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Estimation of Radiation Dose Rate of Radiological Unit Personnels in Some Teaching Hospitals in Southern Nigeria

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Abstract: The purpose of this study was to evaluate the radiation dose received by staff of the radiology departments of four tertiary health facilities in Southern Nigeria. This is of great importance due to the risks associated with ionizing radiation. To acquire occupational radiation dose, the dose history of the workers was retrieved from the personnel data base of the hospitals. Staff dose records were analyzed from Instadose dosimeter readings for the period January to December 2014. The cancer risk to staff was calculated from these results. The results from the Instadose readings show that the risk to staff for the hospitals was in the order; University of Uyo Teaching Hospital (UUTH) > Braithwaite Memorial Specialist Hospital (BMSH) > University of Port Harcourt Teaching Hospital (UPTH) > Federal Medical Center Owerri (FMCO). Federal Medical Center Umuahia (FMCU) staff had readings which were below detectable limits. The annual occupational dose to the workers ranged from 0.03 to 0.32 mSv/y, this is significantly lower than the annual occupational limit of 20 mSv/y averaged over a five year period and 50 mSv/y in any one year set by the ICRP.

Keywords: Instadose Dosimeter, Occupational Dose, Cancer risk, Detectable Limit

1. Introduction

Humans everywhere are regularly exposed to natural low level background radiation. They are also exposed to radiation from man-made sources mostly from medical exposure. Ionizing radiation is known to cause hazardous effects to different organs and systems in the human body such as the digestive system, skin, reproductive system, central nervous system and ultimately the entire body [1]. When humans are exposed to ionizing radiation it can give rise to effects such as skin cancer, erythema, cataracts and mutation of genes [2]. Medical Imaging accounts for the largest radiation exposure of population from artificial sources of radiation [3]. Some X-ray machines of recent design are able to provide information on radiation exposure in the form of absorbed dose. An example of such device would be a large area ionization chamber installed in the X-ray machine, which would allow radiation input to be measured directly. For X-ray machines lacking similar capability, it would be desirable to find an alternative means to measure radiation output. Radiographic film is used to record the skin entrance radiation exposure. It has the ability to record high radiation dose. Radiation exposure poses hazards for health-care providers as well as patients in health-care facilities (HCFs). Radiographic imaging is extremely valuable as a diagnostic tool in medicine, but ionizing radiation and computed tomography (CT) scan carry well-known potential risks. Personnel and radiation safety monitoring is an important safety precaution in the practice of radiography [3].

The first substantial epidemiological evidence for the carcinogenic effects of radiation was obtained from observations on radiologists [4]. The use of radiation in medicine grew throughout the last century and currently includes a variety of diagnostic techniques: (Fluoroscopy, cardiac catherization, dental radiography, radionuclides used for organ imaging in nuclear medicine, radiotherapy and other uses such as biomedical research). Initially it was X-rays that were employed but techniques became more sophisticated such that other radiations (Densely ionizing alpha particles and neutrons) were introduced. Medical workers now constitute the largest group occupationally exposed to man-made sources of radiation [5]

The characterization of medical applications, in terms of occupational exposures, is sometimes done by reporting an average annual individual dose for all exposed and/or measurably exposed workers. In practical radiation protection, this approach is, however, meaningless, as individual doses in the medical field differ substantially. During the evaluation of dosimetric data, one needs information about the distribution of the yearly doses. It is important to know how many people receive doses lower than X and higher than Y? When individual monitoring is used as a tool in practical radiation protection, it is important to know if the order of magnitude of the individual dose is defined by the nature of the procedure, the individual workload, the level of radiation protection measures, or the methodology of the assessment [6].

Monitoring of radiation doses received by staff in radio-diagnostic centers is of great importance to the radiographers in their effort to protect themselves, patients and the general public from the untold effect of excessive radiation. It is clearly sensible for those involved in the use of ionizing radiation in diagnostic radiology to have an appreciation of the possible risks involved. For radiographers measurement of radiation doses received at periodic intervals represent a way of monitoring doses to ensure that they are within safe occupational limits [7].

Personnel radiation monitoring is also essential to ensure that dose limits for staff are not exceeded. The dose limits for staff were published by the International Commission on Radiological Protection (ICRP) [5] and subsequently in the ionizing radiation regulations. A downward revision was done in 1991 by revaluation of data on risks. The effective annual dose limit was formerly 50 mSv and the newly adapted effective annual dose limit is 20 mSv averaged over five years [8]. The downward review of annual dose limit was to put stricter control over the use of ionizing radiation in medicine and minimize possible hazards, especially the stochastic effects [4].

The wide range of medical X- ray equipment in modern diagnostic radiology has led to faster and better diagnoses of large number of diseases. Since X- ray examinations are the most frequently used ionizing radiation in medicine, they have become the most significant source of medical radiation exposure globally. Therefore medical diagnostics using X-rays are the main source of radiation for this study. Medical diagnostics using X – rays include such activities as general/plain X-ray, mammography, fluoroscopy and computed tomography (CT).

The risk from medical radiation exposure is seen to increase with higher radiation doses [9]. There is an increase in the use of radiation in modern medicine arising from the introduction of numerous new radiological procedures [10, 5]. During this medical diagnostic and therapeutic procedures, workers are exposed to certain level of radiation from both primary beam and scattered radiations. The as low as reasonably achievable (ALARA) principle, which emphasizes utilizing techniques and procedures to keep exposure to a level as low as reasonably achievable, should be followed to minimize the risk of radiation exposure to medical professionals. Personnel shielding options (e.g., two-piece wraparound aprons, thyroid shields, and eye protection) should be used to effectively attenuate scattered x-ray levels. [6]. This study is a pilot study to estimate radiological personnel absorbed radiation dose due to exposure to x-rays during medical diagnosis using personnel dosimeter in Teaching hospitals in Nigeria. This research work is intended to provide radiologist and other users of X-ray equipment one means of achieving compliance with the International Commission on Radiological Protection recommendation [3].

2. Materials and Method

A secondary data was used in this study. The radiation doses of some radiological workers were collected from four selected teaching hospitals. The radiology unit staff monitored, were issued with an Instadose Dosimeter. They were then registered on the hospital computer and the device was initialized for use. The staff were expected to wear the dosimeter whenever they are performing any medical procedure, after which it is stored in a safe place. The dosimeter is worn at the chest level below the lead apron.

The radiation safety officer in each hospital is in charge of collecting the dosimeters for reading. They are read quarterly, yearly or as the need arises. The number of staff used for this study from Braithwaite memorial hospital BMSH was 38 which consisted of 5 Consultant Radiologists (CR), 11 Medical Imaging Scientists (MIS), 7 Radiology Specialist Registrars (RSR), 3 Support Staff (SS) and 12 Technicians. The staff of University of Port Harcourt Teaching Hospital (UPTH) used for this study was 26, consisting of 3 Consultant Radiologists (CR), 7 Resident Radiologists (RR), 11 Radiographers (R), 1 Dark Room Technician (DRT), 2 X – ray Assistants (XRA), 1 Admin. Clerical Staff (ACS) and 1 Cleaner (C). The staff of Federal Medical Centre Owerri (FMCO) used for this study were 7 (1 Consultant (C), 1 Registrar (RGT), 1 Dark Room Technician (DT) and 4 Radiographers (R)). University of Uyo teaching hospital (UUTH) had only 2 Radiographers.

The values recorded from the Instadose dosimeters were used to quantify the health risk of those workers that was exposed during their working condition.

3. Estimation of Occupational Radiation Risk

To obtain an effective dose, the absorbed organ dose D_T is first corrected for the radiation type using factor W_R to give a weighted average of the equivalent dose quantity H_T received in irradiated body tissues and result is further corrected for the tissues or organs being irradiated using factor W_T to produce the effective dose quantity (E).

$$E = \sum_T W_T \sum_R W_R \text{ x } \frac{\int_T^1 D_{R\,(x,y,z)\rho}}{\int_T^1 \rho(x,y)} \quad (1)$$

Where E is the effective dose to the entire organism, W_T is the tissue weighting factor defined by regulation, W_R is the radiation weighting factor defined by regulation. DR is the absorbed dose from type radiation type R as a function of location.

The probability of cancer induction due to radiation exposure received by the staff of the selected hospitals was calculated using equation (2).

The ICRP proposes a value of 5% per Sv of the standard population to estimate fatal cancer risk from effective dose calculated for the workers.

$$\text{Probability of Fatal Cancer Risk} = 0.05 * E \quad (2)$$

Where E is the effective dose (mSv).

4. Results

The results of the doses absorbed by deferent workers of the selected teaching hospitals with their organ dose are presented in Tables 1-4.

Table 1. *Dose readings for BMSH and the calculated organ doses.*

S/N	Work Group	Absorbed Dose (mSv)	Dose Equivalent (mSv)	Dose (Gonads) (mSv)	Dose (Lung) (mSv)	Dose (Thyroid) (mSv)	Dose (Skin) (mSv)
1	CR1	0.09	0.09	0.018	0.011	0.005	0.001
2	CR2	0.08	0.08	0.016	0.01	0.004	0.001
3	CR3	0.08	0.08	0.016	0.01	0.004	0.001
4	CR4	0.18	0.18	0.036	0.022	0.009	0.002
5	CR5	0.06	0.06	0.012	0.007	0.003	0.001
6	MIS1	0.09	0.09	0.018	0.011	0.005	0.001
7	MIS3	0.23	0.23	0.046	0.028	0.012	0.002
8	MIS5	0.17	0.17	0.034	0.02	0.009	0.002
9	MIS6	0.2	0.2	0.04	0.024	0.01	0.002
10	MIS8	0.15	0.15	0.03	0.018	0.008	0.002
11	MIS9	0.18	0.18	0.036	0.022	0.009	0.002
12	MIS10	0.25	0.25	0.05	0.03	0.013	0.003
13	MIS13	0.21	0.21	0.042	0.025	0.011	0.002
14	MIS15	0.12	0.12	0.024	0.014	0.006	0.001
15	MIS16	0.09	0.09	0.018	0.011	0.005	0.001
16	MIS18	0.25	0.25	0.05	0.03	0.013	0.003
17	RSR1	0.06	0.06	0.012	0.007	0.003	0.001
18	RSR2	0.11	0.11	0.022	0.013	0.006	0.001
19	RSR4	0.08	0.08	0.016	0.01	0.004	0.001
20	RSR5	0.16	0.16	0.032	0.019	0.008	0.002
21	RSR6	0.06	0.06	0.012	0.007	0.003	0.001
22	RSR7	0.03	0.03	0.006	0.004	0.002	0
23	RSR8	0.09	0.09	0.018	0.011	0.005	0.001
24	SS7	0.14	0.14	0.028	0.017	0.007	0.001
25	SS8	0.14	0.14	0.028	0.017	0.007	0.001
26	SS11	0.06	0.06	0.012	0.007	0.003	0.001
27	T2	0.13	0.13	0.026	0.016	0.007	0.001
28	T3	0.16	0.16	0.032	0.019	0.008	0.002
29	T4	0.16	0.16	0.032	0.019	0.008	0.002
30	T5	0.13	0.13	0.026	0.016	0.007	0.001
31	T6	0.14	0.14	0.028	0.017	0.007	0.001
32	T7	0.16	0.16	0.032	0.019	0.008	0.002
33	T11	0.19	0.19	0.038	0.023	0.01	0.002
34	T12	0.16	0.16	0.032	0.019	0.008	0.002
35	T13	0.12	0.12	0.024	0.014	0.006	0.001
36	T14	0.14	0.14	0.028	0.017	0.007	0.001
37	T15	0.25	0.25	0.05	0.03	0.013	0.003
38	T16	0.06	0.06	0.012	0.007	0.003	0.001
	Average	0.14	0.14	0.03	0.02	0.01	0.001

Table 2. *Dose readings for UUTH and the Calculated Organ Doses.*

S/N	Work Group	Absorbed Dose (mSv)	Dose Equivalent (mSv)	Dose (Gonads) (mSv)	Dose (Lung) (mSv)	Dose (Thyroid) (mSv)	Dose (Skin) (mSv)
1	R1	0.24	0.24	0.048	0.029	0.012	0.002
2	R2	0.16	0.16	0.032	0.019	0.008	0.002
	Average	0.2	0.2	0.04	0.024	0.01	0.002

Table 3. *Absorbed Doses and the Calculated Organ Doses for UPTH.*

S/N	Work Group	Absorbed Dose (mSv)	Dose Equivalent (mSv)	Dose (Gonad) (mSv)	Dose (Lung) (mSv)	Dose (Thyroid) (mSv)	Dose (Skin) (mSv)
1	CR1	0.07	0.07	0.014	0.008	0.004	0.001
2	CR3	0.08	0.08	0.016	0.01	0.004	0.001
3	CR4	0.07	0.07	0.014	0.008	0.004	0.001
4	RR3	0.05	0.05	0.01	0.006	0.003	0.001
5	RR4	0.03	0.03	0.006	0.004	0.002	0
6	RR7	0.32	0.32	0.064	0.038	0.016	0.003
7	RR8	0.11	0.11	0.022	0.013	0.006	0.001
8	RR10	0.07	0.07	0.014	0.008	0.004	0.001
9	RR11	0.05	0.05	0.01	0.006	0.003	0.001
10	RR17	0.06	0.06	0.012	0.007	0.003	0.001
11	R1	0.04	0.04	0.008	0.005	0.002	0
12	R2	0.06	0.06	0.012	0.007	0.003	0.001
13	R3	0.07	0.07	0.014	0.008	0.004	0.001
14	R6	0.09	0.09	0.018	0.011	0.005	0.001
15	R7	0.12	0.12	0.024	0.014	0.006	0.001
16	R8	0.03	0.03	0.006	0.004	0.002	0
17	R9	0.05	0.05	0.01	0.006	0.003	0.001
18	R10	0.17	0.17	0.034	0.02	0.009	0.002
19	R11	0.11	0.11	0.022	0.013	0.006	0.001
20	R12	0.1	0.1	0.02	0.012	0.005	0.001
21	R14	0.12	0.12	0.024	0.014	0.006	0.001
22	DRT3	0.07	0.07	0.014	0.008	0.004	0.001
23	XRA1	0.19	0.19	0.038	0.023	0.01	0.002
24	XRA2	0.14	0.14	0.028	0.017	0.007	0.001
25	ACS5	0.1	0.1	0.02	0.012	0.005	0.001
26	C2	0.06	0.06	0.012	0.007	0.003	0.001
	Average	0.09	0.09	0.019	0.011	0.005	0.001

Table 4. *Absorbed Doses and the Calculated Organ Doses for FMCO.*

S/N	Work Group	Absorbed Dose (mSv)	Dose Equivalent (mSv)	Dose (Gonad) (mSv)	Dose (Lung) (mSv)	Dose (Thyroid) (mSv)	Dose (Skin) (mSv)
1	C1	0.04	0.04	0.008	0.005	0.002	0
2	RGT4	0.12	0.12	0.024	0.014	0.006	0.001
3	DT3	0.03	0.03	0.006	0.004	0.002	0
4	R4	0.16	0.16	0.032	0.019	0.008	0.002
5	R6	0.03	0.03	0.006	0.004	0.002	0
6	R8	0.04	0.04	0.008	0.005	0.002	0
7	R9	0.07	0.07	0.014	0.008	0.004	0.001
	Average	0.07	0.07	0.014	0.008	0.004	0.001

Table 5. *Cancer Risk and associated risk for different work years.*

S/N	Hospital	Mean Staff Dose (mSv)	Cancer Risk	CR after 10 yrs	CR after 20 yrs	CR after 30 yrs	CR after 40 yrs	CR after 50 yrs	CR after 60 yrs	CR after 70 yrs
1	BMSH	0.14	0.007	0.07	0.14	0.21	0.28	0.35	0.42	0.49
2	FMCO	0.07	0.004	0.04	0.07	0.11	0.14	0.18	0.21	0.25
3	UUTH	0.2	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7
4	UPTH	0.09	0.005	0.05	0.09	0.14	0.18	0.23	0.27	0.32

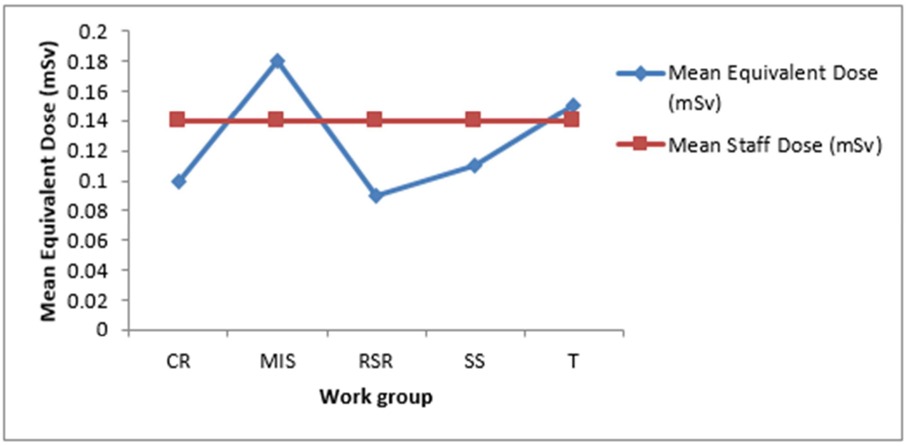

Figure 1. *Comparison of mean equivalent dose for different work groups for BMSH with the staff mean equivalent dose.*

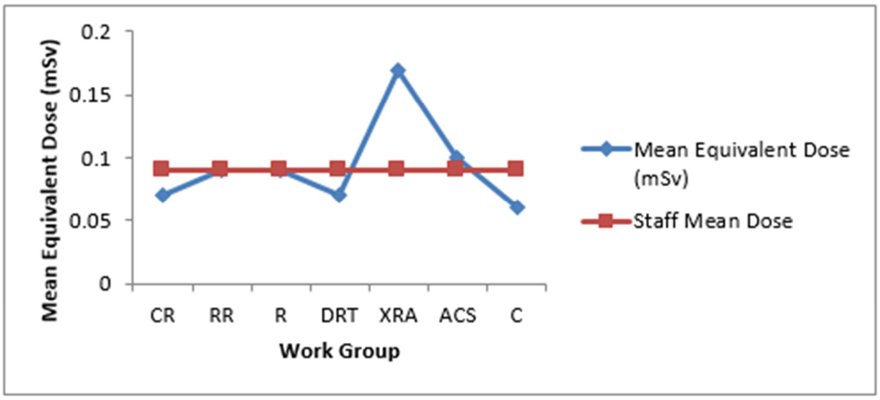

Figure 2. *Comparison of mean equivalent dose for different work groups for UPTH with the staff mean equivalent dose.*

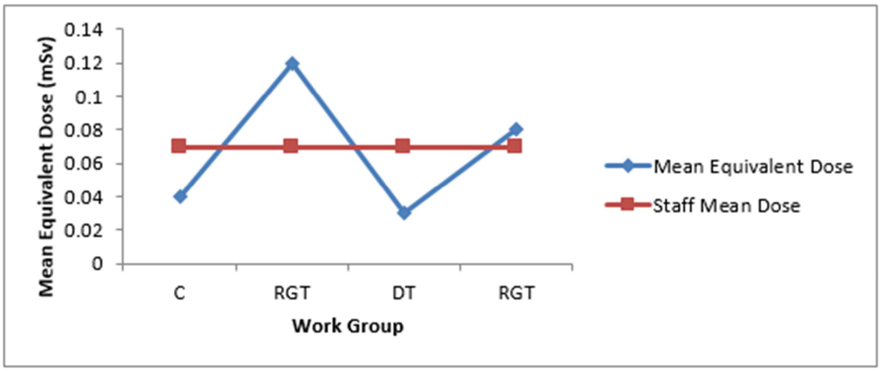

Figure 3. *Comparison of mean equivalent dose for different work groups for FMCO with the staff mean equivalent dose.*

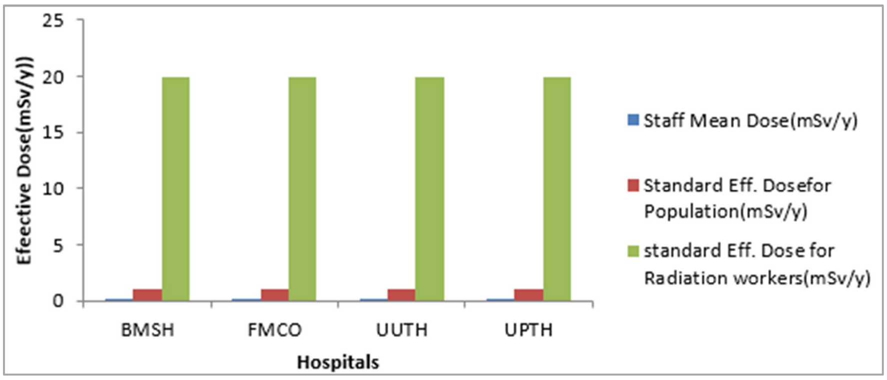

Figure 4. *Comparison of mean staff dose for the hospitals with World standards for general population and radiation workers.*

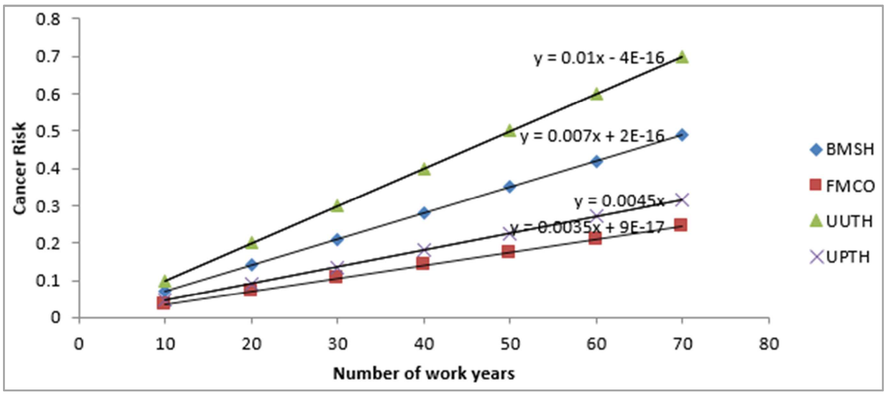

Figure 5. *Cancer risk for the hospitals versus the number of years the staff is in employment.*

5. Discussions

Effective dose and Risk Assessment

Radiological assessment of diagnostic operations and dose to workers are performed as necessary to ensure that the overall dose impact from these activities is As Low As Reasonably Achievable (ALARA) to members of the public, radiological workers and the environment. The assessment also ensures that facilities and operations are in compliance with federal, state and local regulations. The effective dose measured using instadose meter for radiographers and other staff of radiological units of four teaching hospitals are presented in Tables 1-4. The effective dose for BMSH ranged from 0.03 to 0.25 mSv with a mean of 0.14 mSv and UPTH ranged from 0.03 to 0.32 mSv with a mean of 0.09 mSv. The effective dose for FMCO ranged from 0.03 to 0.16 mSv with a mean of 0.07 mSv while that of UUTH ranged from 0.016 to 0.24 with a mean of 0.20 mSv for a duration of one year. The values for the hospital are significantly below the annual occupational limit of 20 mSv/y averaged over any 5 yr period and 50 mSv in any one year set by ICRP [11].

The result from this study is significantly lower than that from other studies. [10] had values that ranged from 1.2 to 2.2 mSv, Memon *et al*. [12] had values that ranged from 0.1 to 3.6 mSv, while Botwe *et al*. [13] had values that ranged from 0.28 to 0.97 mSv. All these results were higher than the one obtained in this work. This could be attributed to a lack of compliance to medical procedure safety guidelines by workers on the usage of the dosimeters during imaging. It is therefore important that the hospital management enforce the wearing of the dosimeters. The total staff used for this study for the hospitals are not the only staff being monitored, but are those whose absorbed dose values are above the detectable limit [14]

Figure 4 shows the comparison of the mean staff dose for the hospitals. The results show that UUTH has the highest staff mean dose and FMCO has the lowest. The mean staff doses for the hospitals are significantly lower than the annual occupational limit of 20 mSv/y averaged over any five year period and 50 mSv in any one year set by the ICRP. Figure 5, shows the relationship between cancer risk and the years a worker puts in at work. The result shows that the cancer risk to staff of the hospitals is in the order of UUTH > BMSH > UPTH > FMCO. UUTH having the highest value could be attributed to the fact that only two staff had readings above the detectable reading and the two values were quite high thereby giving it the highest mean value [15].

The limitation of this study is that the wearing of the radiation badge is subject to the user's capacity of remembering to put the badge on. We did not have an estimate of the compliance for wearing the dosimeter. This may represent a source of significant underestimation of calculated risk. An additional limitation is that we evaluated doses under the apron at chest level. Wearing an additional dosimeter at the collar level above the lead apron would provide an indication of the head (eye) dose and a better approximation (combined with under apron dosimetry) of the whole body dose [16]. However ICRP report 85, states that a single dosimeter worn under the lead apron will yield a reasonable estimate of effective dose for most instances.

6. Conclusion

Protection of workers against radiation is necessary to reduce the level of occupational cancer risk among radiology staff. The occupational exposure of staff in the selected hospital is at an acceptable level. There is need for continuous monitoring to make sure the levels are not exceeded. It was also observed that some of the staff monitored had dose readings below the detectable limit. This can be attributed to lack of discipline in wearing the dosimeters as at when due. One of the hospitals, FMCU had dose readings of zero for all the staff monitored. Therefore it is either the dosimeters are not working or that the staff are not wearing them. It is therefore very important that the hospital management put in place systems that will ensure that the staff wear their dosimeters as they perform procedures

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