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Analysis of Relationship Between Injection Dose and Exposure Dose in PET/CT Scan: Initial Study

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— 영문초록 —

The ^{18}F-FDG is one of the widely used isotopes for PET/CT scans. Dose amount injected to the patient depends on the characteristics of PET/CT systems. Obviously, the technologists who contact with patients would be exposed as well. In this study, we evaluated the exposed dose of the technologist who works on the PET/CT scanner.

The exposed dose were measured every month with the TLDs from 6 technologists. Each technologist is shift-worker who manages 3 different PET/CT systems(Scanner 1(S1): 0.15 mCi/kg, Scanner 2(S2): 0.17 mCi/kg, Scanner 3(S3): 0.12 mCi/kg).

The average exposed doses of technologists for each PET/CT system were measured as 0.76 mSv for S1, 0.93 mSv for S2 and 0.47 mSv for S3. The maximum dose was 1.12 mSv and minimum was 0.42 mSv. The results showed that there was a correlation between exposed dose and PET/CT system($p < 0.005$).

Less injected dose for patient occurs less exposed dose for technologist. Various studies for the low dose PET/CT system are required for not only the patient but also the technologist.

Key Words: PET/CT, Exposure Dose, Injection Dose

Ⅰ. Introduce

Due to PET could measure the biological index quantitatively through imaging many biochemical's in vivo distribution in human body, it is using for determination or diagnosis of biochemical or pathological phenomenon, prognosis after therapy, and therapy plan. The importance of PET is increased recently. A period at the beginning of PET scan, it mainly used for brain examination[1,2]. However, it uses for diagnostic tool and evaluation of cancer. Although, PET is an appropriate diagnostic tool for evaluation of biological function and highly applicative system.The image resolution is poor and hard to Figure out the organs' anatomical location.[3] These limitation could overcome through using with CT as PET/CT. PET/CT was developed in the late 1990s and has been successful in the early 2000s. Each imaging devices set in parallel and CT scan performed first and PET scan started. Therefore, the patients don't have to move and could have both imaging examination in the same location. The transmission imaging (transmission scan) to solve the

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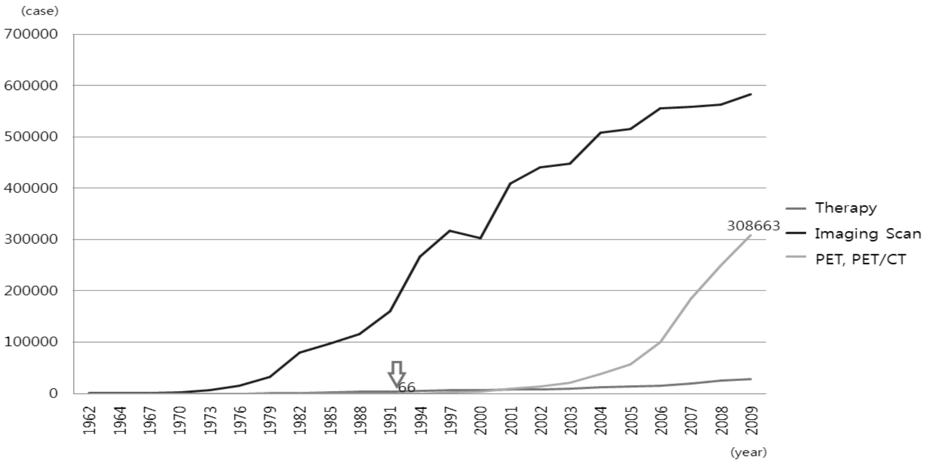

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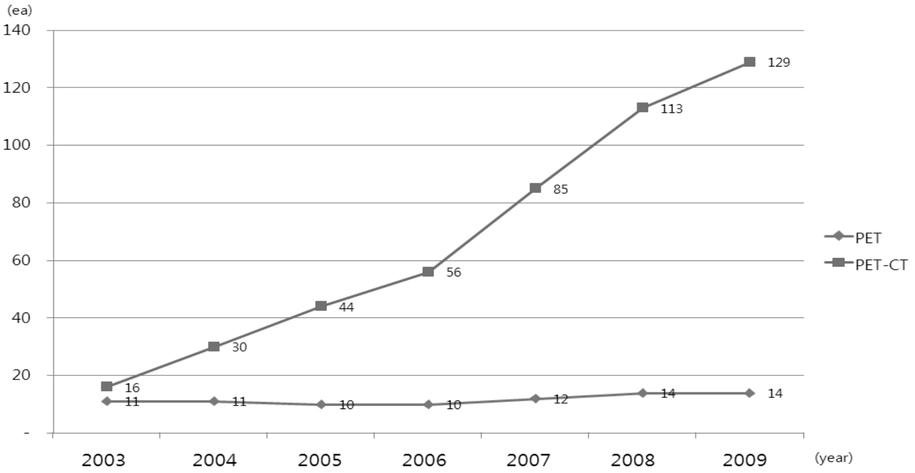

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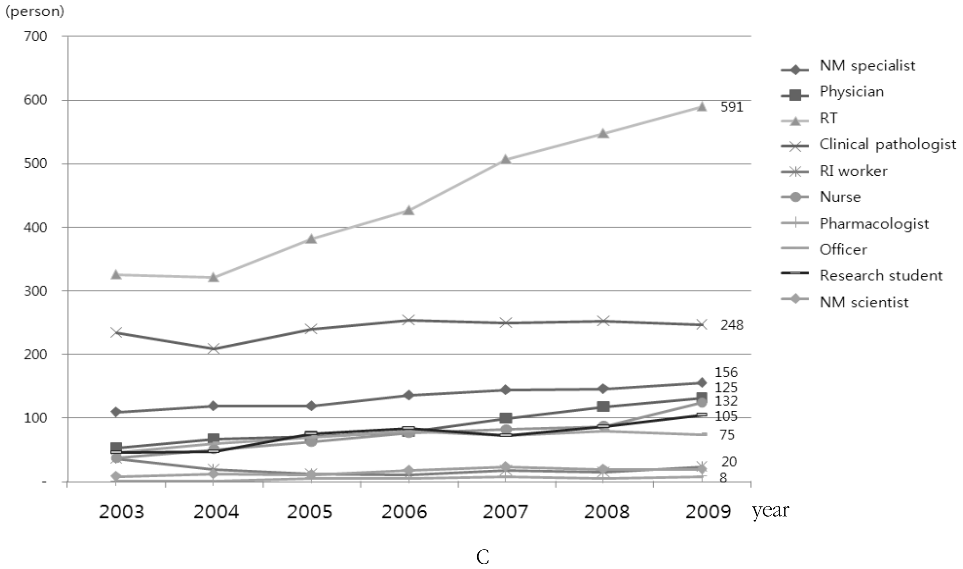

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Figure 1. Number of Annual Nuclear Medicine Examination Cases is on the graph A, PET and PET/CT have steadily grown from the late 1980. Annual Status of PET and PET/CT System is on the graph B, PET/CT have rapidly grown from the early 2000. Annual Status of Nuclear Medicine Worker is on graph C. As the status of PET-CT shows, the number of workers was heavily grown

problems of the background noise caused by Compton scattering and the different attenuation of gamma rays in PET because of various location of organs was replaced to the CT. The acquisition time was able to significantly reduce. Because of these advantages, PET/CT is quickly replaced PET. PET, PET/CT scan is imaging tool using ^{18}F, ^{11}C, ^{13}N, ^{15}O which have the less number of neutrons than the number of protons in the nucleus are an unstable radioactive isotopes. Radioisotope could explain as follows; when a proton converted to a neutron in nuclei, it emits positron to become in a stable state. The emitted positrons flow in a certain distance, and meet the electrons surrounding nuclei and destroyed. At this time, two gamma rays with the energy of 511 keV are emitted.[4) Radio−technologists had exposed from patients who had a injections of radiopharmaceutical. Major affecting factors are injected radiopharmaceuticals volume and the energy, a bio−distribution of radiopharmaceuticals, the image acquisition time, the distance between patients and radio−technologists, and the high exposure of hands during the preparation of radiopharma-ceuticals.[5,6) However, the exposure dose from patients was the highest. Previously, and radiation exposure of technologists in nuclear medicine have been studied(Figure 1).

As PET/CT sections are subdivided, there was a lack of the study, which kind of related factors of job evaluation and job function could affect radiation exposure.[7,8,9) An effort to reduce exposure dose for radio−technologists, and the matter of the heightened environmental awareness and safety are emerging.[10,11,12) Depending on the physical characteristics of PET/CT systems, the injected dose for patients were changed. In this study, the affection to radio−technologists from the injected dose of the patient in the different PET/CT systems were analyzed.

Figure 2. Scanner 1[Discovery STe(General Electric Healthcare, Wisconsin, MI, USA)], Scanner 2[Biograph True point 40(Siemens Medical Systems, CTI, Knoxville, TN, USA)], Scanner 3[Discovery STe(General Electric Healthcare, Wisconsin, MI, USA)]

Ⅱ. Methods

1. PET/CT systems

Three different PET/CT systems were enrolled; Scanner 1[Discovery STe (General Electric Healthcare, Wisconsin, MI, USA)], Scanner 2[BiographTruepoint 40(Siemens Medical Systems, CTI, Knoxville, TN, USA)], Scanner 3[Discovery STe(General Electric Healthcare, Wisconsin, MI, USA)]. The administrated radiopharmaceuticals were same(Figure 2).

2. Injected dose

Based on the recommendation dose from each PET/CT systems, the dose {Scanner1(S1): 0.15 mCi/kg, Scanner2(S2): 0.17 mCi/kg, Scanner3(S3): 0.12 mCi/kg} were injected to the patients.

3. Patients scanning

Patients were fasting at least 6 hours before the test. Takes approximately 10−15 minutes to relax before ^{18}F−FDG injection and drink 500~1000 mL water and was injected intravenously. Motion was prohibited for preventing the uptake of muscle and then take a rest for about 1 hour with lying before examination. Prior to examination, the patient urinated. And take a scout image in the supine position, After whole-body CT scan from skull base to the proximal femur, Average of 7 Bed PET emission testing were conducted during 1 Bed per 2 minutes 30 seconds.

4. Specificity of Radiation Workers

Six Radiation-Workers who had different experiences of radiation exposure were subjected, the radiation exposure dose were measured from August 2008 to December 2008(Figure 3).

5. Rotation Duty Schedule

Six technologists(2 in 1 system) have worked for 6 months through unit rotations with 3 PET/CT systems. In rotation, Senior (A,B,C) and Junior (D,E,F) worked on the same month(Table 1).

6. Data Analysis

A personal dosimetry of radio-technologists, TLD was measured monthly and the results were analyzed with on-parametric test (Kruskal-Wallis test) and multiple regression analysis(SPSS ver.17).

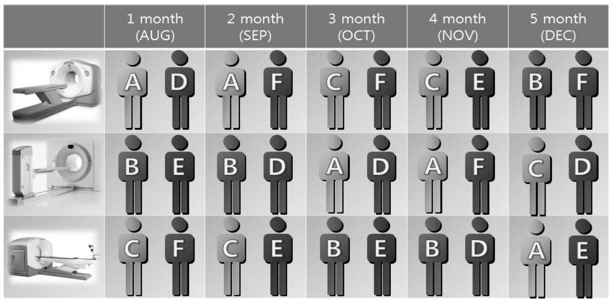

Figure 3. Radiation workers were under the Unit rotation for 5months, they divided into the group of 'senior' and 'junior'

Table 1. The number of Radiation workers

Works	Sex	Duration of Radiation Exposure	Classification
A	Male	12 years 4 month	senior
B	Male	7 years 2 month	senior
C	Male	7 years 1 month	senior
D	Male	3 years 6 month	junior
E	Male	1 years 9 month	junior
F	Male	1 years 1 month	junior

Ⅲ. Results

The individual exposure results were measured from monthly TLD data, there was a statistical significance(p: 0.003). The data were analyzed using the non-parametric test (Kruskal-Wallis test) (Figure 4). On box plot, compare to the senior group (A, B, and C), the radiation exposure dose of the junior group was higher and had various deviations. Through this, we were confirmed a tendency that if the worker had the long experience, the radiation exposure dose was lower(Figure 5).

The number of examination cases were different on their schedule of PET/CT systems(250~450).

The deviation of examination cases showed a largest difference in Scanner 3(Figure 6, 7). The injected dose was calculated with examination case

	Median (mSv)	IQR (mSv)	x^2	Asym. p-value
A	0.630	0.237	17.910	0.003
B	0.475	0.182		
C	0.485	0.140		
D	0.760	0.360		
E	0.895	0.482		
F	1.105	0.940		

Figure 4. Individual radiation exposure

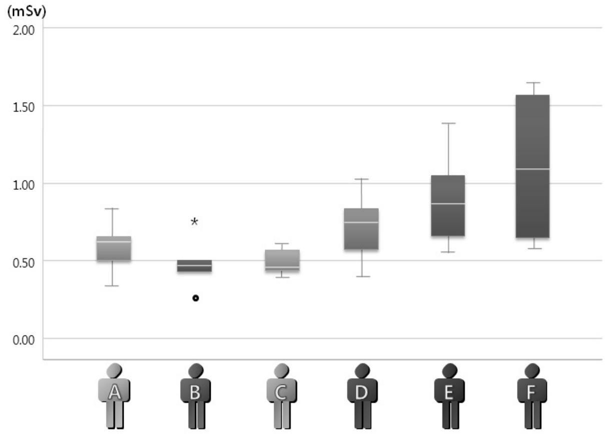

Figure 5. Box Plot: Compare to the group

and patients weight to have the whole amount of the used radiation dose. In Scanner 3, the examination cases were more than Scanner 1 and 2, it used the lower amounts of radiopharmaceuticals(Figure 8).

Through a descriptive statistics, the average of monthly individual radiation exposure dose in each Scanner was obtained. The workers of Scanner 3 showed the lowest exposure rate, and Scanner 1 showed the highest exposure rate. However, these data just showed exposure rate so that the many factors which could affect to exposure rate has not concerned. Therefore, Body Weight, Total Number of Examinations, and whole amount of injected dose were concerned and did a multiple regression

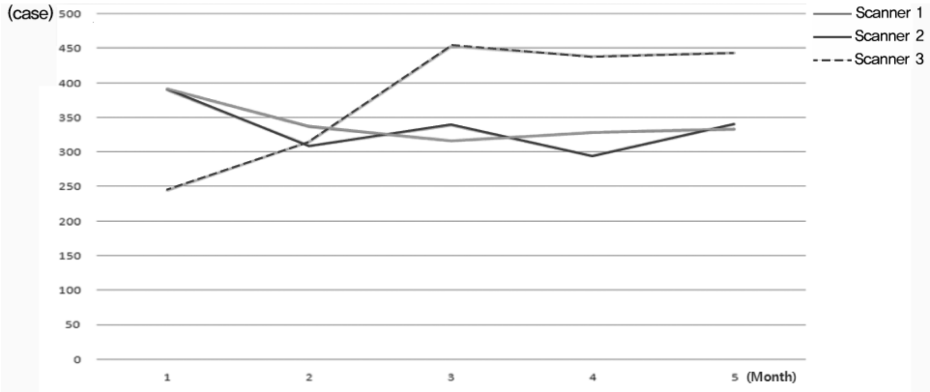

Figure 6. Monthly exam case by PET/CT systems

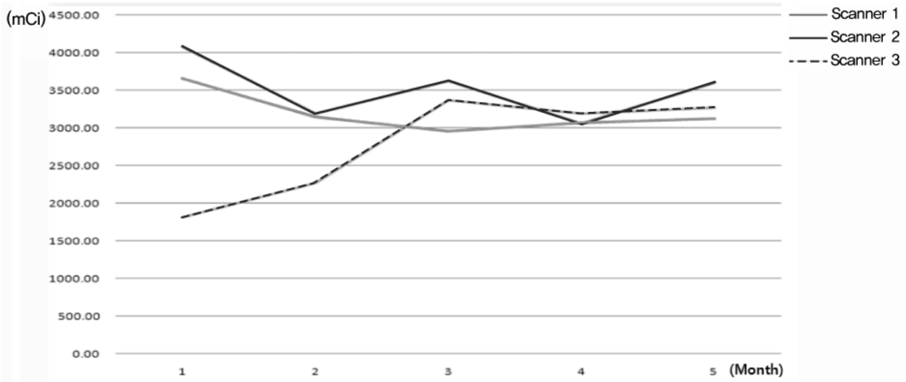

Figure 7. Monthly injection dose by PET/CT systems

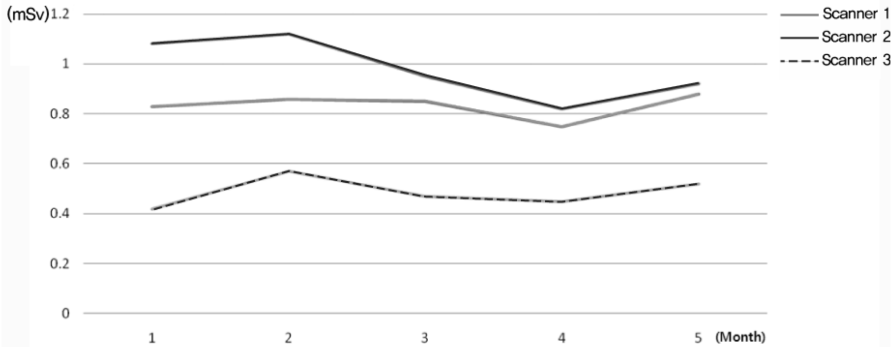

Figure 8. Monthly radiation exposure by PET/CT

Factor		B	Standard aberration	t	Significance Probability
	Standard Scanner 3 (0.12mCi/Kg)				
	Scanner 1 (0.15mCi/Kg)	0.260	0.135	1.924	0.083
	Scanner 2 (0.17mCi/Kg)	0.399	0.109	3.678	0.004
	R^2_{adj} = 0.622				

- Control Factor : Patient weight, Total exam case, Total injection dose
- B factor unit : mSv

Figure 9. Body weight, total number of examinations and whole amount of injected dose were concerned and did a multiple regression analysis

analysis. Individual exposure dose in Scanner 1 increased 0.260 mSv compare to Scanner 3 and 0.399 mSv was decreased in Scanner 2. The factor in these calculation described 62.2% of the individual radiation exposure dose(Figure 9).

Ⅲ. Conclusion

As the limitation of this study, only several workers were on the rotation, and radiation-workers experience was not various so that it had limitations to include several meaningful factors. We focused on the analysis a tendency of working experience. Under the same working condition, radiation-workers who had comparatively long experience showed low radiation exposure rate. The exposure dose was decreased by the individual proficiency of radiation-workers, and the low amount of the injection dose can highly reduce the exposure dose for radiation-workers. Therefore, when the Nuclear Medicine examination performed, it is necessary to use certain amount of radiopharmaceuticals and to be recommended proper and quick use by radiation-workers.

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• Abstract

PET/CT에서 방사성 의약품 주입량이 방사선 피폭에 미치는 영향분석: 초기연구

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박훈희 · 유광열

PET/CT 검사에서 ^{18}F-FDG가 가장 널리 이용되며, 장비의 물리적 특성에 따라 환자 주입 ^{18}F-FDF량이 다르게 권고되고 있다. 또한 검사 특성상 방사선종사자와 환자의 접촉으로 인하여 방사선의 피폭이 불가피하기에 본 연구에서는 각기 다른 PET/CT 장비를 대상으로 환자에게 주입되는 ^{18}F-FDG가 방사선종사자에게 미치는 피폭선량과의 관계를 분석하였다. 총 3대의 각각 다른 PET/CT(Scanner1(S1): 0.15 mCi/kg, Scanner2(S2): 0.17 mCi/kg, Scanner3(S3): 0.12 mCi/kg)를 대상으로 각 장비에 숙련도를 고려하여 총 6명의 방사선종사자를 5개월간 순환근무하였고, 하루에 검사하는 환자수를 일정하게 유지하였다. 또한 검사진행 방법을 유사하게 유지하고, 방사선종사자의 개인피폭선량계인 열형광유리선량계(TLD)를 매월 판독하여 분석하였다. 개인의 월별 평균 피폭선량은 방비에 따라 S1은 0.76 mSv, S2는 0.93 mSv, S3는 0.47 mSv였다. 피폭선량은 개인 최대 1.12 mSv, 최저 0.42 mSv로 숙련도와 경험에 따라 유의한 차이를 보였고, 또한 각 주입량에 따른 PET/CT의 종류에 따라 피폭선량은 유의한 상관관계를 나타냈다. 본 연구를 통하여 주입 ^{18}F-FDG가 적을수록 방사선종사자의 피폭선량이 낮았다. 또한 개인 숙련도에 따라 피폭선량이 감소하였으나, 장비의 특성에 따라 적은 방사선의약품 주입량의 영향이 방사선종사자의 피폭선량을 현저하게 감소할 수 있기에 이에 대한 연구가 보다 활성화 되어야 할 것이다.

Key Words : 양전자방출 컴퓨터 단층촬영(PET/CT), 피폭선량, 주입방사선량