Occupational dose measurement for radiographers during cardiac catheterization procedures

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Abstract- Cardiac catheterization procedures play major role in diagnostic and therapeutic purposes in interventional cardiology. Meantime, concern has been expressed regarding the radiation exposure to medical staff and patient since the significant amount of fluoroscopy imaging is used during the cardiac catheterization procedures. This study investigates the occupational radiation dose to radiographers who work at cardiac catheterization laboratory. This study was conducted at Cardiac catheterization Laboratory (Cath Lab)- B, Sri Jayewardenepura General Hospital, Sri Lanka. 189 procedures were selected for all 3 radiographers in this study among them 123 and 67 procedures were Coronary Angiography (CAG) and Percutaneous Coronary Interventional (PCI) respectively. Two personnel electronic dosimeters were used to measure the effective dose, one dosimeter was placed on the anterior aspect of the chest inside the lead apron, and other dosimeter was placed on the neck outside to the thyroid protective collar. The measured readings were used to determine the effective dose using the formula which is recommended by National Council on Radiation Protection (NCRP). The highest estimated effective dose among all 3 radiographers is 0.0318 ± 0.0027 mSv which is well below the recommended dose limit of 20 mSv. The effective dose ranges per procedures were 0.010 to 0.207 μSv and 0.032 to 0.526 μSv for CAG and PCI respectively. In addition, the experimental measured data provided result that PCI cause to higher dose than CAG. This study concluded that Cath lab radiographers are well below the level of occupational radiation dose recommended by ICRP.

Key words: Cardiac catheterization procedures, Occupational dose, Radiographers, Coronary angiography, Percutaneous Coronary Intervention

I. INTRODUCTION

In last few decades, the number of fluoroscopy guided interventional (FGI) procedures has dramatically increased worldwide due to the numerous advantages offered to the patients over conventional surgery [1]. As FGI procedures are minimally invasive, patients can be recovered in short period of time and also cost effective [2]. Although there are advantages of interventional cardiology to the patients, but higher radiation exposure to the medical staff and patients have been a concern in interventional cardiology as the FGI procedures are usually complex and require more fluoroscopy time and relatively higher number cine acquisitions [3-4].

The occupational radiation protection is a considerable factor in interventional radiation procedures and should be practiced by all medical staff in cardiac catheterization laboratories. Standard tools and equipment, education and the practice are the major concerns in occupational radiation protection. To reduce the occupational dose, the patient dose should be reduced since the highest percentage of the radiation exposure is due to the scattered radiation from the patient. The compulsory usage of three shielding categories is essential to keep the occupational dose in the recommended range. The three categories include the structural, equipment mounted shielding and personal shielding devices. Lead apron with the thyroid collar are the main radiation protection gears. Other than that eye goggles and gloves also include in the personal devices [5].

Standard guidelines are available for the maximum annual exposure of the radiation workers from the NCRP (National council on radiation protection). The recommended average occupational dose per over 5 consecutive years is 20 mSv. Neither 100 mSv per 5 consecutive years nor the 50 mSv per year couldn't be exceeded [6]. A considerable number of studies have been conducted worldwide to evaluate occupational dose and the eye lens dose to cardiologist in interventional cardiology as the cardiologist is more prone to radiation exposure during the interventional cardiology procedures [7-14]. But, very limited studies are available on occupational measurements for other staff such as nurses and radiation technologists (radiographers) who work with interventional cardiology procedures. Therefore, this study aims to measure the effective dose to the radiographers who involve with cardiac-catheterization procedures in Sri Jeyawardenepura General Hospital, Sri Lanka. In addition, Coronary angiography (CAG) and Percutaneous Coronary

Intervention (PCI) procedures will be used for the occupational radiation dose evaluation for radiographers since significant amount of fluoroscopy imaging is used in these cardiac catheterization procedures.

II. MATERIALS AND METHODS

The occupational radiation exposures of 3 radiographers during the procedures of CAG and PCI were measured from July 24, 2018 to October 24, 2018 (3 months) at cardiac catheterization laboratory B of Sri Jayewardenepura General Hospital - Sri Lanka. Total 189 procedures were selected for this study among them 123 and 66 procedures were CAG and PCI respectively. The distributions of cardiac catheterization procedures are as follows: CAG - 65.08%, PCI - 34.92%. All cardiac catheterization laboratory staff exposured to the radiation has followed the radiation protection measures during the all procedures considered in this research study, such as lead attire (lead apron – front lead equivalent = 0.5 mm and back lead equivalent = 0.25 mm), thyroid collar (lead equivalent = 0.5 mm) and equipment provided personal protective equipment (PPE) (table mounted lead curtain and ceiling mounted lead glass). A ceiling mounted, PHILIPSAlluraXper FD Family, with a flat panel detector type of C – Arm machine was used in this study. Two Polimaster (Model -PM1610) electronic personal dosimeters were used to measure the effective dose.

Firstly, the two dosimeters were resettled to zero value. Then the background radiation was measured. After, the two dosimeters attached to the radiographer as follows before the procedure was started. The first dosimeter was attached on the anterior aspect of the chest inside the Lead apron. And the other dosimeter was attached on the neck in the level of the thyroid after wearing the thyroid protective collar. After each procedure was finished, the two readings of the dosimeters were taken; dosimeter at the anterior chest (H_W) and dosimeter at the neck level (H_N). In addition, Fluoroscopy time, Dose area product (DAP), Air Kerma (AK) Tube potential (kVp) and Tube current (mA) were inspected in order to make sure that all the procedures which used in the study have the similar range of characteristics.

The effective dose is calculated using the equation below which has been recommended by NCRP (National Council on Radiation Protection and Measurements, 1993).

$E\ (estimate) = 0.5H_W + 0.025H_N$

Where, H_w is reading at anterior chest level inside the lead apron and H_N is reading at neck level outside the thyroid collar.
Data analysis was performed by using the Statistical Package for the Social Science software (SPSS Software).

III. RESULTS AND DISCUSSION

Effective dose to the radiographers specifically for each procedure

Considering the effective dose to CAG procedures which performed by radiographer 1, the sum is reported as 2.350 µSv, the mean value is reported as 0.057±0.006 µSv. The maximum and minimum readings are 0.190 µSv, 0.010 µSv shown in Table 1.

Table 1: CAG procedures performed by radiographer 1 (n – number of procedures, SD – Standard Deviation)

	n	Minimum	Maximum	Sum	Mean	SD
TOTAL DOSE (µSv)	41	0.010	0.190	2.350	0.057	0.039
NUMBER OF VIEWS	41	6.00	39.00	417.00	10.17	5.18
AIR KERMA (mGy)	41	100.96	2751.14	24486.11	597.22	476.85
DAP ($mGycm^2$)	41	5908.00	133164.00	1574469.00	38401.68	29595.75
FLUORO TIME (seconds)	41	0.59	29.03	252.77	6.17	5.78

Considering the effective dose to PCI procedures which performed by radiographer 1, the sum is reported as 3.230 µSv, the mean value is reported as 0.216±0.026 µSv. The maximum and minimum readings are 0.480 µSv, 0.100 µSv shown in Table 2.

Table 2: PCI procedures performed by radiographer 1

	n	Minimum	Maximum	Sum	Mean	SD
TOTAL DOSE (µSv)	15	0.100	0.480	3.230	0.216	0.102
NUMBER OF VIEWS	15	23.00	75.00	680.00	45.33	17.33
AIR KERMA (mGy)	15	1542.48	6654.41	54637.52	3642.50	1334.95
DAP (mGycm^2)	15	61158.00	273538.00	2639748.00	175983.20	65168.68
FLUORO TIME (seconds)	15	15.38	59.26	491.16	32.74	14.07

Considering the effective dose to CAG procedures which performed by radiographer 2, the sum is reported as 2.330 µSv the mean value is reported as 0.053±0.006 µSv. The maximum and minimum readings are 0.210 µSv, 0.010 µSv shown in Table 3.

Table 3: CAG procedures performed by radiographer 2

	n	Minimum	Maximum	Sum	Mean	SD
TOTAL DOSE (µSv)	44	0.010	0.210	2.330	0.053	0.039
NUMBER OF VIEWS	44	6.00	19.00	426.00	9.68	2.61
AIR KERMA (mGy)	44	127.46	1513.03	20103.44	456.90	270.68
DAP (mGycm^2)	44	7368.00	90847.00	1253117.00	28479.93	18049.65
FLUORO TIME (seconds)	44	1.24	20.29	224.44	5.10	4.93

Considering the effective dose to PCI procedures which performed by radiographer 2, the sum is reported as 2.810 µSv the mean value is reported as 0.113±0.017 µSv. The maximum and minimum readings are 0.350 µSv, 0.020 µSv shown in Table 4.

Table 4: PCI procedures performed by radiographer 2

	N	Minimum	Maximum	Sum	Mean	SD
TOTAL DOSE (µSv)	25	0.020	0.350	2.810	0.113	0.086
NUMBER OF VIEWS	25	8.00	82.00	728.00	29.12	22.60
AIR KERMA (mGy)	25	196.37	4665.26	39332.13	1573.29	1334.24
DAP (mGycm^2)	25	11089.00	162756.00	1647210.00	65888.40	48169.22
FLUORO TIME (seconds)	25	2.00	68.03	457.35	18.29	16.28

Considering the effective dose to CAG procedures which performed by radiographer 3, the sum is reported as 2.310 µSv, the mean value is reported as 0.061±0.008 µSv. The maximum and minimum readings are 0.180 µSv, 0.010 µSv shown in Table 5.

Table 5: CAG procedures performed by radiographer 3

	N	Minimum	Maximum	Sum	Mean	SD
TOTAL DOSE (µSv)	38	0.010	0.180	2.310	0.061	0.047
NUMBER OF VIEWS	38	6.00	39.00	448.00	11.79	8.34
AIR KERMA (mGy)	38	194.04	3108.92	27787.04	731.24	705.57
DAP ($mGycm^2$)	38	8898.00	157760.00	1718318.00	45218.90	41385.13
FLUORO TIME (seconds)	38	1.18	44.09	348.29	9.17	11.92

Considering the effective dose to PCI procedures which performed by radiographer 3, the sum is reported as 5.630 µSv, the mean value is reported as 0.217±0.023 µSv. The maximum and minimum readings are 0.530 µSv, 0.030 µSv shown in Table 6.

Table 6: PCI procedures performed by radiographer 3

	N	Minimum	Maximum	Sum	Mean	SD
TOTAL DOSE (µSv)	26	0.030	0.530	5.630	0.217	0.119
NUMBER OF VIEWS	26	13.00	85.00	1017.00	39.12	20.94
AIR KERMA (mGy)	26	855.35	8535.92	87707.29	3373.357	2375.028
DAP ($mGycm^2$)	26	39071.00	467246.00	4442991.00	170884.27	119538.62
FLUORO TIME (seconds)	26	9.14	103.35	812.30	31.24	20.55

Calculation of annual estimated effective dose for a radiographer

The calculated mean effective dose per each procedure and for three radiographers are shown in table 7. And, the mean procedures per month for each radiographer were calculated from total number of interventional procedures which were collected in duration of three months (table 8).

Table 7: Mean effective dose per procedure

	Radiographer 1	Radiographer 2	Radiographer 3
CAG(D_{CAG})(µSv)	0.057± 0.006	0.053 ± 0.006	0.061 ± 0.008

PCI (D_{PCI}) (µSv)	0.216 ± 0.026	0.113 ± 0.017	0.217 ± 0.023

Table 8: Mean procedures per month

	Radiographer 1	Radiographer 2	Radiographer 3
CAG (N_{CAG})	41/3	44/3	38/3
PCI (N_{PCI})	15/3	25/3	26/3

To calculate the annual effective dose, the following quantities were defined.

Mean effective dose per case for PCI = D_{PCI}
Mean effective dose per case for CAG = D_{CAG}
Mean no of cases per month for PCI = N_{PCI}
Mean no of cases per month for CAG = N_{CAG}

As the effective dose was measured for three months duration, the annual effective dose for each radiographer can be calculated using the formula,

$$Annual\ effective\ dose = (D_{PCI} \times N_{PCI} \times 12) + (D_{CAG} \times N_{CAG} \times 12).$$

The estimated annual effective dose for radiographer 1, radiographer 2, and radiographer 3 were 0.0223±0.0010 mSv, 0.0206 ± 0.0020 mSv, and 0.0318 ± 0.0027 mSv respectively. The highest estimated annual effective dose of radiographer 3 is 0.0318 ±0.0027 mSv is well below the recommended dose limit of 20 mSv as adopted from the ICRP recommendations. The annual occupational dose to the radiographer ranged from 0.0206 ± 0.0020 mSv to 0.0318 ± 0.0027 mSv with an average value of 0.0249 ± 0.0019 mSv. Efstathopoulos E P et.al [15] have been found that the effective dose per year was estimated as 0.04-0.05 mSv for the radiographer and 0.03-0.04 mSv for those who assisted. These measurements for radiographer were similar to the values found from this study. It should be emphasized that such measurements were carried out in a limited number of interventional procedures, doses to staff could be much higher in some other more complex procedures. There are personal radiation monitoring for the staff, this implies that the radiation dose to the operator during cardiac procedures might be reduced by improving radiation protection practices.

This analysis indicates that, higher effective doses during PCI than CAG. Kim K P et al [16] had reviewed available literature and found that the effective dose per procedure ranged from 0.02 to 30.2 µSv for CAG, 0.17 to 31.2 µSv for PCI. In this study the monitored effective dose ranges per procedure were 0.010 to 0.207 µSv and 0.032 to 0.526 µSv for CAG and PCI respectively.

IV. CONCLUSION

The measured annual effective doses for three radiographers who participated in this study conducted at cardiac catheterization laboratory Sri Jayewardenepura General Hospital, Sri Lanka were 0.0223 ± 0.0010 mSv, 0.0206 ± 0.0020 mSv and 0.0318 ± 0.0027 mSv per year respectively. Effective doses to the radiographer depend on the procedure type either CAG or PCI. The radiation protection programme carried out at Sri Jayewardenepura General Hospital was effective due to correctly applying the international and local recommended regulations. Therefore, the occupational radiation dose to radiographers in the studied place is far below than the IRCP recommended value of 20 mSv.

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