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Technical Note

Radiation monitoring of non-lead-lined treatment room in general pediatric ward and adjacent areas for high dose ^{131}Iodine-mIBG

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Abstract

Background: ^{131}I-metaiodobenzylguanidine (mIBG) offers an effectively targeted radionuclide therapy in pediatric patients. According to radiation protection authority in our country, the patient treated with high-dose (>1100 MBq) radioiodine is recommended to stay in the hospital. Hence, this study intends to measure the radiation exposure in non-lead-lined treatment room installing with portable lead shields located in general pediatric ward and surrounding areas. In addition, this study also aims to measure the radiation exposure to the family caregiver in pediatric patients received high dose ^{131}I-mIBG.

Methods: Environmental OSL (optically stimulated luminescence) monitoring devices (InLight®, Al_2O_3:C) were prepared and calibrated by Thailand Institute of Nuclear Technology (TINT). Twenty-five set of OSLs were placed in and surrounded the treatment room. Dose to family caregiver was recorded by digital semiconductor dosimeter (ALOKA PDM-112) also calibrated by TINT. The measurement was carried for four pediatric patients treated with ^{131}I-MIBG (activity 3700 – 5500 MBq).

Results: The ambient doses equivalent and the dose rate were analyzed, the limit of 10 and 0.5 μSv/h are accepted for radiation worker and member of the public, respectively. The dose rate around the patient bed and toilet were high as expected. Dose rates at the wall of adjacent room and corridor were slightly greater than the public limit (range 1.82 to 4.48 μSv/h). Remarkably, the dose rates at caregiver chair (outside the shielding) were exceeded the limits (30.57 ± 5.69 μSv/h). Consequently, this was correlated with high personal dose equivalent to family caregivers which listed as 175, 1632, 6760 and 7433 μSv for the patient age of 15, 5, 1 and 1 year respectively.

Conclusion: These radiation monitoring data provided the important information to manage radiation protection and aware of radiation exposure when using non-lead-lined treatment room in general pediatric ward.

Key words: ^{131}I-mIBG; radiation protection; OSL; ambient dose equivalent; direction dose equivalent.

Introduction

^{131}Iodine-metaiodobenzylguanidine (^{131}I-mIBG) offers an effectively targeted radionuclide therapy for neuroblastoma and pheochromocytoma in pediatric patients. The high activities (3.7 to 5.5 GBq) are usually administered to the patient. After high dose treatment, the patient becomes a potential radiation hazard and should be stayed in the hospital until radiation exposures decrease to acceptable limit [1]. In Thailand, the radiation safety regulations and release limit are based on the basic safety standard (BSS) recommended by IAEA (International Atomic Energy Agency) which states a guidance level of 30 mCi (1100 MBq) for release patients who treat with ^{131}I. In practical, the measured dose rate is below 50 μSv per hour at a distance of 1 meter is used to release a treated patient from the hospital [2].

For ^{131}I-mIBG, the radiation protection principle is similar to high dose ^{131}I-NaI (sodium iodide) for thyroid diseases. Due to ^{131}I-mIBG is administered to pediatric patients, then, it is difficult to control the treated patients and radiation protection might be more complicated. In addition, there is no isolated radiation ward specialized for this group of patients at our institute. Accordingly, the treatment is performed in the general pediatric ward with installation of portable lead shields (an equivalent thickness of 1 inch of lead).

Furthermore, limiting the radiation exposure to their family caregiver in ^{131}I-mIBG in pediatric patients should be concerned [3]. The ICRP (International Commission on Radiation Protection) and HPA (Health Protection Agency) are specified the value in term of dose constraint rather than dose limit. In their recommendations, the dose constrain per episode for caregiver is < 5 mSv [3-5]. In Thailand, there is no written policy specific for pediatric patient caregiver who looks after high dose radionuclide treatment. Moreover, there are minimal data in the literature published on this topic.

This study intends to measure the radiation exposure in the non-lead-lined treatment room and it surrounding areas for ^{131}I-mIBG high dose treatment located inside the general pediatric ward using OSL (optically stimulated luminescence). We also purpose to study the dose that family caregivers would be received when their children were undergone high dose radionuclide therapy.

Methods

Environmental OSL monitoring with aluminum oxide doped with carbon (Al_2O_3:C) InLight® nanoDotTM dosimeter (Landauer, Glenwood, IL, USA) were prepared and calibrated by the Thailand Institute of Nuclear Technology (TINT). The ambient dose equivalent at 10 mm depth H*(10) for estimating of the effective dose was measured for 25 points (2 dosimeters each point) including 13 points in the radionuclide treated room, 3 points in the adjacent-room, 7 points in the hallway and 2 points for background (as demonstrated in **Figure 1**) [6].

In addition as ^{131}I emitted beta particles which are weakly penetrating radiation, the directional dose equivalents for the skin at d = 0.07 mm H'(0.07,Ω) were analyzed in some areas for example caregiver bed and the area behind lead shielding [7,8].

The measurements were performed in four pediatric patients (n=4) whom treated with high dose ^{131}I-mIBG (activity 3700 – 5500 MBq). After measurement, all OSLs read out processes were performed at TINT using the InLight® Automatic reader (Landauer, Glenwood, IL, USA).

In addition, the personal dose equivalent $H_p(10)$ of family caregiver was recorded in the log book following well instructed using the Aloka pocket digital electronic semiconductor dosimeter model PDM-112 (Hitachi-Aloka Medical, Ltd., Tokyo, Japan). The dosimeter was placed on middle of the chest for each caregiver [9].

All procedures in this study were approved by the local committee on human experimentation in accordance with the ethical standards of the Helsinki Declaration. All patients and their family caregivers signed an informed consent form prior to any measurements.

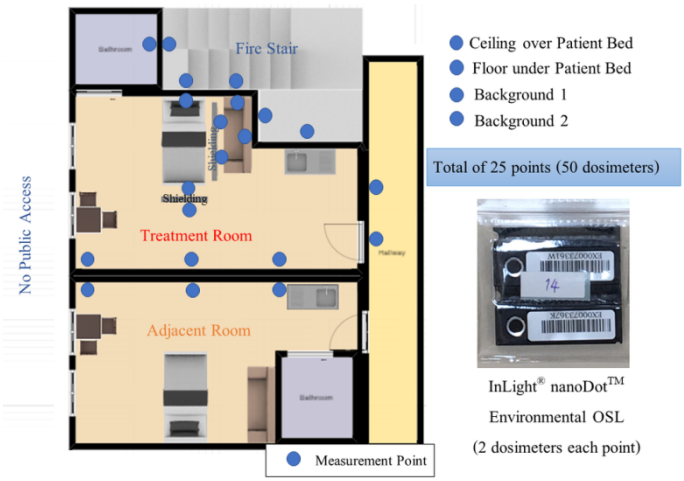

Figure 1. Floor plan of the assigned treatment room, adjacent room and surrounding areas with locations of OSL dosimeter and also OSL dosimeter used in this study. The treatment room is installed the portable lead shields and there is no dedicated lead-lined in the building wall.

Results

The contamination survey was carried out in all areas prior to hospitalize the pediatric patient in order to ensure that there was no radiation contamination in the assigned treatment room. Twenty-five environmental dosimeters were used to perform area monitoring for control effective dose in term of H*(10) and control of skin dose in term of H'(0.07,Ω).

The measurement was carried for 24 hours including the ^{131}I-mIBG administration process in four patients with the treated activity 3700 – 5500 MBq. **Table 1** shows the range of ambient dose equivalent H*(10) inside treatments room, adjacent room and surrounding areas.

Table 2 presents the directional dose equivalent for low penetrating radiation with d = 0.07 mm. H'(0.07,Ω).

The maximum ambient dose range equivalents were 131.64 – 149.61 μSv·h^{-1} at the floor under patient bed; 73.39 – 140.00 μSv·h^{-1} at the patient bed. The ambient dose ranges found to be 22.97 – 30.57 μSv·h^{-1} at the caregiver bed. The ambient dose range equivalents at the adjacent room and the corridor were between 1.82 – 4.48 μSv·h^{-1} respectively.

The maximum directional dose equivalents were 30.78 ± 5.87 μSv·h^{-1} at the caregiver bed. The directional dose equivalents outside the lead shield were ranged from 4.22 ± 0.57 to 10.52 ± 4.59 μSv·h^{-1}. Consequently, the measured personal dose equivalent $H_p(10)$ of family caregiver with patient age are summarized in **Table 3**.

The personal dose equivalents for caregiver were 7433 and 6760 μSv for infant pediatric patients. Compare to the caregiver exposure for older patients, the personal dose equivalents were 175 and 1632 μSv for children age of 15 and 5 years respectively.

Table 1. Dose range of the ambient dose equivalent H*(10) in unit of μSv·h^{-1}

Location	Ambient Dose Equivalent H*(10) μSv·h^{-1}
Inside Treatment Room	
Patient bed	73.39 - 140.00
End of patient bed (behind lead shielding)	3.65 - 4.79
Floor (under patient bed)	131.64 - 149.61
Ceiling (over patient bed)	44.79 - 47.18
Toilet	13.55 - 35.41
Left side of patient bed nearby caregiver bed (behind lead shielding)	6.72 - 9.90
Caregiver Bed	22.97 - 30.57
Wall near Adjacent Room	5.26 - 12.34
Adjacent Room	
Wall near Treatment Room	2.08 - 4.48
Outside Treatment Room	
Hallway	1.82 - 3.85
Fire Exit	2.55 - 3.96
Fire Stair	1.88 - 2.03
Background	1.46 - 1.51

Table 2. Directional Dose Equivalent (mean ± SD) in unit of μSv·h^{-1}

Location	Directional Dose Equivalent H'(0.07,Ω) Mean ± SD μSv·h^{-1}
Caregiver Bed 1 (Head of Caregiver Bed)	30.78 ± 5.87
Caregiver Bed 2 (Middle of Caregiver Bed)	23.44 ± 2.26
Behind Lead Shielding 1 (Nearby Caregiver Bed)	10.52 ± 4.59
Behind Lead Shielding 2 (Nearby Caregiver Bed)	6.88 ± 3.01
Behind Lead Shielding 3 (End of Patient Bed)	4.22 ± 0.57

Table 3. Personal dose equivalent $H_p(10)$ of caregiver with patient age in μSv measured

Patient	Patient Age	Caregiver Dose (μSv)
A	15 Years	175
B	1 Year	7433
C	5 Years	1632
D	1 Year	6760

Discussions

The radionuclide treated patients are the source of radiation exposure and become a potential radiation hazard to other individuals in their vicinity. In this work, we measured the radiation exposures in the non-lead-lined treatment room and surrounding areas using environmental OSL dosimeter. In our previous work, we already reported the radiation exposure from this non-lead-lined treatment room with portable lead shields, those data were collected in adult patient with high dose ^{131}I-NaI. However, the radiation safety management was more troublesome in pediatric patients [10].

In this work, the ambient dose equivalents were measured and tabulated in **Table 1**. From these results, it is important to note that the dose equivalents in almost all areas higher than the dose limits for occupational and also member of the public exposure as recommended by ICRP. The limits are 10 and 0.5 μSv·h^{-1} for occupational and member of the public, however, these limits are calculated based on 2000 working hours per year [11]. Hence, these derived limits are being unrealistic for this situation as the 2000 working hours per year are overly restrictive for calculation. In reality, the isolation is not continuous for 1 year, however, this study provides important information in order to obtain useful case planning and radiation control of this room. Hence, the stay time should be limited for both occupational workers and member of the public.

For the other pediatric patient whom stayed in the adjacent room, the ambient doses at the wall in adjacent room were ranged from 2.08 to 4.48 μSv·h^{-1}. These values were slightly greater than the public limit. However, when consider the exposure at patient bed and visitor chair which are located at opposite wall, the exposure to other pediatric patient and their relatives should well below the regulatory limit. Our results were similar to study by Chu et al. from Memorial Sloan-Kettering Cancer Centre which studied the feasibility of administering ^{131}I-mIBG in treatment room without lead-lined [12]. Chu *et al.* reordered on 16 ^{131}I-mIBG treatments and described that dose rates in two adjacent rooms were ranges (mean ± 1SD) from 4 ± 2 and 4 ± 5 μSv·h^{-1}. In addition, the doses outside the treatment room were slightly higher than our study (2 - 8 μSv h^{-1} in Chu *et al.* versus 1.82 – 3.85 μSv·h^{-1} in our study).

Based on our results, the ambient and directional dose equivalent in the caregiver chair were exceed the permitted limit. As the patients are allowed to move within the admitted room. In addition to the patient's bed, the caregiver bed would

be another relax seating for the patients. Consequently, this was correlated with high personal dose equivalent to family caregivers which listed as 175, 1632, 6760 and 7433 µSv for the patient age of 15, 5, 1 and 1 Year respectively. As recommended by ICRP and HPA, the dose constrain for caregiver is limited to < 5 mSv per episode [3]. The dose received by family caregivers for infant patients were exceeded the limit. As for these infant patients, the patients were just 1 year old, in diapers and necessitating attention than normal. This finding was correlated with work of Markelewicz RJ *et al.* and Gains JE *et al.* [1,3,13]. The study by Gains JE *et al.* reported that caregivers for young patients got higher doses than caregivers for older patients on the 10 years study of radiation exposure in radionuclide treatment of pediatric patient without lead-line treatment room. However, only one caregiver (from 50 caregivers) in Gains *et al.* was exceed the derived caregiver limit. Accordingly from our findings, the local radiation control policies for the caregiver in very young patient should be reconsidered. Optimistically, the use of real-time pocket dosimeter could help the family caregivers to proactively improve their radiation protection.

Conclusion

These radiation monitoring data provided the important information to manage radiation protection and aware of radiation exposure in an adjacent room to minimize the exposure dose for the members of public and medical staffs in the pediatric ward. The radiation exposure to caregivers were associated with the patient age; hence, caregiver exposure for younger pediatric patient tends to receive higher exposure dose as the patient may require more cares and supports.

References

[1] Markelewicz Jr RJ, Lorenzen WA, Shusterman S, *et al*. Radiation exposure to family caregivers and nurses of pediatric neuroblastoma patients receiving 131i-metaiodobenzylguanidine (131i-mIBG) therapy. Clin Nucl Med. 2013;38(8):604-607.

[2] Tonnonchiang S, Sritongkul N, Chaudakshetrin P, Tuntawiroon M. Radiation exposure to relatives of patients treated with iodine-131 for thyroid cancer at Siriraj hospital. J Med Assoc Thai. 2016;99(2):220-224.

[3] Gains JE, Walker C, Sullivan T, *et al*. Radiation exposure to comforters and carers during paediatric molecular radiotherapy. Pediatr Blood Cancer. 2015;62(2):235-239.

[4] Cougnenc O, Defachelles A-S, Carpentier P, *et al*. High-dose 131i-mibg therapies in children: Feasibility, patient dosimetry and radiation exposure to workers and family caregivers. Radiat Prot Dosimetry. 2017;173(4):395-404.

[5] de la Guardia M, Mata S, McCammon S, *et al*. Physician and nursing personnel radiation exposure monitoring experience during the first year of performing i-131 metaiodobenzylguanidine (mIBG) therapy. Conference: Society of Nuclear Medicine and Molecular Imaging, Baltimore, MD. J Nucl Med. 2015;56(Supplement3):1251.

[6] Tuncel N, Karayalcin B, Koca G. The calibration process of OSL detectors used for staff and patient dosimetry in hospital environment. J Nuc Med Radiat Therapy. 2015;6(6):1000259.

[7] Dietze G, Menzel H-G. Dose quantities in radiation protection and their limitations. Radiat Prot Dosimetry. 2004;112(4):457-463.

[8] ICRP. The 2007 recommendations of the international commission on radiological protection: ICRP Publication 103. Ann ICRP. 2007;37(2-4).

[9] Bartlett DT. Personal dose equivalent, Hp(d), and reference point for calibration. Radiat Prot Dosimetry. 2006;121(3):209-210.

[10] Changmuang W, Chamroonrat W, Kositwattanarerk A, *et al*. Radiation from an admitted thyroid cancer patient with high dose I-131 treatment in related hospitalized area and exposure to associated personnel in Ramathibodi's new inpatient unit. Asean J Radiol. 2012;18(2):118-122.

[11] Wrixon AD. New ICRP recommendations. J Radiol Prot. 2008;28(2):161-168.

[12] Chu BP, Horan C, Basu E, *et al*. Feasibility of administering high-dose 131I-MIBG therapy to children with high-risk neuroblastoma without lead-lined rooms. Pediatr Blood Cancer. 2016;63(5):801-807.

[13] Assessment of occupational exposure due to intakes of radionuclides. IAEA Safety Standards Series No. RS-G-1.2. Vienna: International Atomic Energy Agency; 1999.