

Radiation Doses to Pediatric Patients Originated from Adult Patients in Nuclear Medicine Waiting Room

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Abstract

Radiation protection is one of the most problematic issues in the nuclear medicine department. In perhaps the most neglected issue is the pediatric patients who wait in nuclear medicine department. In present study, we measured the radiation doses to pediatric patients originated from adult patients in nuclear medicine waiting room. The situations for pediatric patients at adult waiting room and at pediatric waiting room were separately investigated during 5 days period. In adult waiting room, average daily number of adult patient injected ^{99m}Tc was 16.4 and average administered ^{99m}Tc activity per an adult patient is 630 MBq. Average waiting time for adult patients is 2.6 hours. In pediatric waiting room, average daily pediatric patient's number is 4.4 and the average administrated ^{99m}Tc activity per a pediatric patient is 147 MBq. Average waiting time for pediatric patients is 2.2 hours. According to our measurements, while a pediatric patient waiting in adult room has up to 184.6 µSv dose originated from adult patients injected ^{99m}Tc, a pediatric patient waiting in separate pediatric waiting room has only 18 µSv dose from other pediatric patients. The received radiation doses by pediatric patients originated from other patients at nuclear medicine waiting patient room are completely unnecessary and it can be largely avoided. Our recommendation is that pediatric patients should be waited in a separate waiting room apart from adult patients.

Keywords: Nuclear medicine, pediatric exposure, waiting room, ^{99m}Tc

1. Introduction

The Report-2010 of The United Nations Committee on the Effects of Atomic Radiation (UNSCEAR) stated that 'Diagnostic Nuclear Medicine has increased worldwide from 23.5 million examinations annually in 1988 to an estimated 32.7 million annually during the period 1997–2007, and this has resulted in an annual per capita dose of 0.031 mSv. The estimated annual collective dose has increased from 74 000 man Sv in 1980 to an annual collective dose of 202 000 man Sv by the end of the period 1997– 2007 (UNSCEAR 2010).

As mentioned above report, there is an increasing in the number of nuclear medicine procedures. Nuclear medicine procedure is a noninvasive method and by using radioactive rays emitted radioactive isotopes to facilitate physicians' understanding of diseases, the need for other risk invasive methods can be eliminated. In a nuclear medicine procedure, radionuclides are combined with pharmaceutical compounds to form a radiopharmaceutical and then this radiopharmaceutical is injected to the patients. After the injection, patients wait until radiopharmaceutical can localize to specific organs or tissues and then patients go to the gamma camera room for scanning. Between injection and gamma camera scanning durations, patients have to wait up to 2-3 hours in a waiting room depends on the scintigraphy procedure.
In terms of radiation protection during traditional nuclear medicine procedure, in perhaps, the most neglected area is patient waiting rooms. During this waiting period, radiation protection is one of the most problematic issues in the nuclear medicine department because all patients after the injection are actually a radiation source. While PET imaging and iodine treatment application have an isolated waiting room for each patient (Demir et al; Thompson et al), generally, traditional nuclear medicine applications used gamma camera have not an isolated waiting room for each patient. Therefore, patients in the waiting rooms may irradiate each other. This situation is not appropriate for the patients' health, especially for pediatric patients. Several studies have documented relevant cancer risks when people are exposed to radiation during childhood (Ron et al; UNSCEAR 2006).
In present study, we measured the radiation doses to pediatric patients originated from adult patients in nuclear medicine waiting room and we discussed the measures to be taken.

2. Materials and Methods

In our department, adult patient waiting room has 20 seats and the room dimensions are 5 x 8 m^2. The room walls are isolated against the radiation and it has also two patient's toilets at its corners. Before the separation of waiting rooms, adults and pediatric patients waited together. Pediatric patients are nowadays waiting in a separate isolated room after the injection. Pediatric patient waiting room has 6 seats and the room dimensions are 2.5 x 4.5 m^2. There is no patient toilet in this small room, so children use one of two toilets located in the adult waiting room corners as shown in Fig. 1.

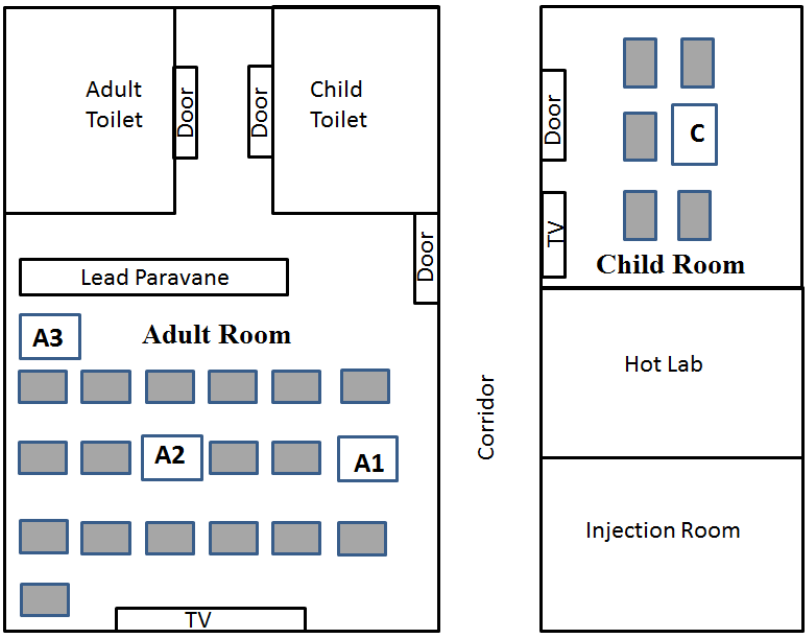

Figure 1: Adult and pediatric patient waiting room sitting plain (not scaled). There are three EPDs placed on the carboys in adult room (EPD-A1, EPD-A2, and EPD-A3) and one EPD in pediatric room (EPD-C).

The situations at the both patient waiting rooms were separately investigated during 5 days period. Adult patients of dimercaptosuccinic acid (DMSA), bone and myocardial perfusion scintigraphy injected ^{99m}Tc were involved to present study. ^{99m}Tc emits 140 keV gamma photons and its half-life is 6 hours. Average total daily number of

adult patient injected ^{99m}Tc in the adult waiting room was 16.4 and average administered ^{99m}Tc activity per an adult patient was 630 MBq. All patients were injected within one hour in every morning and after, they were redirected to the adult waiting room. Average waiting time for adult patients was 2.6 hours, minimum waiting time was 2.1 hours, and maximum waiting time was 3.4 hours. Carboys filled with water (20 liters) for representing the children bodies were used in the adult waiting room during the dose measurements. Electronic Personal Dosimeters (EPDs) were located to the carboys during the measurements. Carboys in the adult room were located according to plan shown in Fig 1.
Similar to the adult group, pediatric patients injected ^{99m}Tc for DMSA and bone scintigraphy were only involved to the pediatric waiting room measurement. Average daily pediatric patient's number was 4.4 and the average administrated ^{99m}Tc activity per a pediatric was 147 MBq. Average waiting time was 2.2 hours, minimum waiting time was 2 hours and maximum waiting time was 2.7 hours for pediatric patients. One of the carboys filled with water (20 liter) representing children bodies was also used in the pediatric waiting rooms during the dose measurements. Therefore, only one EPD was used in the measurement of pediatric waiting room. Carboy in pediatric room was located according to plan shown in Fig. 1.
The detailed daily patient's number and total daily ^{99m}Tc activities for both waiting rooms for 5 days period was given in Table 1.

Table 1: Daily number of patients injected Tc-99m and daily total ^{99m}Tc activity in the waiting rooms (MBq).

	Adult Waiting Room					Pediatric Waiting Room				
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5
Daily patients number injected ^{99m}Tc	17	16	16	16	17	5	4	4	4	5
Daily total ^{99m}Tc activities (MBq)	9470	10720	9835	10285	11350	650	640	730	570	645
Daily Average ^{99m}Tc activity (MBq)	10332 MBq					647 MBq				

3. Results and Discussion

Medical applications containing radiation are rapidly growing in the entire world. These types of applications began to be preferred by doctors because they facilitate the diagnosis of illness (Mettler et al.). Nuclear medicine can allow early diagnosis of disease for treatment because of its high sensitivity. On the other hand, it is difficult to obtain medical information from pediatric patients than adults. Nuclear medicine is a useful diagnostic tool for the evaluation of pediatric patients because of noninvasive nature of it. But, these medical applications are not completely innocent. Patients throughout their lives may be exposed to radiation of more than one. The biological effects of radiation exposure from these applications accumulate over time. Dorfman et al. reported that a pediatric patient will receive average of 7 radiologic examinations up to age of 18. The most prevalent procedure was in a plain radiograph (84.7% of the studies performed), followed by CT (11.9%), fluoroscopy or angiography (2.5%), and nuclear medicine (0.9%) (Dorfman et al).
According to As Low as Reasonably Achievable (ALARA) principle recommended by the International Commission on Radiological Protection (ICRP-26), if a radiation application is not useful, it should be avoided. Three basic principles of radiation protection specified in ICRP-26 are;

i) Justification: No practice shall be made which does not provide any benefit.
ii) Optimization: all exposures shall be kept as low as reasonably achievable (ALARA principle),
iii) Limitation: the dose limits to individuals recommended by ICRP shall not exceed.

Received radiation doses by patient resulted from other patients at waiting room are completely unnecessary. Therefore, PET imaging center and iodine treatment unites in nuclear medicine departments have an isolated waiting room for each patient. Thus, neither other patients nor the medical personnel are not exposed to unnecessary radiation during these procedures. But, traditional nuclear medicine applications using gamma camera have not an isolated waiting room for each patient. There is a significant contradiction here. While for reducing the radiation dose to be administered to the patients consumed a lot of effort, radiation safety is commonly neglected in the waiting rooms.

Radiation is harmful and pediatric patients are more sensitive than the adults against the radiation. This issue is mentioned in detail at Report of UNSCEAR (UNSCEAR-2013). Due to their smaller body and less shielding from overlying tissues, there are different effects of radiation on pediatric patients compared to adults on account of their anatomical and physiological differences. If pediatric patients are exposed by an external dose, the dose to internal organs of pediatric patients will be higher than dose to adult's internal organs. Pediatric patients' growing process occurs quickly. In this growing process, pediatric patients' cells are highly sensitive to radiation hazardous. Because effects of radiation take years to improve, children's youth extends the time for any potential effects from ionizing radiation to occur.

Internal irradiation is inevitable for the nuclear medicine patients due to the nature of the nuclear medicine. According to ICRP Reports (ICRP-60), for 740 MBq injection doses in ^{99m}Tc-Methyl Diphosphonate (^{99m}Tc-MDP) procedure, effective doses of pediatric patients aged from 1 to 15 years are between 2.8 and 4.2 mSv. For 370 MBq in ^{99m}Tc-ethyl cysteinate dimer (ECD) procedure, more effective dose is reported by ICRP report (ICRP-106). Effective pediatric patient doses vary from 4.1 to 5.9 while adult dose is 5.7 mSv according to this report for ^{99m}Tc-ECD procedure. Lastly, Zvonova et al. reported that the range of the effective dose, due to pediatric nuclear medicine examinations, is roughly estimated as 2-6 mSv per examination, approximately the same as in adults (Zvonova et al.).

Above doses originate from the patient' own because of the administered activity. But, as far as we know, there is no any investigation the radiation doses to pediatric patients originated from other patients in nuclear medicine waiting room. In generally, radiation protection studies in nuclear medicine focus on the radiation worker or accompanying person (Barreto et al.; Demir et al.) and patient protection against the external radiation originated from other patients are generally neglected. Especially, unnecessary radiation doses from other patients in the waiting room are of concern for pediatric patients.

In present study, we investigated the pediatric patient doses originated from other nuclear medicine patients. Results are given in the Table 2 and Table 3. It is seen that there are two important factors affecting the dose recorded by EPDs. First, the results of three EPDs placed to the adult waiting room showed that pediatric patient's doses from adult patients depend on the patient sitting position. For example, a pediatric patient who sits at the center of room in adult waiting room (position of EPD-A2 in Figure 1) has average of 186.4 µSv dose originated from adult patients. On the other hand, a pediatric patient who sits at a chair placed out of main patient group in adult waiting room (position EPD-A3 in Figure 1) has average of 57.6 µSv dose originated from adult patients. Second, EPDs results generally vary from day to day, of course, depending on the daily total administrated ^{99m}Tc activities to the patients. For EPD-A2 placed to the center of room as shown in Fig. 1, while average exposure dose for the administered total daily ^{99m}Tc activities of a 11350 MBq (maximum value in 5 days period) at day 5 is 220 µSv, the average exposure dose for the administered total daily ^{99m}Tc activities of a 9470 MBq (minimum value in 5 day period) at day 1 is 151 µSv.

For pediatric waiting room measurements, we used only one EPD as shown in the Fig. 1 (EPD-C). As seen Table 3, the highest doses were read on the day 3 with EPD-C as 20 µSv. At this day, total ^{99m}Tc activity is the maximum (730 MBq) among all study days.

When Table 2 and Table 3 are evaluated together, it is clearly shown that the dose exposures of pediatric patients originated from other pediatric patients are significantly decreased from 184.6 µSv to 18 µSv when a pediatric patient moves from adult waiting room to pediatric waiting room. As mentioned above, the reason for this decreasing is the less total administrated ^{99m}Tc activities to the pediatric patients (total average 647 MBq for average 4.4 pediatric patients per day) than adult patients (total average 10332 MBq for average 16.4 adults per day), and of course, the small number of pediatric patients in the pediatric waiting room (average 4.4 pediatric patients per day) than adult waiting room (average 16.4 adults per day).

Our reported dose values of 184.6 µSv for adult waiting rooms is similar to those reported by Barreto et al. They studied the doses received by the caretakers of nuclear medicine patients. Two significant groups were selected in their study: comforters of adult cancer patients (Group I) and mothers of small pediatric patients (Group II). Barreto et al. estimated an average dose of 270 µSv for caretakers and 290 µSv for mothers of nuclear medicine patients staying in the waiting room. Although our study and Barreto et al. study conditions are similar, both measurements times of studies differ from other. While their total measurement time is 24 hours, our total measurements time are only 3 hours. So, our reported doses are less than their results.

Table 2: Pediatric patient exposure doses resulted from other patients during 1st, 2nd, 3rd hours and total 3 hours (1st+2nd+3rd) waiting time in the adult waiting room.

	Exposure Dose During 1st hour			Exposure Dose During 2nd hour			Exposure Dose During 3rd hour			Total Exposure Dose During (1st+2nd+3rd) hours		
	EPD A1 (µSv)	EPD A2 (µSv)	EPD A3 (µSv)	EPD A1 (µSv)	EPD A2 (µSv)	EPD A3 (µSv)	EPD A1 (µSv)	EPD A2 (µSv)	EPD A3 (µSv)	EPD A1 (µSv)	EPD A2 (µSv)	EPD A3 (µSv)
Day 1	53	58	25	60	62	17	30	31	9	143	151	51
Day 2	83	90	28	55	70	22	32	36	19	170	196	69
Day 3	63	75	25	42	65	16	25	25	8	130	165	49
Day 4	55	88	26	50	72	23	15	31	10	120	191	59
Day 5	80	100	30	61	85	20	22	35	10	163	220	60
Average of Days	66.8	82.2	26.8	53.6	70.8	19.6	24.8	31.6	11.2	145.2	184.6	57.6

Table 3: Pediatric patient exposure doses resulted from other patients during 1st, 2nd, 3rd hours and total 3 hours (1st+2nd+3rd) waiting time in the pediatric waiting room.

	Exposure Dose During 1st hour	Exposure Dose During 2nd hour	Exposure Dose During 3rd hour	Total Exposure Dose During (1st+2nd+3rd) hours
	EPD -C (µSv)	EPD-C (µSv)	EPD-C (µSv)	EPD-C (µSv)
Day 1	8	7	2	17
Day 2	9	7	3	19
Day 3	10	7	3	20
Day 4	9	6	2	17
Day 5	8	6	3	17
Average of Days	8.8	6.6	2.6	18

4. Conclusion

While a pediatric patient who waits in an adult room has up to 184.6 μSv dose originated from adults patients, a pediatric patient who waits in separate pediatric waiting room has only 18 μSv dose originated from other pediatric patients. The received radiation doses by pediatric patients originated from others patients at waiting room are completely unnecessary and it can be largely avoided. There are too many studies showing that cancer-radiation relationship (BEIR-VII; Kleinerman e al.; Li et al; Takahashi et al.). Especially, leukemia is the most common childhood cancer type and radiation-leukemia relationship has been shown (Shih et al.). ALARA principle should be carefully applied in the nuclear medicine department for this sensitive patient group against radiation hazards. Pediatric patients should be kept in a separate waiting room.

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