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Risk Assessment of Occupational Exposure of Workers Engaged in Radiation Practice without Monitoring Devices

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ABI and ADF designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors BBS and ABI managed the analyses of the study. Authors ABI and ADF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Objective: This study was carried out to evaluate occupational dose of personnel, engaged in radiation work without wearing monitoring device, at five diagnostic centres in Abeokuta, Ogun State metropolis, namely, Rainbow, New image, Bethel, Akinolugbade and Abiolad.

Materials and Methods: Thermoluminescent dosimeters (TLDs) obtained from Radiation Protection Services, Lagos State University (LASU), Ojo were used for dose measurements. LASU is accredited by the Nigerian Nuclear Regulatory Authority (NNRA) to provide radiation monitoring services. The TLDs were distributed to each of the centre for personnel and area (control and supervised) monitoring. The period of exposure of the TLDs was three months. The exposed TLDs were returned to LASU for processing. The effective dose received by personnel per quarter was extrapolated to annual effective dose to make comparison with the International Commission on

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Radiation Protection (ICRP) recommended dose limit. The stochastic effect of the measured dose was also estimated.
Results: Annual effective dose received by all personnel ranged from 1.16 - 2.54 mSv. While the highest value was obtained by personnel at Bethel diagnostic centre, the lowest value was obtained at Akinolugbade. The risk of cancer associated with these values, estimated for a million population, was 112 and 61 at Bethel and Akinolugbade respectively.
Conclusion: This study showed that the annual effective doses to personnel at these centres were below the ICRP recommended dose of 20 mSv per annum. However, the Managements of these diagnostic centres should provide monitoring devices for their radiation workers in line with NNRA authorization requirements.

Keywords: Radiation workers; personnel monitoring devices; effective dose; radiation risk; diagnostic centres.

1. INTRODUCTION

Radiation is the energy emitted from a source, transmitted through an intervening medium or space and consequently absorbed by another medium [1]. Transmission is in the form of either waves or particles and this reflects the dual nature of radiation under quantum physics [1]. Ionizing radiation has sufficient energy to produce ions in matter at the molecular level and this could result into damages to DNA and denaturation of proteins [2]. These damages to individual cell are called radiation hazards and can be conveniently divided into two classes namely, somatic effects and hereditary or genetic effects [3]. Somatic effects are those arising from damages to the cell of the body and affect only the irradiated person [3]. Hereditary effects are effects due to damage of the cell in the reproductive organ, which may later manifest itself in the offspring and the future generation [3,4]. The magnitude of radiation hazards is a function of radiation absorbed dose by an individual through either medical exposure or occupational exposure [5]. Monitoring of radiation doses received by radiation workers is of great importance and it is part of the principles of radiation protection measures needed to be put in place to ensure adequate protection of personnel from excessive radiation exposure during their routine working hours [5]. The assessment of radiation doses received by radiation workers at regular intervals will ensure their occupational safety at work.

Also, personnel radiation monitoring is a means by which radiation workers can be assured that their annual absorbed dose does not exceed the dose limit recommended by the International Commission on Radiological Protection, ICRP [6]. The ICRP's recommended dose limit for radiation worker was 50 mSv per annum as at 1977 but a downward review, done in the year 1991, brought the dose limit to 20 mSv per annum averaged over five years. The downward review of annual dose limit was adopted in order to put a stricter control over the use of ionizing radiation in medicine and minimize possible hazards, especially the stochastic effects [7]. In spite of the hazards associated with radiation exposure of radiation workers, personnel radiation monitoring is still not being practice in some diagnostic centres in Nigeria. All the diagnostic centres considered in this study did not provide monitoring devices for their workers, thereby exposing workers to radiation doses that cannot be quantified. Without wearing appropriate monitoring devices, the record of radiation absorbed dose by radiation workers becomes difficult thereby making it impossible to evaluate the workers' radiation history and possible associated risk. Also, proper record of radiation dose received by personnel enhances radiation protection practice in clinical settings. According to Rosenbloom [8], determination of radiation dose received by personnel will ensure reduction in possible biological effects of ionizing radiation. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported that cancer can be induced in radiation workers due to long excessive exposure to ionizing radiation [9]. Although personnel radiation monitoring is an important safety precaution in radiation practice, it does not in itself provide protection against ionizing radiation. Its main purpose is to measure radiation dose received by radiation workers against the permissible dose limit of 20 mSv per annum averaged over 5 years [10]. Personnel monitoring is also needed to fulfil the regulatory requirements for a good radiation practice. Thermoluminescent dosimetry (TLD) is the most widely used technology for personnel monitoring dosimetry [11-13]. A well designed, not too aged and maintained x-ray equipment coupled with the use of appropriate exposure parameters by trained operators can significantly minimize unnecessary radiation exposure to patients with no loss in image quality. This will in turn produce a decrease in scattered radiation dose reaching the operators.

The Nigerian Nuclear Regulatory Authority, NNRA, expected the Licensee or the Registrant to provide their radiation workers with personnel monitoring devices for measurement of their absorbed dose at work as part of the authorization requirements for licensing a centre for radiation practice [14]. However, there are still many diagnostic centres in Nigeria, who are yet to comply with the NNRA regulation making it difficult to determine the radiation doses received by their radiation workers and at other diagnostic centres, where personnel are provided with monitoring devices, they are not processed as at when due and their provisions in some cases are insufficient for all radiation workers. The aim of this study is to assess occupational exposure of radiation workers, who were actively engaged in radiation practice but were not provided with appropriate radiation monitoring devices, at selected private diagnostic centers in Abeokuta, Ogun State and estimate the stochastic effect of their absorbed doses of radiation.

2. MATERIALS AND METHODS

Five diagnostic centres located in Abeokuta, Ogun State metropolis were included in this study. They are Rainbow diagnostic centre along Ewang road (Rainbow), New image ultrasound and diagnostic centre at Olorunsogo road (New Image), Bethel diagnostic centre at Ijaye road (Bethel), Akinolugbade hospital at Akinolugbade road (Akinolugbade) and Abiolad medical diagnostic center at Fajor along Obantoko road (Abiolad). Three radiation workers, who operated the X-ray machine, were monitored at each of the centres.

Five thermoluminescent dosimeters (TLD) for measuring radiation doses were used per centre: Three were worn by radiation workers (Radiographers) during their working hours while the remaining two were placed in the control and supervised areas of the department respectively. The TLD badges worn by the Radiographers were processed after three months (quarter of a year) of wearing and the absorbed dose extracted while the TLDs placed in the control and supervised areas were processed after one month of exposure for three consecutive months. All the exposed TLDs were processed for extraction of the effective doses at the Radiation Protection Unit, Lagos State University, Ojo. The TLDs measure doses to the whole body and the skin in terms of the radiation quantities H_p (10) and H_p (0.07) as displayed by the TLD reader. The depth dose or H_p (10) is the dose at an average depth of 10 cm, representing average dose to organs while the skin dose or H_p (0.07) represents the dose to the skin [15]. All radiation doses are calculated as average of these values.

The detailed information about the X-ray machines found at each centre, the effective dose obtained from the processed TLDs and the estimated risk of cancer were recorded and presented in Tables. The risk of cancer was calculated using the equation below:

$$Risk\ of\ cancer\ = Effective\ dose\ (mSv) * dose\ to\ risk\ conversion\ factor\ for\ cancer$$

The conversion factor of 5×10^{-2} per Sv was used to estimate the risk of cancer from the extrapolated annual effective dose.

3. RESULTS

The basic information about the X-ray machine found at each of the centre considered in this study are presented in Table 1. The mean radiation dose measured at the control and supervised areas at each centre for a period of three consecutive months is presented in Table 2. The accumulated radiation doses received by three different personnel at each of the centre for a period of three months (one quarter) are presented in Table 3. The average dose received by personnel at each centre per annum, extrapolated from the average dose received per quarter is presented in Table 4. The estimated risk of cancer (stochastic effect) to which radiation workers at each of the centre are being exposed is presented in Table 5.

4. DISCUSSION

It was observed that the age of most (60%) of the diagnostic x-ray machine considered in this study are above 10 years (13 – 16 years) while the rest are below 10 years (5 – 6 years) as presented in Table 1. Out of the five centres considered, only one has 2-unit of x-ray machine making a total of

6 units. Of these x-ray units, 4 (66%) are analogue while 2 (33%) are digital type x-ray machine. The maximum tube voltage (kVp) of most of these x-ray machines is 125 while the maximum tube loading (mAs) of most of them was 200.

The effective dose (mSv) measured in the control and the supervised areas in all the diagnostic centres considered in this study is less than 1 mSv (0.33 – 0.78 mSv) as presented in Table 2. The effective dose (mSv) received by individual personnel per quarter at each of the centres

Table 1. Basic information about X-ray machine at the centres under study

Centres/ parameters	Rainbow	New image	Bethel	Akinolugbade	Abiold
No. of X-ray Machine	1	1	2	1	1
Type of X-ray Machine	Digital	Analogue	Both	Analogue	Analogue
Model No	AMX4	5189248	E7239X	YZ-300	E7239X
Manufacturer	General Electric	Ge Hualin Medical Sys	Eschmed Medical Eng.	Gulfex Medical Eng.	Allengance
Year of Manufacture	2003	2013	2014	2006	2005
Filtration	2.0 mm Al @ 100 kVp	1.5 mm Al @ 100 kVp	1.5 mm Al	-	0.9 mm Al @ 75 kVp
Max kVp	125	150	125	125	125
Max mAs	200	-	400	189	200

Table 2. Effective dose at the control and supervised areas of centres under study

Diagnostic centres	Radiation in the control area (mSv)		Radiation in the supervised area (mSv)	
	Depth dose	Skin dose	Depth dose	Skin dose
Rainbow	0.53	0.58	0.49	0.47
New Image	0.41	0.43	0.32	0.34
Bethel	0.71	0.78	0.69	0.70
Akinolugbade	0.34	0.35	0.33	0.34
Abiolad	0.35	0.38	0.34	0.36

Table 3. Effective doses received by personnel at each of the centre under study

Diagnostic centres	Radiation dose to personnel 1 (mSv)		Radiation dose to personnel 2 (mSv)		Radiation dose to personnel 3 (mSv)	
	Depth dose	Skin dose	Depth dose	Skin dose	Depth dose	Skin dose
Rainbow	0.49	0.49	0.30	0.60	0.49	0.53
New Image	0.33	0.35	0.32	0.33	0.39	0.41
Bethel	0.50	0.58	0.63	0.64	0.51	0.51
Akinolugbade	0.25	0.34	0.28	0.30	0.32	0.33
Abiolad	0.40	0.44	0.29	0.37	0.39	0.32

Table 4. Average effective dose (Quarterly and annually) by personnel at each centre

Diagnostic centres	Radiation dose to personnel 1 (mSv)		Radiation dose to personnel 2 (mSv)		Radiation dose to personnel 3 (mSv)	
	Per quarter	Per year	Per quarter	Per year	Per quarter	Per year
Rainbow	0.49	1.96	0.45	1.80	0.51	2.04
New Image	0.34	1.36	0.33	1.30	0.40	1.60
Bethel	0.54	2.16	0.64	2.54	0.51	2.04
Akinolugbade	0.30	1.20	0.29	1.16	0.33	1.32
Abiolad	0.42	1.68	0.33	1.32	0.36	1.44

Table 5. Estimated risk of cancer from each of the centre under study

Diagnostic centres	Avg. effective dose to personnel per annum (mSv)	Estimated risk of cancer
Rainbow	1.93	9.7×10^{-5}
New Image	1.42	7.1×10^{-5}
Bethel	2.25	11.2×10^{-5}
Akinolugbade	1.23	6.1×10^{-5}
Abiolad	1.48	7.4×10^{-5}

ranged from 0.29 – 0.64, while the extrapolated value per annum ranged from 1.16 – 2.54 mSv as presented in Table 4.The average annual effective dose (mSv) to personnel in all the centres ranged from 1.23 – 2.25, the lowest being received by personnel at Akinolugbade diagnostic centre and the highest was received by personnel at Bethel diagnostic centre as presented in Table 5. Also, presented in Table 5 was the estimated risk of cancer associated with radiation exposure of personnel at all the diagnostic centres.

Although, the annual effective dose received by personnel at Bethel diagnostic centre was the highest, it is still lower than the ICRP dose limit recommended for occupational exposed person, which is 20 mSv per annum averaged over 5 years for whole-body irradiation [16].

5. CONCLUSION

This study has measured the effective dose received by personnel at some private diagnostic centres in Abeokuta Ogun State, who were operating x-ray machine without using the monitoring devices. This study has found that the radiation practice, with respect to personnel monitoring, at these centres are unacceptable even though the annual effective dose received by personnel working at these centres within the period of this study is within the ICRP recommended dose limit for radiation worker. Also, to say that the radiation workers at these centres will always receive minimal radiation exposure is not guaranteed as long as the workers are not provided with appropriate monitoring devices to validate their radiation exposure per unit time.

Therefore, the Managements of these diagnostic centres should ensure adequate protection of their radiation workers through provision of appropriate personnel monitoring devices and adopt a system of regular personnel monitoring.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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