Assessment of Radiation Protection Measures in a Nigerian Tertiary Health Care Center

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Abstract
Radiation protection is critical and poses an increasing international concern in this era of evidence based practice and the approach to the use of ionizing radiation should be conscientious and cautious. Ionizing radiation in any quantity is potentially deleterious to health however, its benefit far outweighs the risk. This study was carried out in the radiology department of a tertiary health care center in Nigeria with the aim of assessing radiation protection measures in the hospital in comparism with international standard. Several factors were evaluated such as the integrity of the shielding used, the x ray room design , technical considerations, management's role in provision of good equipment, staff and training, effectiveness of workplace and personnel monitoring, quality control and records as radiation protection tool. This study showed that all the parameters assessed and radiation doses were acceptable and below the annual permissible dose indicating that the radiation protection measures employed by the hospital were good and complied with international standard, though record keeping seemed to be a major challenge.
Keywords: Radiation protection, Ionizing Radiation, X-ray, Quality Control, Quality Assurance

1.1 INTRODUCTION

The increasing use of diagnostic radiology is unquestionably beneficial however, per-capita exposure to medical radiation has grown some six fold in the last two decades and appears to be still increasing[1]. The issue of medical radiation protection is therefore achieving central importance for the health of both patients and radiation professionals[2],[3]. It can be said to be well established that the effects of radiation are cumulative and lead to increased incidence of cancers, cell deaths, genetic damage and numerous forms of body tissue pathology[2],[4]. Ionizing radiation in any quantities is potentially deleterious to health[2],[5]. Radiation damage can show up in many ways including skin erythema, hair loss, vascular damage, internal bleeding, cataracts, cancers, weakened immune systems, sterility, mutations in offspring, premature ageing and death[5],[6],[7]. Before undertaking any radiological examination, it is important that the radiologist, radiographers and supporting workers understand the potential risks of radiation and also its advantages to the patients[8],[9],[10]. The current radiation protection standards are based on three general principles,justification of a practice which implies that no practice involving exposures to radiation should be adopted unless it provides sufficient benefit to offset the detrimental effects of radiation [24,25,26,27] . Protection should be optimized in relation to the magnitude of doses, number of people exposed and to optimize it for all social and economic strata of patients[10].

Dose limitation, on the other hand, deals with the idea of establishing annual dose limits for occupational exposures, public exposures, and exposures to the embryo and fetus[12],[13]. Optimization of protection can be achieved by "optimization of the radiological procedure" so as to reduce radiation exposures to the minimum levels[13]. This optimization is possible by good quality assurance and quality control[13]. Factors which can contribute to dose reduction and quality assurance are high frequency three phase generator equipment, high KV technique and low mAs, using the shortest exposure time, beam collimation and proper beam filtration[13],[14]. The other factors which contribute to optimization of procedure are using a x-ray table top which allows high beam transmission, anti-scatter grids, high speed films with rare earth screens, optimal film processing and largest possible source to image receptor distance [15]. Radiation's impact is potentially cumulative and all possible precautions should be taken to minimize exposure[5],[15]. A linear no-threshold model of radiation damage has long been accepted[23,24]. ` According to this model there is no safe minimum threshold for radiation received and danger increases linearly with dose[16],[17].The International Commission on Radiological Protection recommends an upper limit of 2 rem per year (20mSv/yr) of whole-body radiation for radiological workers[28]. "In accordance with current knowledge of radiation health risks, the Health Physics Society recommends against quantitative estimation of health risks below an individual dose of 5 rem in one year or a lifetime dose of 10 rem above that received from natural sources"[15][25][35] . According to the Society's position, health risks below those estimates are unknown and cannot be estimated[16]. The position paper relates to estimation of health risk only[16]. This study seeks to explore ways of minimizing such risks.

1.2 Aim and Objectives of the Study

The aim of this research work is to assess the radiation protective measures in the Radiology Department of the Federal Medical Centre, Keffi, Nasarawa State, Nigeria. This aim would be achieved via the following Objectives:

i To assess the integrity of the shielding used and the X- ray room design in reducing radiation exposure,
ii. To evaluate management's role in provision of good equipment, staff and training,
iii. To assess the effectiveness of workplace and personnel monitoring, quality control and records as radiation protection tool,
iv. To compare the results obtained to what is expected to make necessary recommendations .

2.1 MATERIALS AND METHODS

The study included only 11 radiation health workers that constituted the staff of the Radiology department of a tertiary health center in Nigeria. A non experimental exploratory study was employed in this study, Primary source of data collection was adopted for this research. Characteristics of X-ray machine is extracted from the available machine specific data such as type model, waveform, and filtration, year of manufacture, equipment age, generator type, dose reproducibility, were recorded. TLD badges - dosimeter for measuring radiation doses were used. TLD chips of square rounded 3.2mm *3.2 *0.9 mm in size. The dosimeter material used is LiF (Mg,Ti), which is supplied by RADOS Technology Oy, Finland.TLD reader; RE 2000 Serial number 280010 .Year of manufacture is 2006, calibration factor is 0.53*exp-53mSv/count for Hp(10) and 0.51*exp-05mSv/count for (0.07). Parameters to be assessed were categorized into three, Technical parameter which involved the assessment of the Shielding integrity and the acceptability of the design and layout of the department in radiation dose reduction, management's role here, the types of equipments were assessed, numbers of staff and regularity of training as a radiation protection tool was evaluated, Monitoring which includes workplace and Personnel monitoring to check collective dose, quality control, role of repeats, reports of incidences and record keeping also formed the next set of factors that informed the acceptability of the protective measures as an effective one.

In carrying out this test, four TLD badges were placed outside the four walls of the X- ray room (Wall H, Wall AB, wall CDE and wall F at the level of about 1.5metres from the floor) and radiation exposures made. The TLD badges are read and recorded.

Structurally, the x-ray room is designed such that radiation emitted from the source, x - ray machine, does not reach the Radiographer who is most likely positioned behind the wall G (fig 2.1), which serves as a secondary barrier. Routinely, this Radiographer has a TLD badge while working. This is read and the recorded.Thus, the size of the rooms, doors and walls, ceiling and floors, windows and air conditioning units, protective cubicles, radiation warning notices and the general state of the radiography rooms were checked and matched with the minimum requirements of the regulatory body in Nigeria, NNRA. The findings are noted.

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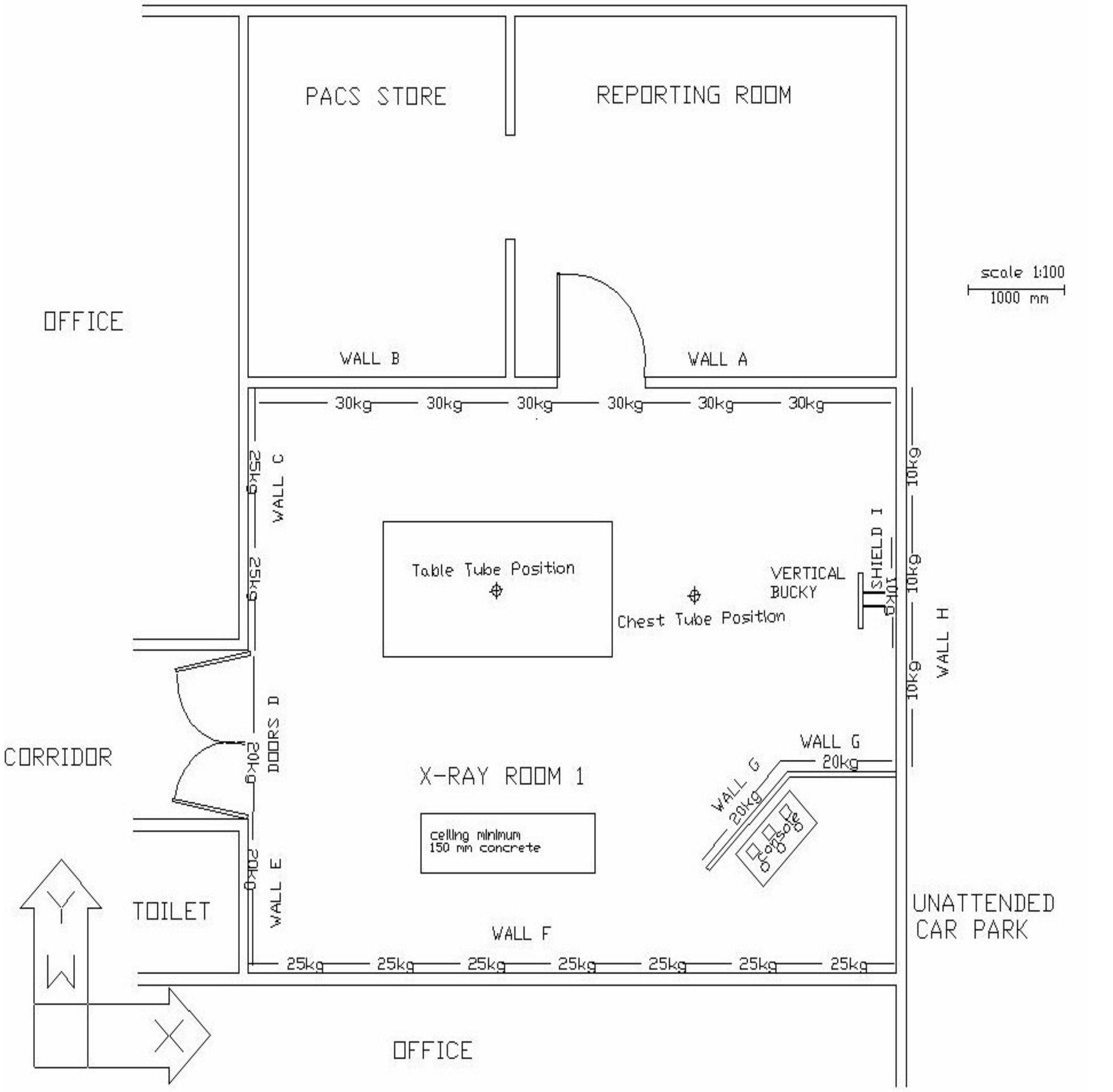

Figure 2.1 X-Ray Room Layout[30,39]

3.0 RESULTS

3.1 Technical Assessment

Table 3.1 Recordable Radiation Dose on Wall ABCDEF&H

S/N	WALL TYPE	RECORDABLE RADIATION DOSE (YES OR NO)
1	$W_{A/B}$	NO
2	$W_{C/D/E}$	NO
3	W_F	NO
4	W_H	NO

Table 3.2: First Quarter Dosimetry Record

S/N	+Hp (10) Dose (mSv)	+ Hp (0.07) Dose (mSv)	Remark
TL $_{1A}$	0.33	0.26	OK
TL $_{2A}$	0.31	0.31	OK
TL $_{3A}$	0.33	0.27	OK
TL $_{4A}$	0.29	0.29	OK
TL $_{5A}$	0.29	0.23	OK
TL $_{6A}$	0.34	0.23	OK
TL $_{7A}$	0.32	0.26	OK
TL $_{8A}$	0.39	0.39	OK
TL $_{9A}$	0.43	0.40	OK
TL $_{10A}$	0.30	0.39	OK
TL $_{11A}$	0.30	0.26	OK
TL $_{Total}$	**3.63**	**3.29**	

Table 3.3: Second Quarter Dosimetry Record

S/N	+Hp (10) Dose (mSv)	+ Hp (0.07) Dose (mSv)	Remark
TL $_{1B}$	0.33	0.26	OK
TL $_{2B}$	0.31	0.31	OK
TL $_{3B}$	0.33	0.27	OK
TL $_{4B}$	0.30	0.26	OK
TL $_{5B}$	0.29	0.23	OK
TL $_{6B}$	0.29	0.23	OK
TL $_{7B}$	0.34	0.23	OK
TL $_{8B}$	0.39	0.26	OK
TL $_{9B}$	0.39	0.39	OK
TL $_{10B}$	0.43	0.40	OK
TL $_{11B}$	0.30	0.29	OK
TL $_{Total}$	**3.7**	**3.13**	

Table 3.4: Third Quarter Dosimetry Record

TL $_{1C}$	0.34	0.25	OK
TL $_{2C}$	0.32	0.29	OK
TL $_{3C}$	0.34	0.25	OK
TL $_{4C}$	0.30	0.29	OK
TL $_{5C}$	0.30	0.30	OK
TL $_{6C}$	0.32	0.20	OK
TL $_{7C}$	0.30	0.20	OK
TL $_{8C}$	0.39	0.26	OK
TL $_{9C}$	0.43	0.37	OK
TL $_{10C}$	0.30	0.27	OK
TL $_{11C}$	0.29	0.26	OK
TL $_{Total}$	**3.63**	**2.94**	

Table 3.5: Fourth Quarter Dosimetry Record

S/N	+Hp (10) Dose (mSv)	+ Hp (0.07) Dose (mSv)	Remark
TL $_{1D}$	0.33	0.26	OK
TL $_{2D}$	0.31	0.31	OK
TL $_{3D}$	0.33	0.27	OK
TL $_{4D}$	0.30	0.26	OK
TL $_{5D}$	0.29	0.29	OK
TL $_{6D}$	0.29	0.23	OK
TL $_{7D}$	0.34	0.23	OK
TL $_{8D}$	0.32	0.26	OK
TL $_{9D}$	0.39	0.39	OK
TL $_{10D}$	0.43	0.40	OK
TL $_{11D}$	0.30	0.29	OK
TL $_{Total}$	**3.62**	**3.19**	

Table 3.6: Annual Accumulated Radiation Dose

S/N	+Hp (10) Dose (mSv)	+ Hp (0.07) Dose (mSv)
TL_1	**1.34**	**1.03**
TL_2	**1.25**	**1.22**
TL_3	**1.33**	**1.06**
TL_4	**1.19**	**1.10**
TL_5	**1.17**	**1.10**
TL_6	**1.24**	**1.05**
TL_7	**1.30**	**0.92**
TL_8	**1.64**	**1.17**
TL_9	**1.64**	**1.55**
TL_{10}	**1.46**	**1.46**
TL_{11}	**1.19**	**1.10**

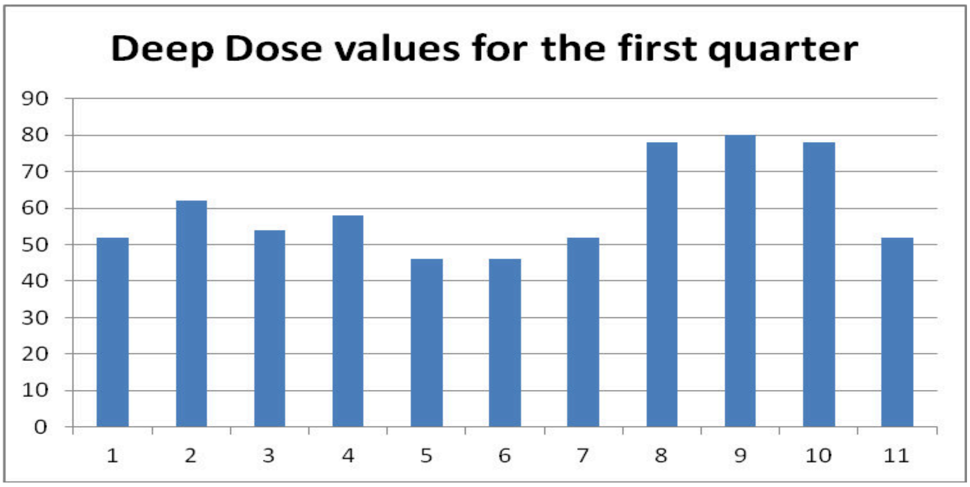

Fig. 3.1 Deep Dose values for the first quarter

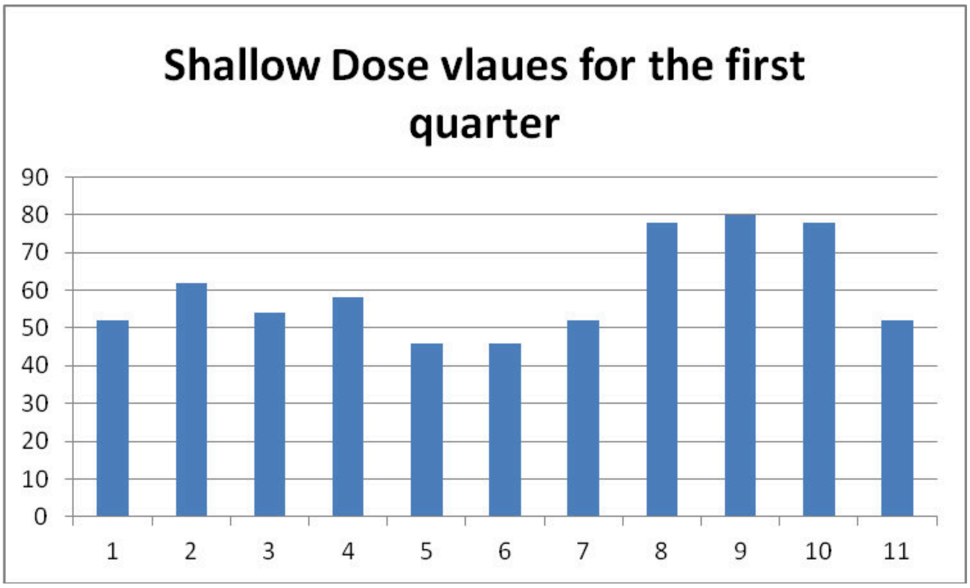

Fig. 3.2 Shallow Dose values for the first quarter

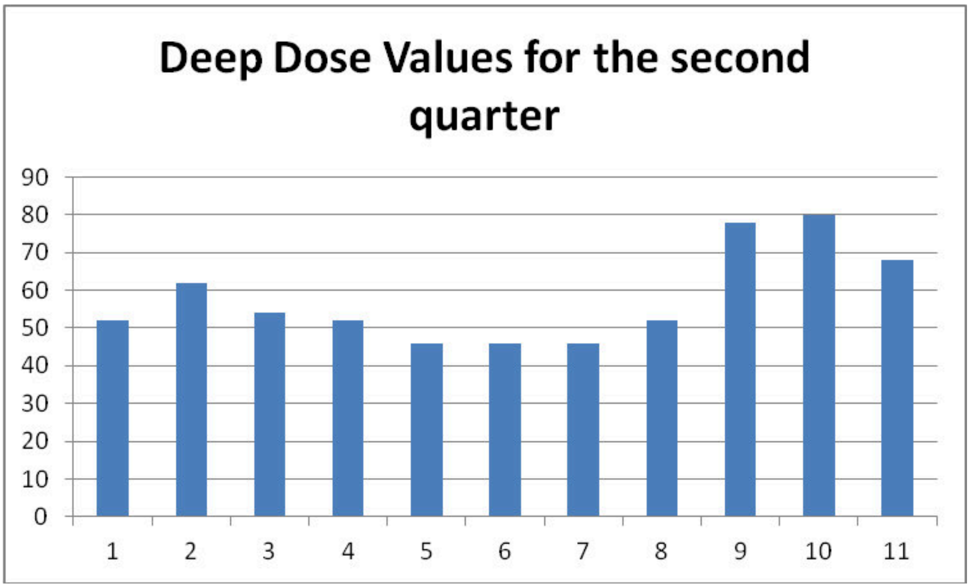

Fig. 3.3 Deep Dose values for the second quarter

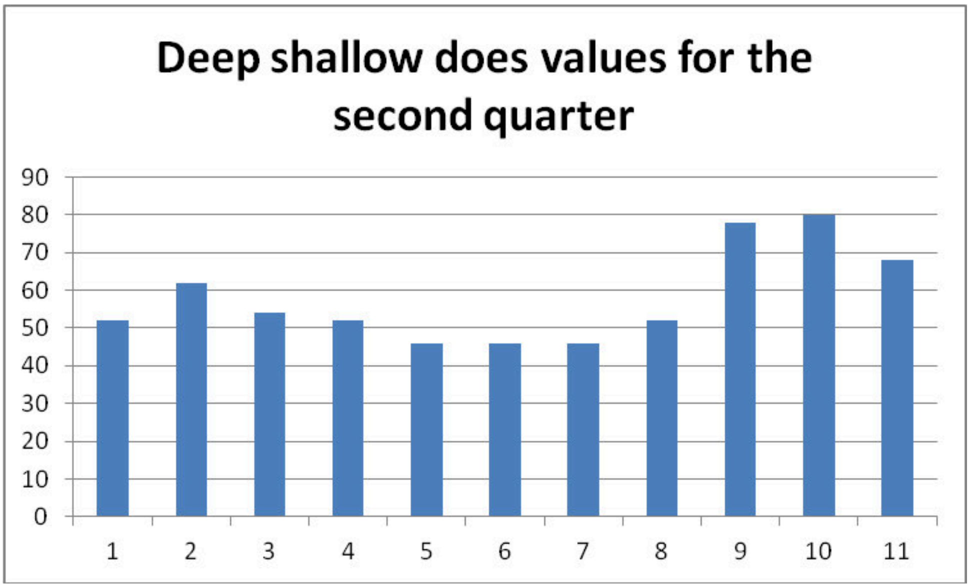

Fig. 3.4 Deep Shallow does values for the second quarter

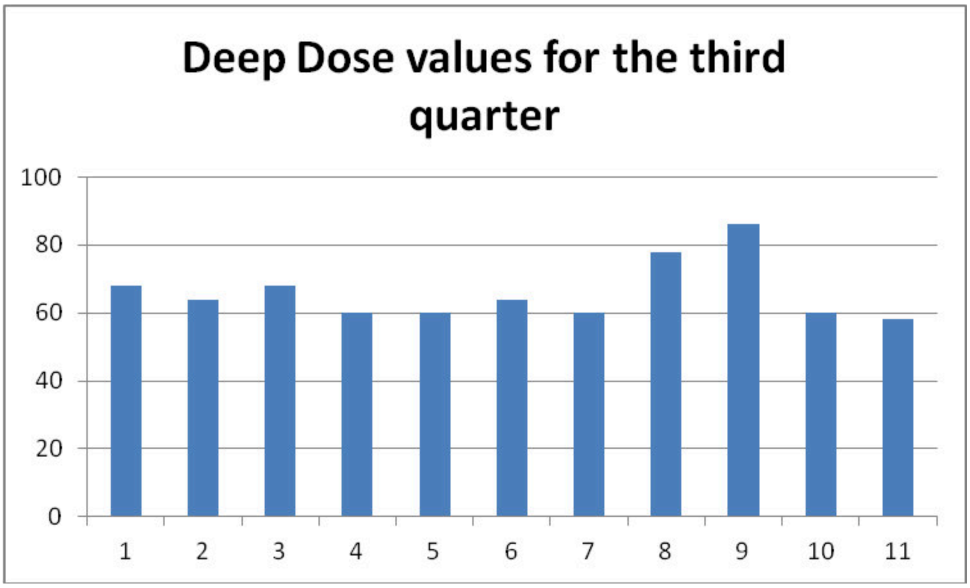

Fig. 3.5 Deep Dose values for the third quarter

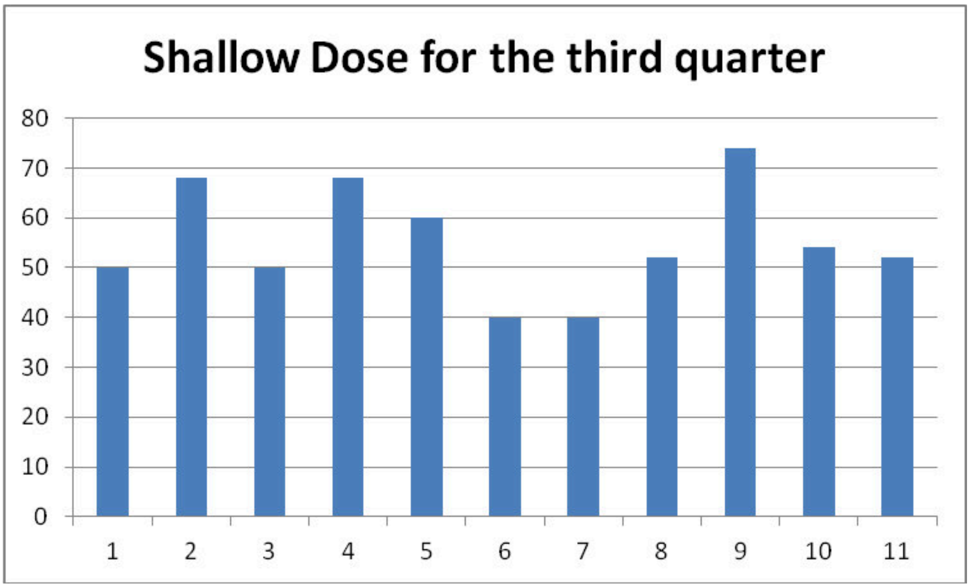

Fig. 3.6: Shallow Dose for the third quarter

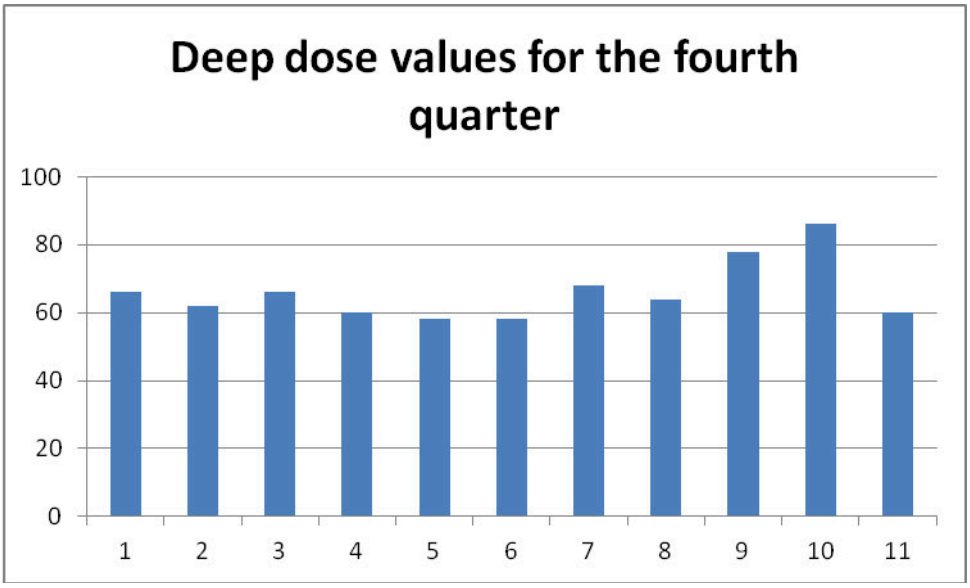

Fig: 3.7 Deep dose values for the fourth quarter

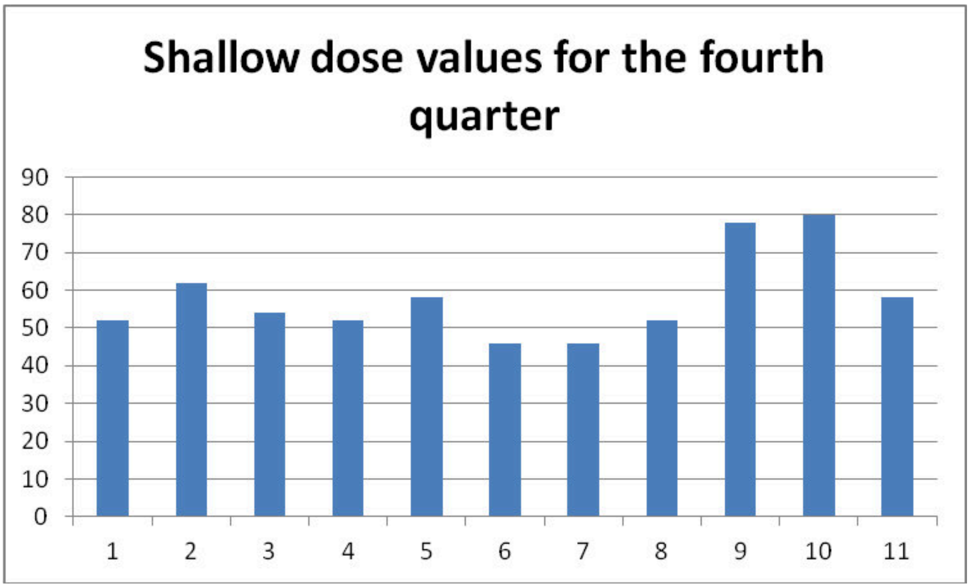

Fig: 3.8 Shallow dose values for the fourth quarter

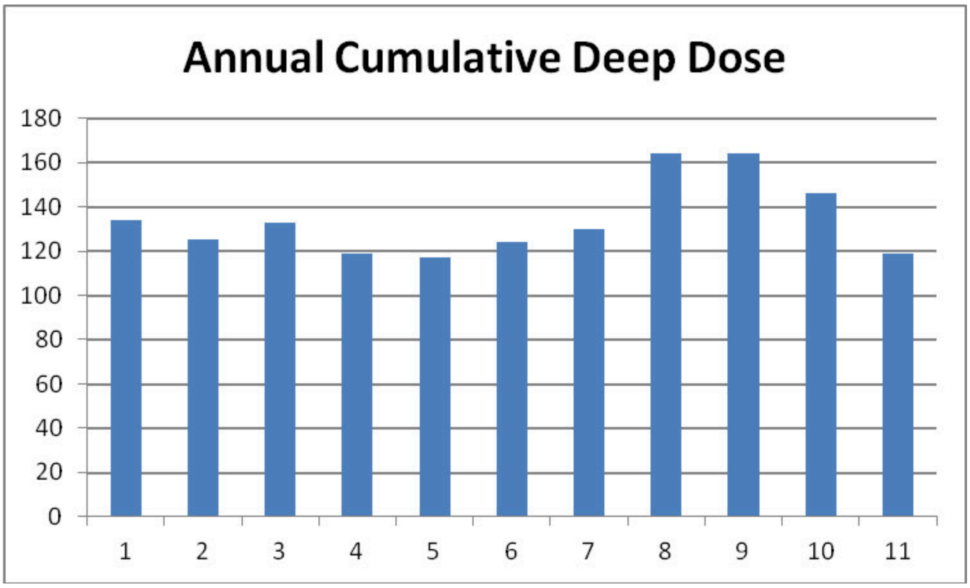

Fig: 3.9 Annual Cumulative Deep Dose

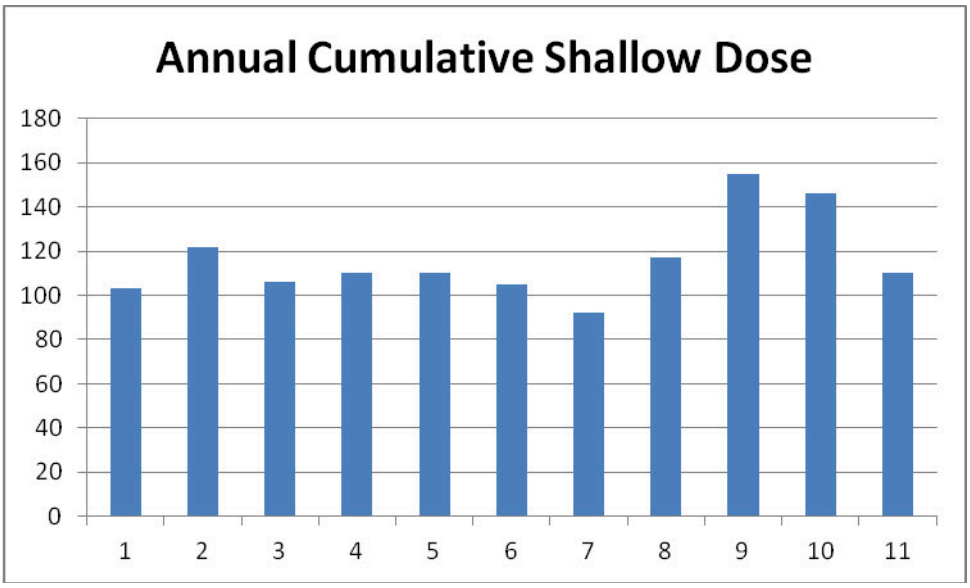

Fig: 3.10 Annual Cumulative Shallow Dose

3.2 Managements Role

Here an inventory of the machines were taken, staff and training.

Table 3.7: Inventory of machines

Name of equipment	QTY	Functionality	Year of Management
CT Scanner	1	Functional	2010
Conventional X-ray Machine	1	Functional	2005
Mobile X-ray machines	2	Functional	2006
Mammography Machine	1	Installed not commissioned	2010
Automatic processor	2	Functional	2005

Staff Training Records

Table 3.8: Staff Training Records

Staff complement	Training need	Area of Training	Training done
i. Radiologist	Rad Protection	Rad Protection	Yes
ii. Radiographer	Rad Protection	Rad Protection	Yes
iii. Darkroom Technicians	Rad Protection	Rad Protection	Yes
iv. Medical Officer/Registrar	Rad Protection	` Rad Protection	No
v. Medical Physicists	Rad Protection	Rad Protection	No

3.3 Monitoring (Workplace Monitoring)

Average Background Measurement =105nSvhr-[1]. Indicating there is no radiation leakage from tube assembly.

Table 3.9: Area Survey Record

Area	Measured Dose Rate µSv/hr	Comment
1. Behind operating console	1.83	Satisfactory
Darkroom Area	1.22	Ok
X-ray Room Door	1.05	Ok
Toilets/Dressing Room	0.95	Satisfactory
Passage/Departmental Corridor	0.56	Satisfactory
Patient working Area/veranda	0.10	Satisfactory

3.3.1 Personnel Monitory Records:

Table 3.10:Annual Dose Record

S/N	+Hp (10) Dose (mSv)	+ Hp (0.07) Dose (mSv)
TL_1	0.33+0.33+0.34+0.34 = **1.34**	0.26+0.26+0.25+0.26 = **1.03**
TL_2	0.31+0.31+0.32+0.31 = **1.25**	0.31+0.31+0.29+0.31 = **1.22**
TL_3	0.33+0.33+0.34+0.33= **1.33**	0.27+0.27+0.25+0.27 = **1.06**
TL_4	0.29+0.30+0.30+0.30 = **1.19**	0.29+0.26+0.29+0.26 = **1.10**
TL_5	0.29+0.29+0.30+0.29 =**1.17**	0.23+0.23+0.30+0.29 =**1.10**
TL_6	0.34+0.29+0.32+0.29 = **1.24**	0.32+0.23+0.20+0.23 = **1.05**
TL_7	0.32+0.34+0.30+0.34 = **1.30**	0.26+0.23+0.20+0.23 = **0.92**
TL_8	0.39+0.39+0.43+0.39 = **1.64**	0.39+0.26+0.26+0.26 = **1.17**
TL_9	0.43+0.39+0.43+0.39 = **1.64**	0.40+0.39+0.37+0.39 = **1.55**
TL_{10}	0.30+0.43+0.30+0.43 = **1.46**	0.39+0.40+0.27+0.40 = **1.46**
TL_{11}	0.30+0.30+0.29+0.30 = **1.19**	0.26+0.29+0.26+0.29 = **1.10**

$TL = TL_{A+B+C+D}$ - - - - - - Equation.3.1

Collection dose, $S = \sum E_i . N_i$ - - - - - - Equation 3.2

Where, E_i is the mean effective dose to population subgroup$_i$ and

N is the number of people in population subgroup$_i$

In calculating the collective dose,

The individual doses are summed up, divided by 4 (by the four quarters in the year) and then multiplied by the number of staff :

$+ Hp\ (10) = \sum E_i = 14.6/4 = 3.65$ - - - - - -Equation 4.3

$N_i = 11$

$\sum E_i . N_i = 3.65 \times 11 =$ **40.15man-S** - - - **Equation** 4.4

+Hp (0.07) Dose = 12.73 /4 x 11= **3.1825x 11** - **-Equation** 4.5

Collective Dose = **35.0075man-S**

3.3.2 Verification Of Records

Table 3.11: Record Analysis

S/N	RECORD TYPE	REMARKS
1.	Are there records of film reject analysis	Yes
2	Are records for maintenance and repair being kept	Yes
3	Are instrument test and calibration records being kept	No
4	Are incident/accident records and reports being kept	No
5	Is there evidence of health surveillance records	No
6	Is there documentation on audit and review of radiation safety records.	No

3.3.3 Quality Control Results: Radiography Results

1. Reproducibility Exposure

Large Focus

Table 3.12: Reproducibility Exposure, large focus

S/N	Measured kVp	Dose mGy	Time mS
1	88.7	1.161	29.7
2	89.6	1.164	29.9
3	88.2	1.169	29.8
4	90.0	1.164	29.9
5	87.5	1.166	29.9
Average	88.8	1.1648	29.84

Using a KVp of 80 and 20mA for five separate exposures with Large Focus, the average measured kVp was 88.8, does was 1.165 mGy and the time = 29.84mS. The Standard Deviation (SD) is 1.02 while the Reproducibility Variance (%CV) = 1.15

Table 3.13: Reproducibility Exposure, Small focus

S/N	Measured kVp	Dose mGy	Time mS
1	82.0	1.12	95.8
2	79.5	1.12	95.6
3	81.2	1.12	95.6
4	80.4	1.12	95.6
5	80.1	1.12	95.6
Average	80.6	1.12	95.68

Using a KVp of 80 and 20mA for five separate exposures with Small Focus, the average measured kVp was 80.6, does was 1.12 mGy and the time = 95.68mS. The Standard Deviation (SD) is 0.98 while the Reproducibility Variance (%CV) = 1.12

2. kVp Accuracy (Large Focus)

Table 3.14: kVp Accuracy (Large Focus)

Set kVp value	Measured kVp	% Error
40	51.67	29.18
50	62.43	24.86
60	72.38	20.63
70	81.56	16.51
80	90.87	13.59
90	102.8	14.22
100	109.7	9.70
119	106	-2.31
117	114.3	-2.31
125	122.2	-2.24
Set kVp value	**Measured kVp**	**% Error**
40	39.01	-2.48
50	49.6	-0.80
60	58.57	-2.38
70	68.49	-2.16
81	79.53	-1.81

3. **Linearity Test (Large Focus)**

Table 3.15: Linearity Test (Large Focus)

MAs	1st Exposure mGy	2nd Exposure	3rd Exposure	Mean Exposure
10	0.082	0.093	0.102	
20	0.171	0.191	0.183	
40	0.363	0.371	0.348	
80	0.742	0.724	0.754	
160	1.347	1.456	1.461	
320	3.055	3.070	3.073	

Linearity Variance = 0.035

Linearity Test (Small Focus)

Table 3.16: Linearity Test (Small Focus)

MAs	Mean Exposure mGy
2.5	0.32
5	0.64
10	1.28
20	2.58
40	4.15
80	10.32

Linearity Variance = 0.078
Adequate linearity exists when the variance is less than 0.1 (10%)

Summary of Quality Control Tests of the Radiographer X-Ray Machine

Table 3.17: Summary Of Quality Control Tests

S/N	QUALITY CONTROL TEST	RESULTS	REMEDIAL ACTION
1.	Reproducibility Exposure (LF	Slightly Ok	Require Tuning
2	Reproducibility Exposure (SF)	Satisfactory	None
3	Radiation Output (Large Focus)	Ok	None
4	Radiation Output (Small Focus)	OK	None
5	kVp Accuracy (Large Focus)	Not Satisfactory	Adjustment Required
6	kVp Accuracy (Small Focus)	Satisfactory	None
7	Linearity Test (Large Focus)	Ok	None
8	Linearity Test (Small Focus)	Ok	None
9	Film Screen Contact	Satisfactory	None
10	Collimation/Beam Alignment	Ok	None

4.1 DISCUSSIONS, CONCLUSION AND, RECCOMMENDATIONS

4.1.1 Discussion

Installed radiation shielding is the primary means of restricting the exposure of persons in areas adjacent to facilities which house radiation sources. The radiation may be electrically generated,for example an x-ray set or a linear accelerator [37].

The results presented in tables 3.1 - 3.6 showed the various radiation doses of TLD badges placed behind walls A, B , C, D, E, F and H. Values obtained from behind wall G are those of the Radiographer working in the x-ray room which are read quarterly. TL1A , for instance , refer to the radiation dose of a Radiographer for a period of three(3) months, one(1) quarter. For this particular Radiographer, the values for the four (4) quarters gives: 0.33, 0.33, 0.34, and 0.34, totalling, 1.34mSv (for the deep dose) and 0.26, 0.26,0.25, 0.26, totalling 1.03mSv (for the shallow dose) .Graphically, this is presented in figure 3.1 - 3.8. The ICRP recommends limiting occupational radiation exposure of 50 mSv (5 rem) per annum and 100 mSv (10 rem) in 5 years. The three sources of radiation which need to be considered in any examination of the shielding problem can be grouped into two distinct types, primary and secondary radiation. Secondary radiation has two components, scatter and leakage . The primary beam consists of the spectrum of radiation emitted by the x-ray tube prior to any interaction with the patient, grid, table, image intensifier . The energy fluence of the primary beam will be several orders of magnitude greater than that of either of the secondary radiations. In the majority of all radiography, the primary beam will be collimated so that the entire beam interacts with the patient. Exceptions include extremity radiography and are confined to low kVp, low mAs exposures. Interactions within the patient results in considerable attenuation of the primary radiation [18,19].Scattered radiation is inevitable in diagnostic radiology and is a direct result of the Compton effect. The fluence of scattered radiation depends on the volume of the patient irradiated, the spectrum of the primary beam and the field size employed. Both the fluence and quality of the scattered radiation are dependent on angle at which they are measured. A simple generalisation is that the scattered kerma is between 10-5 and 10-6 of the incident kerma per cm2 of the incident beam.

Leakage radiation arises because x-rays and are emitted in all directions by the target. The outer shell of the tube housing is generally constructed of a light alloy with adequate mechanical properties. Evidently, such an alloy will not absorb enough of the radiation to reduce the kerma of the unwanted radiation to the legal maximum. The housing is therefore lined with lead where appropriate[18,19]. Any radiation transmitted through this protective shield is termed leakage radiation[20]. Manufacturers often protect tubes well beyond the legal minimum with the possible exception of those used in mobile radiography, where weight is especially important. Because it generally passes through two or more mm of lead, leakage radiation will be considerably harder than radiation in the primary beam. Leakage is usually defined at the maximum operating potential of an x-ray tube generator combination and is specified at the maximum continuous tube current possible at that potential[35].

The Ionising Radiations Regulations 1999 require that work involving exposure to external radiations should be performed in rooms which are provided with adequate shielding[28]. If there is public access to the surrounding area or access is permitted to employees who are not directly involved in the work, the shielding should be designed to reduce dose rates to the lowest level that is reasonably practicable[23,30]. It is therefore necessary to formulate design criteria to ensure that this requirement is met.

Table 3.10 depicts all the cumulative values of recorded radiation doses for eleven Radiation workers for one (1) year and indicates that these values are lower than the annual dose limits for occupationally exposed persons. Graphically shown in figure 3.9 - 3.10. It was recommended that occupational doses below 1–2 mSv per year do not warrant regulatory scrutiny[24]. Thus it can be seen that the design and layout of the facility is an effective one in radiation protection though " for operator protection, as recommended in A study ,the distance from the unit must be increased to at least 2 metres to achieve a dose level of less than 1 mSv per annum[35]. The dose constraint of 0.3 mSv per year could only be achieved by using an operator distance slightly in excess of 3 metres. Alternatively, the use of a 0.5 mm lead protective shield would enable this requirement to be met".

Tables 3.7 and 3.8 show some of the equipments provided by management. Also shown is the staff and the various trainings acquired. On a critical analysis, the effort of management could be seen as a fairly good one as the basics in terms of training and equipment had been provided. Up to date and state of the art equipments are provided and almost all the specialties in diagnostic imaging are covered . Training wise, only a few Registrars and House Officers who were newly employed with some Medical Physicists (termed Scientific Officers) who missed the specialized trainings. As such ,management's role is recommendable.

Quality Control (QC) is normally part of the Quality Assurance(QA) programme and quality control are those techniques used in the monitoring (or testing) and maintenance of the technical elements or components of an X-ray system. The quality control techniques thus are concerned directly with the equipment that can affect the quality of the image i.e. the part of the QA programme that deals with instrumentation and equipment[23,25].

Tables 3.12- 3.17 show the range of test carried out to assess the suitability of the x ray machine for use. A summary of the various test carried out signified that the result is quite satisfactory and meets the minimum requirement specified by the Nigerian Nuclear Regulatory Authority (NNRA) and other International Regulatory Agencies[24]. The values for the background radiation levels and the area survey seem very satisfactory. This is very significant as it gives an idea on the safety of the Radiation workers and members of the public. The darkroom area, toilets and dressing rooms, patient sitting area and corridor were some of the areas checked which proved that the areas are very safe.

The collective effective dose, dose quantity (S), is calculated as the sum of all individual effective doses over the time period or during the operation being considered due to ionizing radiation. It can be used to estimate the total health effects of a process or accidental release involving ionizing radiation to an exposed population.The values for the collective dose (for deep and shallow doses) is **40.15man-Sv** and **35.01man-Sv** respectively .Both values are lower than the annual dose limit recommended for occupational exposure which is 50mSv per annum for whole-body irradiation[25,26,27].

As evidenced in Table 3.11, the department has been found wanting in the area of record keeping. Recording of repeats in the form of film reject analysis is another way of monitoring incidences in Radiation protection. Repeats will most likely involve an exposure ,and an unjustified one, hence, there is need to keep a good record and ensure compliance.

4.1.2 Conclusion

This study assessed the radiation protection measures of a tertiary health care center in Nigeria and found it to be of an acceptable level, meeting national and international regulatory standard. This work also showed that the technical aspect of the study which involved shielding assessment and the suitability of the design and layout in radiation protection is quite adequate as a safeguard against radiation. Management's role in provision of equipment, personnel and training is recommended. Workplace monitoring and personnel monitoring were excellent as the recorded radiation doses were below the annual permissible dose indicating that the radiation protection measure is an effective one though record keeping seemed to be a major challenge. A dose constraint value of 5mSv per annum for all radiation workers in the hospital could constitute a good measure in ensuring an acceptable level of exposure occupationally.

4.1.3 Recommendation

There should be a good culture of film reject analysis and proper record keeping to check incidences.

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