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ORIGINAL RESEARCH

Radiation Protection Evaluation in Standalone X-ray Diagnostic Radiological Centres within Lagos Metropolis, Lagos State, Nigeria.

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Abstract:
Introduction: Standalone diagnostics centres are be established in compliance with the radiation protection and safety measures.
Aim: The study aims to evaluate the radiation safety level in standalone X-ray diagnostic radiological centres.
Methods: Five Standalone radiological diagnostic centres have been studied in terms of the mAs, kVp and the annual effective dose obtained during radiological procedures. The annual effective dose is estimated from the instantaneous doses' measurement using a radiation survey meter (survey meter was held at about 1.2 meters high), Geiger counter version BR- 9C with threshold setting based on the World Health Organisation (WHO). The measurement ranges between 0 µSv/h and 99.99 µSv/h, with real-time measurement and real-time error ≤ 10%. The mAs and kVp measurements were obtained directly from the X-ray machines used.
Results: The highest kVp obtained is 80kV, and the lowest is 45kV; while the highest mAs is 129.7 mAs, and the lowest is 2.83 mAs. The highest annual effective dose from these radiological diagnostic centres is 21.23 mSv/y, and the lowest is 2.31 mSv/y.
Discussion: The annual effective dose obtained from this study is within the recommended dose (whole body) by ICRP for radiation workers. However, for the patients, it is high for individuals, but the standalone radiological diagnostic centres are safe.
Conclusion: The variation in X-ray tube currents and the kVp values are factors that contributed to radiation doses in these studied centres, and the annual effective doses due to the scatter radiation shows significant effect on the annual cumulated doses on both the patients and radiation workers in most of the centres. The lowest value of annual effective dose from all the centres is 2.31 mSv/y, high for an individual part of the body for non-radiological workers. Unprotected patients or workers during the diagnostic procedures are at high risk of the highest radiation doses obtainable from the X-ray machine at any given time.
Keywords: protection, cancer, radiation, physics, patient, radiology, exposure.

All co-authors agreed to have their names listed as authors.

1. INTRODUCTION

Radiologists use techniques such as X-ray imaging to detect and diagnose diseases and injuries, manage patient care, and guide many forms of medical treatment. Radiographers or technologists have the responsibilities and duties to protect patients and health workers from unnecessary radiation exposure through the optimisation of imaging protocols. This may be attained by performing regular quality control of radiological equipment to ensure patient protection [1]. One of the contributors to the cumulative radiation dose exposure to radiographers or patients is radiation emitted during the X-ray procedures. Thus, this contributor of dose exposure is minor, but it is unwanted because they are potential health risk to both the patients and the medical staff in the diagnostic centres [2]. Radiation safety should be a great concern for patients, physicians, and staff in many radiology diagnostic centres.

Radiations are usually ionising or non-ionising in nature, depending on the energy of the radiation. In this study ionizing radiation is the relevant radiation of choice. Thus, the role of ionising radiation in the medical field is enormous, in that ionizing radiation has become in-separable tool used for the diagnosis and treatment of a variety of medical conditions. Ionizing radiations are mainly involved in both the diagnostic and therapeutic uses, and this may cause tissue changes or damage as they deposit energy in human cells. As a result, there has been an increase in lifetime cumulative doses both to patients and medical personnel in diagnostic centres. It is very necessary to reduce or minimise any unwanted radiation exposure to the minimum dose clinically. X-rays are notable in comparison to lower energy photons since they are powerful enough to break molecular bonds and ionize atoms [3]. Thus, causing ionization and then producing free radicals, which are chemically active compounds that may indirectly damage DNA [4].

Medical staff and patients may generally be exposed to X-ray radiation either as scattered X-rays or by direct exposure to the X-ray beam. Scattered X-rays give up part of their energy during the scattering process, and energy is deposited in tissues. Scattered X-rays have lower energy when compared to directly X-ray source [5]. The radiation biological effects produced are either a dose-dependent effect or a dose-dependent probability [6].

There are three basic principles of radiation protection: justification, optimisation, and dose limitation. Justification involves an appreciation for the benefits and risks of using radiation for procedures or treatments [7, 8]. Reducing the kV will increase patient exposure because both the output exposure of the X-ray tube and the penetration of the radiation through the patient are reduced, thus; an increase in the tube loading (mAs). It is best to select a kV value for a specific clinical procedure that provides the appropriate balance of image contrast and patient exposure [9, 10]. An overexposed radiograph may look good, but may cause unnecessary exposure; thus, this is not recognised. Since radiation protection is the main focus here, the ALARA principle must be practised in all therapeutic and diagnostic centres [11, 12].

In addition to this, maintaining high-quality film processing reduces unnecessary patient exposure in many ways. It is worth noting that patient exposure to radiation is affected by the area covered by the X-ray beam, reducing the size of the beam. Some tissues and organs are kept outside the direct beam. The main aims of radiation protection are to reduce unnecessary radiation exposure with the goal of minimising the harmful effects of the ionizing radiation [13]. However small the X-ray establishment, the services of a physicist experienced in the properties and effects of radiation should be sought to act as radiation protection adviser. The physicist should help to plan new radiological services and should regularly review existing services for X-ray protection with the aid of radiation surveys [14]. In many of the radiological diagnostic centres, it has been reported that the majority of them do not follow the radiation procedures and personnel monitoring [15]. This study evaluates radiation safety in standalone X-ray diagnostic radiological centres within the metropolis of Lagos, Nigeria.

2. METHODOLOGY

Lagos metropolis is a densely populated commercial city in south-west Nigeria. The evaluation of radiation safety from five selected standalone X-ray radiological diagnostic centres was carried out. The selection of the radiological diagnostic centres was based on *the following factors:* how busy the centre is over a period of time, *accessibility to data collection and permission from the centres and this was done* *randomly and labelled* centres A, B, C, D, and E. *Data were collected from each centre during operation of the X-ray machine and also after the use of the machine for a period of two weeks.* The location of interest within the radiological diagnostic centre is the patient's observation room, where both patients and radiographers/radiology technicians are working.

Dose rate (µSv/h) and milliampere seconds (mAs) were measured from the patient's observation room using a radiation survey meter (survey meter was held at about 1.2-meter-high) Geiger counter version BR- 9C with threshold setting based on the World Health Organisation (WHO). The measurement range is between 0 µSv/h and 99.99 µSv/h, with real-time measurement with real-time error ≤ 10%. The detector was calibrated at the National Institute of Radiation Protection and Research, University of Ibadan, Nigeria, which is a certified secondary standard laboratory.

2.1 Estimated annual equivalent dose

From the Literature Review, UNSCEAR, 1988 recommended 1 or 100% to Occupancy Factor. That is the proportion of the total time during which an individual is exposed to radiation. That people spend 80% of their time indoors, which is 0.8 out of 1 and 20% of their time outdoors, which is 0.2 out of 1.
In a year, there are 365 days. 365 days in a year by 24 hours to convert the Survey meter readings, which were per hour to per year, to 8760 hrs. per year. Note that 1mSv is equal to 1000 µSv, so to convert µSv to mSv, we divide the µSv value by 1000.
The readings obtained in µSv/hr were converted to years by using these relations: Indoor Equivalent Dose rate (H_i)

$$H_i \left(mSvy^{-1}\right) = H_O \times P \times F \times 10^{-3} \quad \text{..............................1}$$

Where H_O is the mean equivalent dose in units of µSv/h, P (h/y) is the number of hours worked per year, taken as 4600 h/y in this study, F is the indoor occupancy factor, taken as 0.8, and 10^{-3} is the conversion factor [16]

The estimated annual dose record is needed for the purpose of the patients' monitoring because of radiation protection, thus the equation above is applied for the estimate. Generally, in all radiological centres, measures are expected to be in place to drastically reduce unwanted radiation doses to both patients and the radiological service providers. Table 1 below shows the X-ray dose limits for both the radiological workers (occupational exposure) and that of an individual (public exposure) as recommended [17, 18]

Table 1. X-ray Dose Limits

Part of the body	Occupational Exposure	Public Exposure
Whole body (Effective dose)	20 mSv/year average over 5 consecutive years 30 mSv in any single year	1 mSv/y
Lens of eyes (Equivalent dose)	150 mSv in a year	15 mSv/y
Skin (Equivalent dose)	500 mSv in a year	50 mSv/y
Total Organ (Equivalent dose)	50 mSv	
Extremities (Equivalent dose)		
Hands and Feet	500 mSv/y	-
For pregnant radiation workers, after declaration of pregnancy, 1 mSv on the embryo/fetus should not be exceeded.		

There are many important factors governing radiation exposure to radiological workers. These may be categorised into two, firstly, factors that are under the control of the workers, this may include the time of putting on the X-ray machine, with or without the presence of the staff, the beam size, etc. The second category may be included as structural shielding, X-ray room layout, the design of the X-ray equipment and lastly protective equipment and clothing. The responsibility of radiation protection in radiological centres lies both on the employing authority and the workers carrying out radiological procedures.

Nonetheless, in all five standalone radiological centres that were studied, some of the radiographers or radiological procedure providers do not put on protective clothing. However, the majority of the workers adhered to the norms. During the interaction and observations during the data collections, the radiology technicians or radiographers are familiar with the accepted radiation doses to different body parts, as indicated in Table 2 below.

Table 2. Average Effective Dose (mSv) for Diagnostic radiology procedures

Exam	Dose(mSv)
Dental x-rays	0.01
Mammogram	0.04
Chest x-ray	0.01
Abdomen x-ray	0.7
Lumbar spine	1.5

For the radiological diagnostic procedure, the dosage to the chest at one shot is 0.01 mSv and to the abdomen is 0.7 mSv [18]. Radiation dose guidelines and recommendations based on scientific data have been published by several international organizations and the facts are available in the literature.

3. RESULTS AND DISCUSSION

The statistical data of the mAs values from the X-ray machine of each centre are as indicated in Table 3, with centre B having the highest mean and centre C with the minimum mean.

Table 3. The X-ray tube mAs values from Diagnostic Centres

	mAs			
Centres	Standard Dev	Min	Max	Mean
A	2.23±0.18	4.01	9.06	6.52
B	56.26±9.04	2.83	129.70	29.08
C	4.87±1.87	4.60	16.12	7.68
D	11.50±4.32	4.04	31.19	10.73
E	10.24±2.07	8.08	32.82	16.94

In each radiological centre, before taking any measurement, the background readings of the survey meter were taken. On average, the obtained value was found to be 0.12μSv/hr. These centres have been coded as A – E, and the average instantaneous dose rate have measured by the survey meter and is presented with each daily activity as well as the mean of each centre in weekly daily activities.

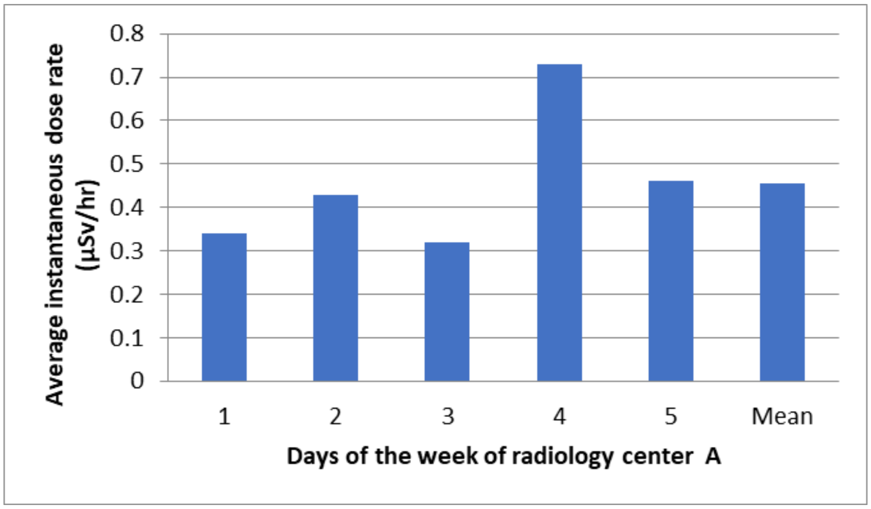

Fig. 1. Average instantaneous dose rate from centre A

The average instantaneous dose rate from radiological centre A is shown in Figure 1 above. The lowest instantaneous dose was recorded on the third day of the week, and the highest value was 0.73 µSv/hr. obtained on the fourth day of the week, however, the mean of this dose rate for the whole in the centre A is about 0.46 µSv/hr. indicating that this value is higher than most of the obtained values from the daily average.

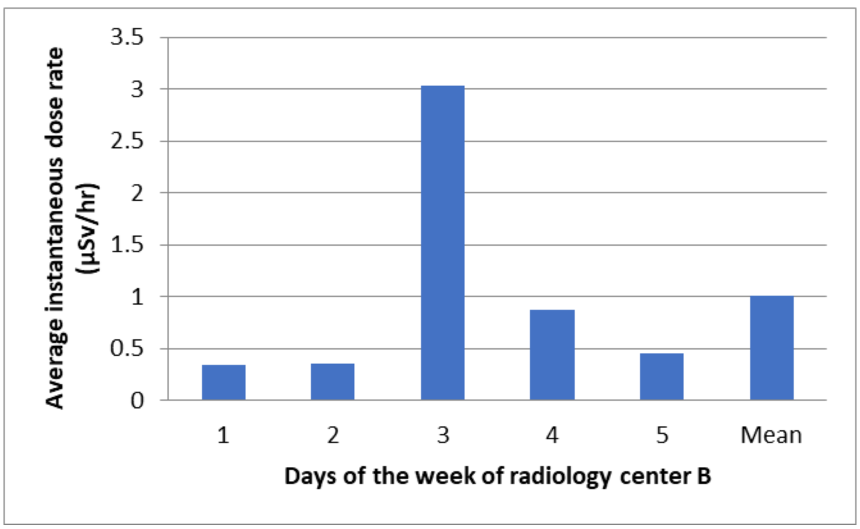

Fig. 2. Average instantaneous dose rate from centre B

Figure 2 above illustrates the instantaneous dose rate from radiological centre B, and the range of the values is between 0.34 µSv/hr. and 3.03 µSv/hr. The highest value was obtained on the third day of the working week; on this day, the value of the dose rate is about 10 times the values obtained for the rest of the working week. Nevertheless, the mean dose rate from this radiological centre is 1.01 µSv/hr. It is worth noting that there is variation in the mAs used during the week; mAs is a measure of radiation

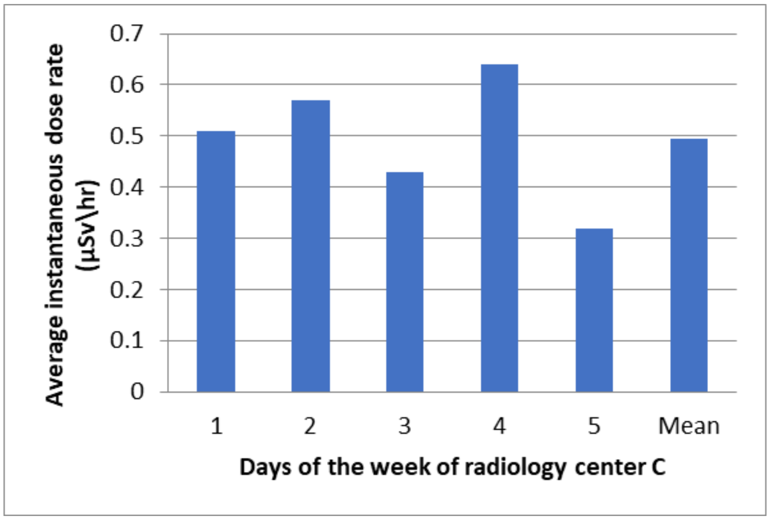

Fig. 3. Average instantaneous dose rate from centre C

output for a set amount of time via an X-ray. These variations thus affect the radiation dose at any point in time. It is not limited to this alone, but also the signal-to-noise ratio is affected by some other factors. The measured instantaneous dose rate from radiological centre C is as shown in fig 3 above; thus, the mean dose rate from this centre is 0.49 µSv/hr, while its dose rate is in the range of 0.32 µSv/hr and 0.64 µSv/hr. Each day of the week in this centre has its instantaneous dose rate above 0.3 µSv/hr. In Figure 4 below, the average instantaneous dose rate from radiological centre D has been shown.

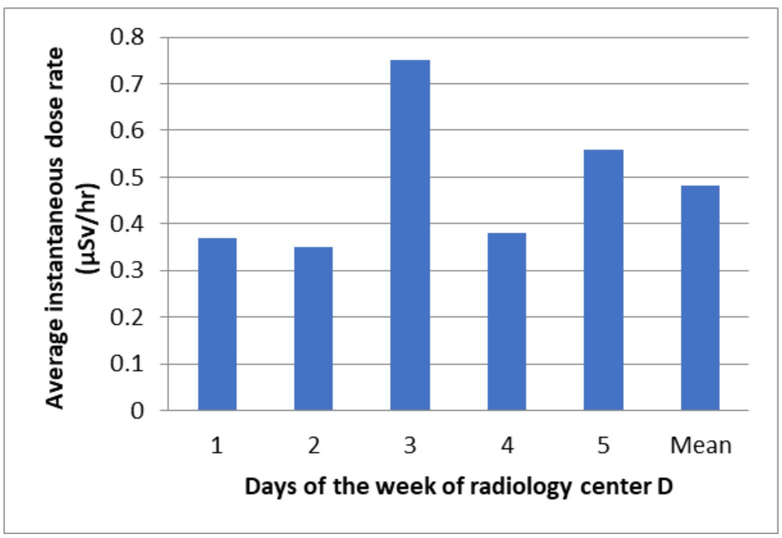

Fig. 4. Average instantaneous dose rate from centre D

This centre produces instantaneous dose rates that are generally above 0.30 µSv/hr, as seen in the previous centres; hence, the lowest value was 0.35 µSv/hr, and the highest dose rate was 0.75 µSv/hr. The centre's mean over a whole five days of high radiological activities is 0.48 µSv/hr.

This may be as a result of increasing mAs value during the course of radiological procedures, because an increase in mAs will produce more electrons from the x-ray tube and subsequently increase the amount of radiation exposure both to the patients and the radiological personnel.

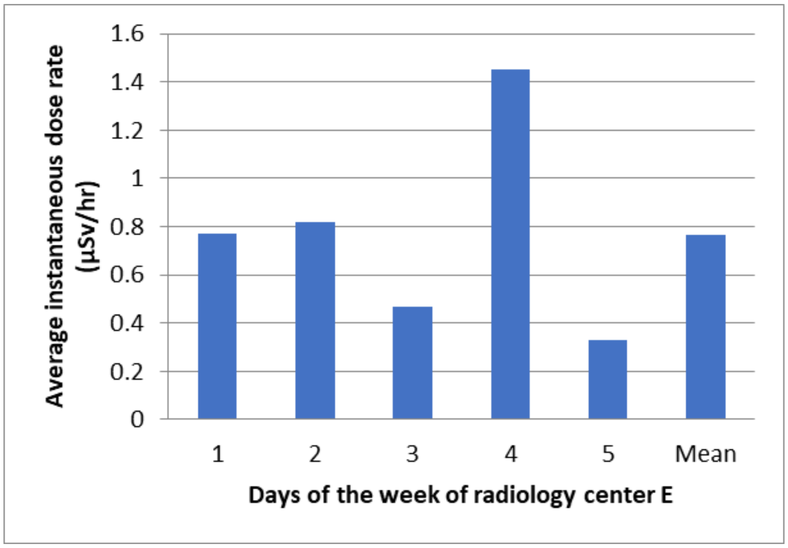

Fig. 5. Average instantaneous dose rate from centre E

Variation occurrence in the mAs does not change the penetrating ability of the X-ray beam or the amount of scattered radiation, but it directly affects the dose rate to the patient and the radiological worker within a reasonable distance from the X-ray machine. For the radiological centre E, the range of the measured instantaneous dose rate is 0.33 µSv/hr and 1.45 µSv/hr, thus resulting in a weekly mean of 0.77 µSv/hr.

The measure dose rate is affected by both the mAs and the kV set up of the machine at any particular time of diagnostic session, however; the effects of the mAs have mentioned above and it seen that mAs is a factor to be considered when treating radiation safety in any radiological centre therefor figure 6 below shows the comparisons of the mAs from each of the radiological centres.

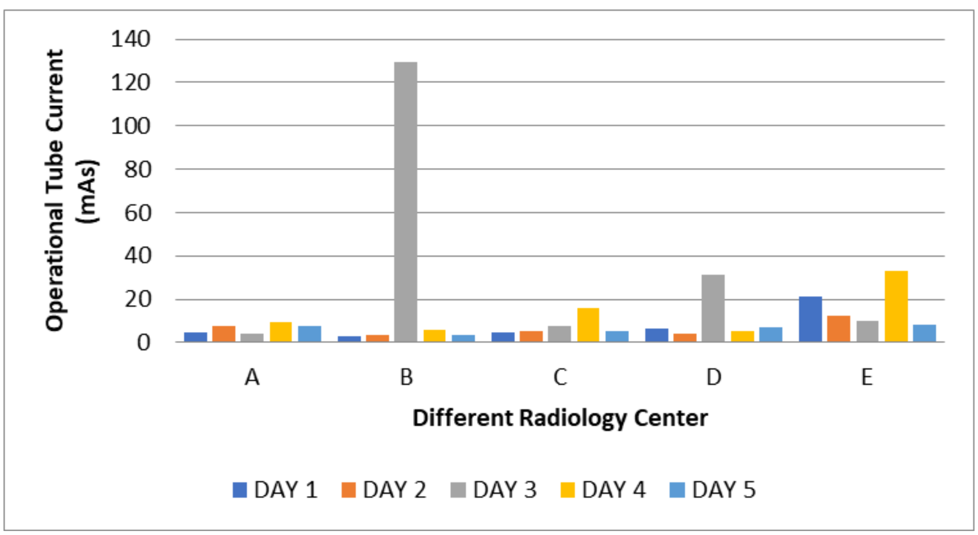

Fig. 6. Comparison of the mAs from all the centres

These two factors, mAs and kV plays a very important role in radiation protection in radiological procedures, thus figure 6 shows the comparison of the operational tube current mAs from the studied radiological centres for five days in a row. For centre A, the operational tube current range from 4.01 mAs to 9.06 mAs; from centre B operational tube current is in the of range 2.83 mAs and 129.7 mAs; then centre C has the mAs range between 4.60 mAs – 16.12 mAs and centres D and E, mAs measured values are in the range of 4.04 mAs to 31.19 mAs and 8.08 mAs to 32.82 mAs respectively.

However, kV, the kilovolts, have to do with the energy of the electrons that are produced during the production of X-rays; the higher the kV value, the more energy the X-ray beam has. Therefore, the more the energy of the X-ray beam, the greater the penetrating power. Kilo voltage determines the proportion of scattered radiation reaching the patient; it is an exposure factor.

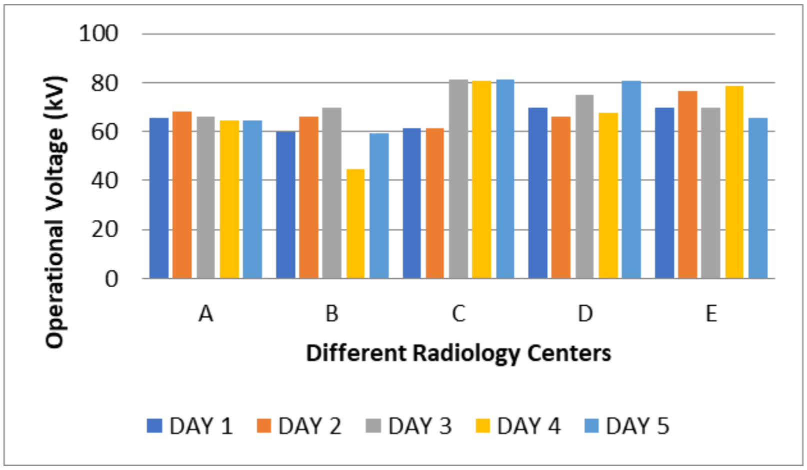

Fig.7. Comparison of the kV from all the centres

It is a fact that a low kVp beam has more photons with low energy, and those are more easily absorbed by the atoms of the patient's body. An already absorbed photon cannot be scattered again; depending on the energy of the photon, the radiobiological effect(s) can become health issues. Thus, the operational voltage values from the radiological centres are compared in Figure 7 above. In centre A, the operational voltage values are in the range of 65 kVp – 68 kVp; centre B has an operational voltage range of 45 kVp and 70 kVp; centre C has an operational voltage between 60 and 80, while the operational voltage of centres D and E falls within the range of 66 kVp - 80 kVp and 65 kVp - 78 kVp, respectively. This variation also causes changes in the X-ray tube current (mAs); hence, increasing mAs produces more electrons in an X-ray tube and subsequently increases the amount of radiation exposure, which may result in additional excess radiation dose to the patient or radiological worker. With this background information, the annual effective radiation dose in each centre has been estimated and compared in the entire centre studied, as illustrated in Figure 8 below.

Average annual effective dose as estimated from each centre is as shown in Figure 8; thus, from Centre A effective dose is in the range between 2.24 mSv/y and 5.11 mSv/y, and the weekly average is 3.20 mSv/y. Centre B have the highest annual effective dose of 21.23 mSv/y, and the lowest is 2.38 mSv/y; the weekly average is 7.06 mSv/y.

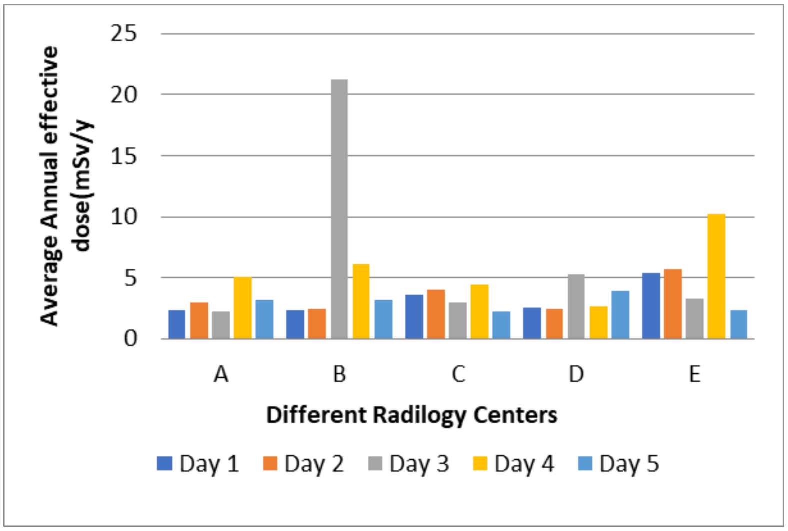

Fig. 8. Comparison of the average annual effective dose from all the centres

From radiological diagnostic centre C, the annual effective dose obtained is in the range of 2.24 mSv/y to 4.49 mSv/y, and the recorded weekly average of 3.46 mSv/y was observed. Centre D have a weekly average of annual effective dose of 3.92 mSv/y, the highest dose of 5.26 mSv/y and the lowest value of 2.45 mSv/y. The last radiological centre studied is centre E, with the highest annual effective dose of 10.16 and the lowest effective dose of 2.31; however, the centre recorded a weekly average of 5.38 mSv/y. In the entire radiological centres studied, centres B and E have a weekly average that is greater than 5.00 mSv/y, while other centres have a weekly average above 3.00 mSv/y.

4. CONCLUSION

Five selected standalone radiological diagnostic centres were studied for radiation protection and safety, in terms of the mAs, kVp and annual effective dose; the obtained results vary from one centre to another.
In most of the diagnostic centres studied, most of the radiological procedures were observed to be X-ray diagnostic of the chest, arms, shoulder or knees, abdomen, skull and pelvic region and therefore, low radiation doses were absorbed, thus resulting in low annual effective doses from each centre. From these centres, the highest kVp is 80kV, and the lowest is 45kV, while the mAs highest is 129.7 mAs and the lowest is 2.83 mAs. In addition, the highest annual effective dose from these radiological diagnostic centres is 21.23 mSv/y, which is within the range recommended by ICRP (whole absorption) for radiological worker that is recommended occupational annual effective dose; however, this is on the high side for an individual (patient). The lowest value of annual effective dose from all the centres is 2.31 mSv/y, high for an individual part of the body for non-radiological workers.
Unshielded or unprotected patients or workers during the diagnostic procedures are at high risk of the highest radiation doses obtainable from the X-ray machine at any given time. It was observed in all the centres that most of the radiology technicians or radiographers do not take their personal protection seriously, they have no lead apron, gonad shield, lead eye goggle, and lead glove lead apron, gonad shield, lead eye goggle, and lead glove on, they sometimes carelessly exposure themselves to a lot of radiation fallouts from the X-ray machine. The observed radiation dose is within limits, but there is a need for standard practice by these centres. However, in some centres, technicians or radiographers were not provided with these protective devices. The attention of the highest authority of each centres were called to this attitude of the radiology technicians or radiographers.

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COMPETING INTERESTS

There is no known conflict of interest in this research work. The research work is purely academic for better scientific information within the scientific community and society at large.

AUTHORS' CONTRIBUTIONS

Kayode Idowu Ogungbemi designed the research work, supervised the data collection, and drafted the first documents called the manuscripts.
While Muteeu Abayomi Olopade and Ayo Zaccheaus supervised data collections from designated centres and proofread the final write-up of the manuscript before submission
Jadesola Fatimah Iyowu, Oluwamayowa Joseph Adeoye and Samuel Abisoye Shittu contributed to data analysis, software administrator and corrected the draft.

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ETHICAL APPROVAL (WHEREVER APPLICABLE)

There is no need for any Ethical or consent approval for this research work.

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