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Review Article

Hospital Radiation Safety and Radioactive Waste Management (Radiation Protection in Nuclear Medicine - What's our role ? -)

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I. INTRODUCUCTION

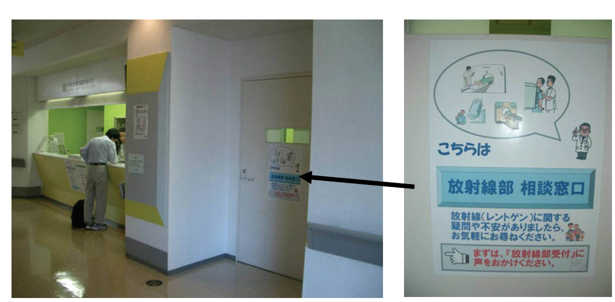
We use radioisotopes (RI) in nuclear medicine, and it is very important to ensure that patients, medical workers and the public are safe from radiation. In this lecture, I outline the specific radiation protection tasks performed in Japan. Although many of the problems faced are common worldwide,[1,2] there are differences in radiation protection between Asia and western countries. This paper discusses the roles of radiological technologists and medical technologists in radiation protection in nuclear medicine.

II. RADIATION PROTECTION OF PATIENTS

First, I'll describe the radiation protection of patients. A paper of Berrington and others[3] published by The Lancet had a global influence. Then, the media reported on the radiation protection of patients in Japan, and people became concerned about medical exposure. Medical exposure in Japan is considered to be very large, with one Japanese paper reporting exposure of radiation diagnosis of 3.2%.

Medical exposure is a global concern. ICRP raised interest over medical exposure, and published many reports since 2000. As discussed in Chapter 7, new recommendations[4] were adopted by the main committee of ICRP on March 24, 2007. Furthermore, IAEA presented a guidance level for medical exposure in BSS No. 115.

Medical exposure is a problem in the rest of Asia. Mr. Lee of the Korea Food and Drug Administration (KFDA) visited Yokohama Rosai Hospital (YRH) on December 14 last year. In Korea, medical workers cannot reply to patients' questions about medical exposure with certainty, so Mr. Lee wished to refer to the situation of medical radiation administration in Japan. The KFDA created a "Guideline for Patients" in December, 2007. This guideline refers to the situation in Japan and western countries. It refers to estimations of the exposure dose of patients by all medical diagnostic examinations in YRH. The hospital estimates the dose using an index dose and a standard organs dose. Figure 1 shows the consultation window for the Radiation Section, which is next to the reception of the Radiation Section in YRH (Fig. 1). A patient can consult about various radiographic examinations here. Moreover, patients are given the "Roentgen-rays Notebook," created by The Japanese Association of Radiological Technologists (JART).



A : Reception area in the Radiation Section   B : Consultation Reception

Fig. 1. Consultation window for Radiation Section in Yokohama Rosai Hospital in JAPAN.

*The author thanks President Chang-Ho Kim and members of KSNMT for the opportunity to give this talk.

Table 1. Investigation data and Guideline 2006 in PET in Japan

Examination	RI	2D (Dimension) Acquisition						3D (Dimension) Acquisition					
		Facility [number]	Ave [MBq]	Max [MBq]	Min [MBq]	75% tile [MBq]	Guidline [MBq]	Facility [number]	Ave [MBq]	Max [MBq]	Min [MBq]	75% tile [MBq]	Guideline [MBq]
Tumor	^{18}F-FDG	20	258	394	185	316	320	29	217	380	125	240	240
Tumor	^{11}C-Methionine	4	599	740	442	696	700	4	283	320	206	306	310
Tumor	^{11}C-Choline	1	482	482	482			0					
Myocardial blood flow	^{13}N-Ammonia	6	653	1,110	374	740		1	320	320	320		
Myocardial metabolism	^{18}F-FDG	8	291	370	125	370	370	4	231	370	160	210	210
Myocardial metabolism	^{11}C-Acetic acid	3	580	740	300			0					
Brain metabolism	^{18}F-FDG	11	227	370	84	300	300	15	214	379	100	296	300

The percentage response of the questionnaire was 61.5% (48/78, facilities). June (2005)

Our activities were accepted by JART, and YRH became the first medical exposure reduction facilities authorization system to be recognized by JART in 2005.

A dose index such as a guidance level or a guideline is useful for optimizing the dose. JART created a guideline unique to Japan in 2000, and JART revised the guideline in 2006. I took charge of Nuclear Medicine in the guideline in 2006.[5]

The dose index is shown by medication radioactivity to patients in Nuclear Medicine. Table 1 shows the PET guideline. I investigated patients' medication radioactivity in PET facilities all over the country in order to create a guideline in 2005. The percentage response to the questionnaire was 61.5% (48/78, facilities). In PET, 2D collection differs in medication radioactivity from 3D collection. I made 75% tile of replies to the guideline. However, comments on the number of replies was removed. Optimization of medical exposure is an international subject. A guideline that grasps and optimizes the dosage by CT of PET/CT or SPECT/CT should be created based on the actual situation in each country.

III. RADIATION PROTECTION FOR MEDICAL WORKERS

Figure 2 shows the average occupation dose of medical workers in 2003 in Japan. The effective dose of medical workers, radiological technologists and nurses is 0.26 mSv, 0.68 mSv and 0.12 mSv respectively. There

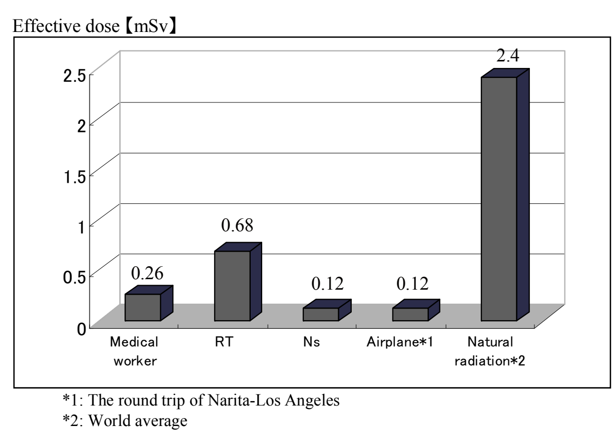


Fig. 2. Comparison of exposure dose.

Table 2. Anxiety regarding exposure to medical workers

Group	Very anxious	Anxious	hardly anxious	Not anxious at all	Unentered or Invalid
Doctor (Clinician)	11.4	31.4	44.3	12.9	0.0
Radiologist	4.8	38.1	28.6	28.6	0.0
Nurse	18.6	35.6	36.4	8.5	0.8
Radiological technologist	2.7	21.8	53.6	19.1	2.7

(%)

Table 3. Data on the PET study facilities

Items	Surveyed datas average(min-max)	Standard model
The injected doses[MBq]	231(185-300)	230
The number of patients(Cases)	140(35-217)*1	152(7)*1
The waiting time [min.]	52(30-60)	60
The distance of each patient during waiting [cm]	57(30-150)	90(60)*2
The distance in between patient and medical staff during waiting [m]	5(2.5-7)	5
PET scan time [min]	33.1(21-60)	30
Time after FDG injection to the end of the PET study [min]	92.6(71-126)	90
Residual activity in the end of the PET study [MBq]	132(108-170)	104*3
Time after the PET study to the release of patient [min]	52(23-120)*4	–
Time after FDG injection to the release of patient [min]	158(120-210)*4	–
Residual activity at the time of release [MBq]	88(51-117)*4	–

＊1: Persons per PET camera in a month. The figure in parenthesis in the standard model indicate persons per PET camera in a day.

＊2: Distance between the centers. The figure in parenthesis is the distance between body surfaces.

＊3: The standard model considers the biological half-time.

＊4: The data excludes one hospital performing another examination.

is no major change each year. The average dose of radioactivity of Ns or Dr is low. However, half of doctors and nurses were found to be anxious about the effects of exposure (Table 2).[6] About 45% of clinicians were very anxious or slightly anxious, and about 54% of nurses were found to be very anxious or slightly anxious in our investigation data.

These results suggest that medical workers need education and counseling. I am also responsible for the radiation management of the whole hospital, and teach medical workers about many doses of radioactivity. Lectures on the theme of medical safety of the Radiation Section and radiation protection are held 5 days per year in YRH. I confirm whether medical workers are over the dose limit using individual data. In particular, I am counseling pregnant female medical workers.

IV. RADIATION PROTECTION OF PUBLIC

Medical checkups rapidly began adopting FDG-PET examinations in Japan, and we began evaluating the exposure dose of the hospital staff and the public.[7] We defined the standard model for evaluation based on data from 2004. I evaluated the data of clerical staff, other examination staff and restaurant staff (Table 3~5). We decided the number of patients, clerical staff, distance and estimated time, etc. Consequently, in facilities having three PET cameras, the dose of clerical staff in charge of accounts was 1890 μSv. That is, the general public's dose limit may be exceeded. Similarly, we evaluated the dose of other examination staff, such as by echo, and restaurant staff in a hospital. That is, the general public's dose limit may be exceeded. Similarly, we evaluated the dose of drivers and bus passengers, train passengers, taxi drivers, family, partner and infants at home and care staff, etc. These results suggest that we have to instruct FDG medicated patients on protecting hospital staff and the public. Moreover, these results suggest that dose assessment of the public, etc. is very important.

Table 4. Effective doses for clerical staff, staff at restaurants and medical staff after PET patient release from controlled area

Scenario	Subjects	Number of patients*4	Estimatied time (minutes)	Distance (m)	Effective dose (μSv/y)	
					one PET camera	three PET cameras
① accounting	patientA*1	1(3)	30	0.35(1)*5	54.3	67.7
	patientB*2	3(9)	20	1	27.6	82.8
	clerical staff	7(21)／d	20	1(5)*6	630	1,890
② another examination	medical staff	7／d	10	1	3,640	5,720
③ meal	patientC*3	1	45	0.4(0.1)*7	59.6	78.6
	staff at the restaurant	7(21)／d	60	1 , 3	1,729	4,423

Exposure doses(effective doses) and parameters for the subjects following the scenario after the PET study (90 min after the administration of FDG). Only US examination assumed to take thirty minutes before starting.

*1: Person sits next to PET patient for accounting.

*2: Patient visits hospital six times per year.

*3: Person sits next to the PET patient for meals at the hospital's restaurant.

*4: The number in parenthesis shows the situation for three PET cameras

*5: Distance between (person sits next to the PET patient) PET patient. The number in parenthesis means the distance between the non-PET patient and another PET patient.

*6: Distance of clerical staff to PETpatient face to face. The number in parenthesis means the distance between the center of non-PET patient body and that of PET patient.

*7: Distance between the centers. The number in parenthesis is the distance between body surfaces.

V. MANAGEMENT OF RADIOACTIVE WASTE

In the management of radioactive waste, Decay in Storage (DIS) is employed in Korea, but not in Japan.

Management of radioactive waste and progress of the disposal method are advanced in Japan, so, a special research group has been composed and this problem is being tackled by the Japanese Society of Radiological

Table 5. Effective doses for the public exposed to PET patients after release from controlled area

Scenario	Subjects	The number of PET patients[*9]	Estimated time	Distance[*10] (m)	Effective dose (μSv/y)	
					one PET camera	three PET cameras
④ Bus	Passenger A[*1]	1	60min	0.3(0)	135	–
	Passenger B[*2]	0.028(0.083)	30min	1	48.8	144
	Driver	0.016(0.048)	30min	1	81.7	245
⑤ Train	Passenger A[*1]	1	60min	0.3(0)	135	–
	Passenger B[*2]	0.014(0.083)	30min	1	20.7	62.2
⑥ Shinkansen	Passenger C[*3]	1	180min	0.35(0.05)	177	–
⑦ Taxi	Driver	0.038(0.11)	8min	1	17.1	51.3
⑧ Private car	Patient's family	1	60min	1	12.0	–
⑨ At home	Family[*4]	1	12h	1	38.2	–
	Partner[*5]	1	13h	1 , 0.3	94.2	–
	Infant[*6]	1	13h	0.55 , 0.1	2360	–
After return to patient's room	Patient other than PET study patient[*7]	1	24h	2	16.3	–
Care	Caretaker[*8]	1	24h	1	65.5	–

Exposure doses(effective doses) and parameters for estimated object person follow scenario after PET study. The US examination was assumed to take 30 minutes before starting.
*1: Passenger sits next to PET patient
*2: Passenger using the same bus with PET patients when commuting.
*3: Passenger sits next to PET patient
*4: Included pregnant women
*5: PET patient stays with the partner for 5 hours at 1 meter and cuddles up to the partner for 8 hours.
*6: PET patient stays with infant for 5 hours at 1 meter and cuddles up to the infant for 8 hours.
*7: Patient other than the PETpatient stays with the PET sutudy patient for 24 hours after the PET study.
*8: PETpatient is cared during 24 hours after the PET study.
*9: The value in parenthesis is the value when there are three cameras.
*10: Distance between the centers. Parenthetic number is the distance between body surfaces.

Technology.

Particular areas of interest include activation using a generator and DIS. We measured activation in cooperation with a special researcher. Moreover, we are helping to introduce a law and creating a guideline in cooperation with a government agency that has jurisdiction over radioactive waste. Toward this end, we conducted a national investigation to grasp the actual condition of medical use of an accelerator.

VI. DIFFERENCES BETWEEN ASIA AND WESTERN COUNTRIES IN RADIATION PROTECTION

Medical radiation protection is important worldwide. I inspected a British hospital in 2004, and studied how medical radiation protection is organized in Britain. Special staff responsible for radiation protection are stationed in British hospitals (Fig. 3). The Radiation Protection Adviser (RPA) is the chief executive of radiation protection of the whole hospital. A Radiation Protection Supervisor (RPS) is responsible for each section, such as the Diagnostic Section, CT Section, and NM Section. The RPS is responsible for measuring occupational exposure, educational training, etc. of medical workers. The radiation protection staff are responsible for evaluating medical exposure. These radiological protection staff evaluate the patient's exposure dose in case a new examination method is introduced, and advise on the examination method from this viewpoint. On the other hand, in the U.S., medical physicists are responsible for radiological protection in hospitals.

VIII. CONCLUSION

Radiation protection is very important in Nuclear

Medicine. However, as for Asia, unlike in western countries, the staff of a radiation protection specialty are not stationed in the Radiation Section. Radiation technologists and medical technologists should take charge of radiation protection in Asia. The countries of Asia should cooperate in establishing medical radiation protection.

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