Estimation of Radiation Dose to the Eye during Radiopharmaceutical Preparation and scan procedures at a selected private hospital in Sri Lanka

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Abstract: Radiopharmaceuticals are radioactive compounds used in nuclear imaging procedures. The purpose of this study was to estimate the average equivalent dose to the eye. This study was conducted at the nuclear medicine department of Lanka hospitals PLC, Sri Lanka. A total number of 137 procedures were selected: bone, renal (DTPA - Diethylenetriamine pentaacetic acid) and whole body iodine (WBI), and dose was measured during the radiopharmaceutical preparation. Measurement of eye dose need to be done using $H_p(3)$ type dosimeter, but due to unavailability of that dosimeter, $H_p(10)$ type electronic pocket dosimeter was used for measurements. The dosimeter (Brand-POLIMASTER and model-PM1610) was placed in between the eyes during the dose measurement with the help of custom made head band. The highest estimated average equivalent eye dose of 6.93 (± 5.36) µSv was received by the technician during 1st week from newly installed radio nuclide generator. Annual estimated equivalent eye dose have received by personals involved in dose administration, and patient handling were 0.34 (± 0.24) $mSvy^{-1}$ and 0.08 (± 0.01) $mSvy^{-1}$ respectively. A strong positive correlation (r=1.0000) was found between total equivalent eye dose and eye dose received by the technician during radiolabeling. Further, the total equivalent eye dose during DTPA procedures and the dose received by eye during DTPA dose withdrawal (preparation of dose vials for each patient from total dose volume) have shown a positive correlation (r=0.9980). This study concluded that the estimated annual radiation dose to the eye of personals involves in dose administration and patient handling were far below than the ICRP recommended equivalent dose limits.

Keywords: radiopharmaceutical, eye dose, equivalent dose

Introduction

In both diagnostic and therapeutic nuclear medicine patient becomes a source of radiation which causes for own exposure and also for staff, caregivers and the general public. It remains until the radioactive material has decayed or is excreted from the body (Mattsson and Hoeschen, 2013). It was reported that the workers expose to nuclear medicine occupational exposure during the preparation of radiopharmaceuticals in hot lab and administration, higher than the exposure during imaging procedures (Delacroix et al., 2002). It is due to the staff is working closer to relatively large amounts of radioactivity while preparing radiopharmaceuticals and when administering, radiopharmaceuticals flow out of the shielding material into the patient. But during imaging workers spend only a few minutes closer to the patient (Kollaard et al., 2018).

The International Commission on Radiological Protection (ICRP) has revised that the human eye lenses have become more radiosensitive than previously assumed. It is not only for cancer induction but also due to cataract induction in the lens of the eye. Hence a specific annual dose limit of 150 mSv has been introduced by ICRP for occupationally exposed persons and 15 mSv for the public. But during past decades, more findings caused for reduction of that dose limit from 150 mSv to 20 mSv per year averaged over 5 years but not exceeding 50 mSv in a single year. So this new dose limit is lower than previous by more than a factor 7 and it implies the further need for monitoring radiation exposure of the eye region (Bruchmann et al., 2016).

Consideration of radiation dose accumulated in the eye region is very crucial. Studies on the exposure dose on the eyes are being frequently carried out in the field of radiology involving cardiovascular and interventional procedures using x-ray fluoroscopy. But studies on eye dose assessment in the field of nuclear medicine are currently lacking (Cho, Kim and Kim, 2017). Nuclear medicine staff subjected to unavoidable radiation exposure as they need to work with unsealed radioactive materials directly. Therefore, we planned to estimate occupational radiation dose to the eye region of the staff in the nuclear medicine department. As it is important to find out whether the average eye dose limit is within the recommended dose limit and to evaluate any risk of irradiation of the eyes.

Methodology

This study was a cross sectional study which involved with dose measurement of the eye region of the nuclear medicine staff. Data were collected from three staff personnel who involve with routine work procedures in the Nuclear Medicine Unit at Lanka hospital PLC from 26th of August to 26th November 2019.

Total number of 138 procedures which were (33) preparation of radiopharmaceuticals and three nuclear medicine scan procedures (Number of 35 from each): Bone scan, DTPA scan and Whole Body Iodine scan, performed at Lanka hospital PLC, were considered in this study.The equivalent eye dose received by the nuclear medicine staff was measured for each procedure during data collection period. 3 staff members involved with this study. Distribution of workload among each personnel is mentioned in the below Table 1. Data were categorized according to each procedure and manipulated radioactivity.

Dose measurements were obtained by using real time electronic pocket dosimeter. Brand is POLIMASTER and model is PM1610. Dosimeter enables measure personal dose equivalent (DE) of continuous and pulsed x-ray and gamma radiation. Dose equivalent indication range is

0.001 μSv to 12.0 Sv. Doses were measured in μSv per procedure, because the direct equivalent dose is measured by the dosimeter. Dosimeter was placed on the forehead in between the eyes of the staff members. We used a velcro back comfortable head band for placement of the dosimeter.

Firstly, the dosimeter was resettled for the zero value. Background radiation was measured for each and every hot lab procedures. Background radiation dose in the imaging room was ignored as the value was very small and only affected when an injected patient was there. Dosimeter was attached in-between the persons' eyes using the head band before starting the procedure. Readings were taken at the end of the each procedure.

Table1: Procedure involved by the staff

Personnel	Involved procedure
Staff 01	Dose administration and dose withdrawal
Staff 02	Patient handling
Technician	Preparation of radiopharmaceuticals

Calculation of the equivalent eye dose per individual personnel: Equivalent eye doses for each personnel according to each procedure were calculated as mentioned in Table 2.

Table 2: Total Equivalent Eye Dose per procedure

Personnel	Total Equivalent Eye Dose per procedure
Staff 01	(ED1+ED3) - BKG_H + (ED2)
Staff 02	ED4+ ED5
Technician	(ED6+ ED7) - BKG_H

Equivalent Eye Dose while, DTPA dose withdrawal (ED1), DTPA dose administration (ED2), bone dose administration (ED3), bone patient handling (ED4), WBI patient handling (ED5), elution (ED6), radiolabelling (ED7), Background radiation dose in the hot lab (BKG_H)

Results

The normality test was applied for all data sets and almost all the data resulted significance value of the Shapiro-Wilk test is below 0.05, the data significantly deviate from a normal distribution. Therefore median values were used for further analysis.

Considering the total equivalent dose received by the eye region of the staff 01, staff 02 and technician during 1st week of generator and 2nd week of generator; the median values are reported as 0.75 (± 0.26) μSv, 0.15 (± 0.03) μSv, 6.93 (± 5.36) μSv, 1.97 (± 1.03) μSv respectively. 20.91 μSv, 0.47 μSv were the maximum and minimum doses received by the eye region of the technician during 1st week of generator and the sum is reported as 94.46 μSv. Maximum and minimum doses received by the staff 01 and 02 were 1.27 μSv, 0.31 μSv and 0.21 μSv, 0.10 μSv.

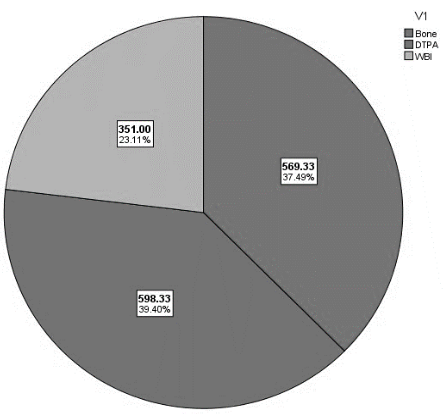

Figure 4: Average number of procedures performed per year

Table 3. Median equivalent eye doses per procedure

		Median equivalent eye dose
Technician	Generator 1st week	6.93 ± 5.36 μSv
	Generator 2nd week	1.971 ± 1.028 μSv
Staff 01	Total	0.75 ± 0.26 μSv
	Total DTPA procedure	0.27 ± 0.20 μSv
	Bone dose administration	0.32 ± 0.22 μSv
Staff 02	Total	0.15 ± 0.03 μSv
	Bone scan patient handling	0.13 ± 0.02 μSv
	WBI scan patient handling	0.13 ± 0.02 μSv

Estimated annual equivalent eye doses for staff 01 and staff 02 are 0.34 (± 0.24) $mSvy^{-1}$ and 0.08 (± 0.01) $mSvy^{-1}$.

When consider the correlations in between data sets we have observed that there was a strong positive correlation (r=1.000) and there was a significant difference ($p<0.05$) between total ED and ED7 (Radiolabeling) of the technician during both 1st and 2nd weeks. But a positive moderate correlation (r=0.460) and a moderate positive correlation (r=0.343) with no significant difference ($p>0.05$) between total ED and generator activity were observed in 1st and 2nd weeks of generator respectively. And for staff 02 Total ED (Bone + WBI procedures) derived a positive strong correlation (r=0.721) and a positive moderate correlation (r=0.460) with a significant difference ($p<0.05$), with ED4 (bone patient handling) and ED5 (WBI patient handling).

Discussion

The aim of this study was estimating the average occupational eye dose received by staff who works in the nuclear medicine department while above all selected studies.

Nuclear medicine staff maintained good radiation protection while the procedure such as lead apron, thyroid collar, lead shielding etc.

As the normality test results derived the not normal distribution of our data set, median values were utilized for further analysis. The highest estimated equivalent occupational eye dose is received by the technician who involved in radiopharmaceutical preparations, 6.93 (± 5.36) μSv and 1.971 (± 1.028) μSv for 1st and 2nd weeks of radionuclide generator. Average eye dose received by technical staff who direct contact with radiopharmaceuticals was 3.5 (± 0.3) $\mu SvGBq^{-1}$ according to Szumska, Budzanowski and Kopeć, (2014). Those values can't be compared as the investigated workloads involved by the staff members are different. As well as estimated median equivalent eye doses during assessed number of procedures for staff 01 and staff 02 were 0.75 (± 0.26) μSv, 0.15 (± 0.03) μSv respectively.

Annual median equivalent eye doses are estimated as 0.34 (± 0.24) $mSvy^{-1}$ for the personnel who involved with radiation dose administration and 0.08 (± 0.01) $mSvy^{-1}$ for the personnel who involved in patient handling. The estimated results are well below the dose limit (20 mSv) for the eye region according to the ICRP recommendations. Summers et al., (2013) have concluded that 1.85 mSv was the annual dose to the eye during ^{99m}Tc radiopharmaceuticals administration. The expected results from our study are lower than but approximately similar to value mentioned above. It should be mentioned that the investigations were conducted in selected number of procedures which expected to be provided a significant dose to the eye region of staff. The excluded procedures were which the staff didn't involve routinely making difficult to take measurements, impracticalities to wearing pocket dosimeter and used very low radiation activities. Those procedures also would be a reason for further increasing the dose received.

Estimated absorbed dose rate of eye lenses by Cho, Kim and Kim, (2017) was 1.228 μSvh^{-1}. Measurements were very sensitive as they used a phantom and $H_p(3)$ dosimeter instead of using POLIMASTER dosimeter in the present study. So the expected results may be more accurate if used a Thermo Luminescence Dosimeter (TLD) for dose measurements and increase the number of procedures investigated.

Our study results demonstrated significant association between total equivalent eye dose and the eye dose during radiolabeling by the technician ($p<0.05$), Total equivalent eye dose during DTPA procedures and eye dose during DTPA dose withdrawal ($p<0.05$) and weak correlation between generator activity and eye dose during elution of ^{99m}Tc radionuclide during 2nd week of generator and moderate during 1st week of generator. It elaborates manipulations of high activities for a considerable time increases the radiation dose received. But Dabin et al., (2016) results displayed no significant correlation with the manipulated activities reminding that associations are limited by the measurement uncertainty. We observed that total equivalent eye dose received by the staff 02 correlates strong and moderate positively with eye dose received during patient handling in bone scan and WBI procedures. We consider that noticeable time taken for patient handling in bone scan, assigns the above correlation.

Conclusion

The estimated annual equivalent eye dose received by selected nuclear medicine staff for this study conducted at nuclear medicine department Lanka hospital, Sri Lanka were 0.34 (± 0.24) $mSvy^{-1}$, 0.08 (± 0.01) $mSvy^{-1}$ for the personnel who involved in dose administration and patient handling respectively. Average median equivalent eye doses received by the technician were the highest among average values; 6.93 (± 5.36) μSv and 1.971 (± 1.028) μSv for 1st and 2nd weeks of radionuclide generator. During the 1st week of the radionuclide generator, there was a moderate positive correlation with the generator activity and the total eye dose of the technician. The entire resulted annual occupational radiation doses to the eye region of staff in the studied place are far below than the ICRP recommended value of 20 mSv. Therefore, optimum radiation safety is maintained in this hospital.

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