Measurement of the Whole Body, Eye Lens and Extremity Occupational Doses in Nuclear Medicine Staff at King Chulalongkorn Memorial Hospital

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Abstract. Nuclear medicine staff have handled several radionuclides of gamma and beta emitters which result in obtaining occupational radiation risk. In 2018, the Government of Thailand announced the reduction of the eye lens dose limit from 150 to 20 mSv per year for the consecutive 5 years as of ICRP No. 118 in 2011. In Thailand, the personal effective dose to whole body, Hp(10) and the personal equivalent dose to the extremity, Hp(0.07) have been measured using optically stimulated luminescence dosimeter (OSLD) in nuclear medicine staffs while the personal equivalent dose to the eye lens, Hp(3) has never been measured. The objective is to measure Hp(10), Hp(3), and Hp(0.07) using OSLD in nuclear medicine staff who dispense high activity of radionuclides at King Chulalongkorn Memorial Hospital (KCMM). The correlations between the Hp(10), Hp(3) and Hp(0.07) were analyzed. The personal occupational dose has been measured in 10 nuclear medicine staff. Three sets of OSLD are attached at whole body, finger, and eye lens (left and right) of each personnel arranged by Thailand Institute of Nuclear Technology (TINT). As some radionuclides emit beta and gamma, most staff perform best practice in routine work, the short exposure time and the short range of beta rays to reach eye dosimeters which result in the estimated annual whole body, eye lens and extremity were less than the annual dose limit. The correlations between Hp(3) and Hp(10), Hp(0.07) and Hp(10), Hp(3) and Hp(0.07) had been recorded, while Hp(3) could be estimated from Hp(10).

Keywords: eye lens, nuclear medicine, Hp(10), Hp(3), Hp(0.07), OSLD

1. Introduction

Due to the epidemiology evidence of cataract and eye lens opacity, the International Commission on Radiological Protection (ICRP) Publication 118 changed the dose limit for the eye lens of occupational exposure from 150 mSv per year to 20 mSv per year, averaged over 5 year period, no single year exceeding 50 mSv [1].

In 2018, the Government of Thailand announced the reduction of eye lens dose limit from 150 mSv per year to 20 mSv per year. Personal occupation exposure was measured and represented by personal dose equivalent, Hp(d). It is operational quantity for individual monitoring of soft tissue under body surface at d mm. Hp(10) and Hp(3) represents equivalent dose of whole body and eye lens. Hp(0.07) represents equivalent dose of skin, hand and feet [2].

Occupational exposure of nuclear medicine staff received from unsealed and sealed sources of ionizing radiation, which they received the ionizing radiation from many radionuclides. The utilization of radionuclides in nuclear medicine department can be separated into 2 groups. The first group is for diagnosis for example: Tc-99m, I-131, F-18 and Ga-68. The second group is for therapeutic, such as I-131 and Lu-177. After ICRP changed the eye lens dose limit from 150 mSv per year to 20 mSv per year, eye lens dosimetry had been measured using thermoluminescent dosimeter (TLD) [3,4,5,6].
In Thailand, OSLD is commonly used. Therefore, Hp(3) could be measured by OSLD in nuclear medicine staff who involve the radiopharmaceutical preparation. The aim of this study was to measure Hp(10), Hp(3) and Hp(0.07) using OSLD and to analyze the correlations between the Hp(3) and Hp(10), Hp(0.07) and Hp(10), Hp(3) and Hp(0.07).

2. Materials and methods
This is a prospective study which consists of ten nuclear medicine staff; 1 radiopharmacist, 2 radiochemists, 4 technologists and 3 nurses. In hot lab, radiopharmacist prepares radiopharmaceutical for diagnosis, therapeutic and research purposes. In case of radiochemists, they prepared radiopharmaceutical for routine diagnosis only. The duties of technologists are radiopharmaceuticals calibration, radionuclides imaging and treatment. The nurses inject all radiopharmaceutical to patients.

Optically Stimulated Luminescence Dosimeter (OSLD), is calibrated for whole body, eye lens, and finger dosimeters in this study. The crystals of OSLD are aluminum oxide dope with carbon. The whole body dosimeter is InLi light model. The eye lens and finger dosimeters are nanoDot model. All of dosimeters manufactured by Nagase Landauer, Japan.

Three set of OSLDs were attached at whole body, eye (left and right) and finger of each personnel during working hours. The personal occupational dose was measured for 3 months in 10 nuclear medicine staff after that the OSLDs were read by MicroSTAR reader and annual doses were estimated. The correlations of Hp(3) and Hp(10), Hp(0.07) and Hp(10), Hp(3) and Hp(0.07) had been determined.

3. Results and Discussion
The estimated annual personal dose of nuclear medicine staff at whole body Hp(10), eye lens Hp(3) and finger Hp(0.07) are shown in table 1. Annual personal dose of radiopharmacist is highest but within the annual dose limit.

Table 2 shows that the radiopharmacist received the highest radiation dose due to his ring dosimeter is worn outside rubber glove. If the contamination occurred, the ring would also be contaminated. The activity of Lu-177 is ranged from 150 to 200 mCi per case and Ga-68 (beta emitter) is 3-5 mCi as well as the large number of cases annually. So this is the reason why his Hp(0.07) is close to 500 mSv per year. The distance between radioactive source to the eye dosimeter is quite far from his arm. Therefore, the eye lens dose is not high but the dose at the hands are very high. Radiochemists received lowest Hp(3) due to the radionuclide preparation is within the fume hood with lead shield. Therefore, the eye lens dose is not high. Technologists received lowest Hp(10) and Hp(0.07) because of distance from patients to technologist is far and the decay of radioactivity. The nurses received low Hp(0.07) according to their good radiation protection such as the use of syringe shields and high experience.

The annual dose of Hp(10), Hp(3) and Hp(0.07) are varied between the nuclear medicine staff. Along with the annual dose should be within three-tenths of the ICRP dose limit [7] most values of Hp(10), Hp(3), and Hp(0.07) were well below three-tenths of ICRP dose limit except the Hp(10) and Hp(3) of radiopharmacist that were closed to dose at three-tenth of the ICRP dose limit, Hp(0.07) is over the three-tenth of ICRP dose limit, and almost close to the dose limit as in figure 1. All nuclear medicine personal dose at Hp(10) Hp(3) and Hp(0.07) are not exceed the dose limit when compared Hp(10), Hp(3) and Hp(0.07) with other studies. The result showed Hp(10) in this study is higher than Piwowarska-Bilska et al [5] but is less than Dabin et al [4] because in Piwowarska-Bilska et al study, they used only Tc-99m and I-131 but in Dabin et al study used Tc-99m, F-18, Ga-68, C-11, I-131 and Y-90.
### Table 1. Annual personal dose for nuclear medicine staff.

| Occupational group | Hp(10) (mSv) | Hp(3) (mSv) | Hp(0.07) (mSv) |
|--------------------|-------------|-------------|---------------|
| Radiopharmacist    | 5.56        | 4.67        | 422.49        |
| Radiochemist 1     | 0.64        | 0.65        | 1.96          |
| Radiochemist 2     | 2.28        | 0.26        | 33.63         |
| Technologist 1     | 1.20        | 1.15        | 0.28          |
| Technologist 2     | 0.84        | 0.42        | 1.96          |
| Technologist 3     | 1.56        | 0.32        | 1.16          |
| Technologist 4     | 0.84        | 1.37        | 4.64          |
| Nurse 1            | 3.28        | 2.06        | 1.84          |
| Nurse 2            | 1.48        | 1.95        | 0.64          |
| Nurse 3            | 0.16        | 0.08        | 5.26          |

Average (Range) 1.78 (0.16 - 5.56) 1.29 (0.08 - 4.67) 47.39 (0.28 - 422.49)

### Table 2. Average (Range) annual personal dose for nuclear medicine staff.

| Occupational group | Average (Range) |
|--------------------|-----------------|
|                    | Hp(10) (mSv)    | Hp(3) (mSv) | Hp(0.07) (mSv) |
| Radiopharmacist    | 5.56            | 4.67        | 422.49         |
| Radiochemists      | 1.46 (0.64 - 2.28) | 0.46 (0.26 - 0.65) | 17.79 (1.96 - 33.63) |
| Technologists      | 1.11 (0.84 - 1.56) | 0.81 (0.32 - 1.37) | 2.01 (0.28 - 4.64) |
| Nurses             | 1.64 (0.16 - 3.28) | 1.36 (0.08 - 2.06) | 2.58 (0.64 - 5.26) |
Figure 1. Annual Hp(10) Hp(3) and Hp(0.07) in mSv of 10 nuclear medicine staff, with the ICRP dose limit (solid line) and three - tenths of the ICRP dose limit (dash line).

Table 3. shows the ratio of Hp(3)/Hp(10), Hp(0.07)/Hp(10) and Hp(3)/Hp(0.07). The ratio of Hp(3)/Hp(10) for radiopharmacist, technologist and nurses are possibly used for eye lens dose determination. In this study, ratio of Hp(3)/Hp(10) close to 1 is the same as Kopec et al study [6] because the same radionuclides had been used. The relationship between Hp(3) and Hp(10), Hp(0.07) and Hp(10), Hp(3) and Hp(0.07) showed weak correlations which r equals to 0.494, 0.292 and -0.376 respectively.

Table 3. Hp(3)/Hp(10), Hp(0.07)/Hp(10) and Hp(3)/Hp(0.07) ratio.

| Occupational group | Hp(3)/Hp(10) | Hp(0.07)/Hp(10) | Hp(3)/Hp(0.07) |
|--------------------|--------------|-----------------|----------------|
| Radiopharmacist    | 0.84         | 75.99           | 0.01           |
| Radiochemists      | 0.56         | 8.91            | 0.17           |
| Technologists      | 0.82         | 2.21            | 1.22           |
| Nurses             | 0.82         | 11.29           | 1.40           |

Figure 2. The correlations between Hp(3) and Hp(10), Hp(0.07) and Hp(10), Hp(3) and Hp(0.07) of nuclear medicine staff at KCMH.
4. Conclusion
The average (range) of Hp(10), Hp(3) and Hp(0.07) using OSLD in nuclear medicine staff at KCMH are 1.78(0.16-5.56), 1.29(0.08-4.67) and 47.39(0.28-422.49) mSv per year respectively. Those are within the annual dose limit. The ratio between Hp(3)/Hp(10), Hp(0.07)/Hp(10) and Hp(3)/Hp(0.07) varied in wide range. Hp(3)/Hp(10) of radiopharmacist, technologist and nurses are close to 1. Good radiation protection in radiopharmaceuticals preparation is best method to reduce the radiation dose.

It can be concluded that at this center, the eye lens dosimeter is not necessary because the ratio of Hp(3)/Hp(10) from the study could be used to roughly estimate the eye lens dose if necessary. The other reason is the small number of staff according to the availability of label compound in the market at reasonable price. The ratio of Hp(3)/Hp(10) of radiopharmacist, Technologist and Nurses close to 1, it was possible to determine eye lens dose from the ratio.

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