv in the left wrist, and 1.05 mSv in the right wrist, indicating that the exposure dose was the highest in the right wrist. Due to the nature of radiation exposure, which is inversely proportional to distance, the exposure of the hand directly controlling the ^{18}F-FDG was at least 4 to 5 times higher than that of the chest area. The reason why the exposure dose of the right hand is about 30% higher than that of the left hand in the hand area is evaluated as the effect caused by the right-handedness of the ^{18}F-FDG handler.

4. CONCLUSION

This study was conducted to confirm the safety of the operator's radiation exposure in the micro PET-CT image acquisition experiment using ^{18}F-FDG. In order to compare the result of measuring the exposure dose of ^{18}F-FDG handlers at B University with the dose limit for radiation workers, the experiment period of 2 months (^{18}F-FDG brought in 19 times in total) was applied as a standard, and when converted into annual dose, exposure to the chest area of the handler. The dose is 0.21 mSv/2 months × 6 = 1.26 mSv y^{-1}, left wrist 0.8 mSv/2 months × 6 = 4.8 mSv y^{-1}, right wrist 1.05 mSv/2 months × 6 = 6.3 mSv y^{-1}. This dose falls far short of the effective dose limit of 50 mSv per year for radiation workers and the equivalent dose limit of 500 mSv per year for hands, feet and skin. However, the exposure dose significantly increased compared to the exposure dose of the existing unopened RI users except for ^{18}F-FDG was measured.

In addition, since the exposure dose can further increase according to the number of times of use of ^{18}F-FDG, it is judged that the exposure dose compared to the handling amount of ^{18}F-FDG shown in this study can be used as reference data. Therefore, as changed environments such as the use of substances other than the existing unopened RI are occurring in education and research environments, such as the use of ^{18}F-FDG at University B, radiation exposure is reduced with more interest in safety management by checking the factors of radiation exposure of the handler concerned It is assumed that it should be possible to do so.

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REFERENCES

1. Kwak BJ, Ji TJ and Min BI. 2009. The Safety Assessment of Surrounding Dose on Nuclear Medicine Test by Use The ^{18}F-FDG. *J. Korean Soc. Saf.* **24**(6):157-162.
2. Jung JW and Han EO. 2011. Prediction model for radiation damage defense environment of PET-CT. *J. Radiat. Prot. Res.* **17**(7):360-361.
3. Cho YG, Kim SC and Ahn SM. 2013. Measuring external Radiation dose Ratio by Traits of Patients during Positron Emission Tomography (PET). *J. Korea Contents Assoc.* **13**(12):860-868. https://doi.org/10.5392/JKCA.2013.13.12.860
4. Townsend DW. 2008. Multimodality imaging of structure and function. *J. Phy. Med. Biol.* **53**(4):1-39. https://doi.org/10.1088/0031-9155/53/4/R01
5. Lang TF, Hasegawa BH, Liew SC, Brown JK, Blankespoor SC, Reilly SM, Gingold EL and Cann CE. 1992. Description of a prototype emission-transmission computed tomography imaging system. *J. Nucl. Med.* **33**(10):1881-1888.
6. Jang DG. 2012. A Study on the Characteristic of ^{18}F-FDG Excretion According to Use Diuretics in ^{18}F-FDG of PET/CT. The

Graduate School of Hanseo University.

7. Park HH, Lee JB, Jong PK, Lee JD, Won JW and Roh JH. Radiotechnologists and Radiation Exposure from PET and PET/CT Systems . *J. Korean Occup. Environ. Med.* **24**(1):86-95. https://doi.org/10.0000/kjoem.2012.24.1.86
8. Cho KS and Ahn SM. 2015. A study of Brain Micro-PET Imaging and Bindingpotential with a Different Specific Activity of ^{18}F-Fallypride in the Small Animal. *J. Korea Contents Assoc.* **15**(9):418-424. https://doi.org/10.5392/JKCA.2015.15.09.418
9. Kim HS, Kim DH, Kim RG, Kim JM, Chung EH, Pedro RN, Lee MC and Kim HI. 2014. A rat model of photothrombotic capsular infarct with a marked motor deficit: a behavioral, histologic, and micro PET study. *J. Cerebral Blood Flow & Metabolism*. **34**(4):683-689. https://doi.org/10.1038/jcbfm.2014.2
10. Kang IS and Ahn SM. 2014. Evaluation of Usability and Radiation Dose Measurement Using Personal Radiation Exposure Dosimeter. *J. Korea Contents Assoc.* **14**(11):864-870. https://doi.org/10.5392/JKCA.2014.14.11.864