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EVALUATION OF SHIELDING BARRIER OF A COMPUTED TOMOGRAPHY UNIT

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ABSTRACT
Recently, concerns have been expressed on the radiological standards of Computed Tomography (CT) units in terms of radiation protection. This study was carried out in the CT scan unit of General Amadi Rimi Specialist Hospital (GARSH), Katsina, Nigeria. The study aimed to evaluate the radiation shielding barrier of a Computed Tomography unit of GARSH, Katsina, Nigeria. The main objective of this study is to determine the shielding barrier thickness required to attenuate the unshielded radiation. Calculations of the shielding barrier thickness were carried out using XRAYBARR software. The total workload for the CT modality was found to be 48.32 mA-min per week for an average of 32 patient per week. The shielding barrier thickness required in attenuating the unshielded radiation dose for wall 1, 2, 3, 4, control area, floor and ceiling was 155.1, 146.8, 112.5, 98.10, 98.10, 193.0 and 128.0 mm thickness concrete, respectively. The already constructed shielding barrier thickness was found to be 244mm thickness concrete. Ratio of the calculated barrier thickness to the designed barrier thickness was less than 1. This showed that the constructed shielding barrier thickness was adequate and safe. The area monitoring of the strategic areas in the CT unit was carried out using calibrated radiation survey meter. The result revealed that, the background and leakage radiation doses were within the recommended dose limit. High radiation dose was recorded at the door of the CT scan room. It was recommended that the occupational workers should always use thyroid shield and light-lead glasses in the controlled area.

Keywords: Xraybarr, Ionizing radiation, Controlled area, Uncontrolled area

INTRODUCTION

Ionizing radiation has many medical applications in radio-diagnosis and radio-therapy. This includes among others x-ray, computed tomography, fluoroscopy, mammography and interventional radiology. Computed Tomography is a medical modality used to provide the cross sectional imaging of the human body in 3-D format (Kalender, 2006). However, it involves higher radiation than conventional radiographic modalities (Miglioretti et al., 2013). Computed Tomography is of great interest due to high radiation dose and rapid increase in use. The increased use of Computed Tomography raises concern on the detrimental effects from exposure to ionizing radiation. This includes among others cancer, sterility, skin damage, fibrosis of bone marrow, radiation induced mutation and early death (Brenner and Hall, 2007). There has been a justifiable concern over the high radiation generated by the CT scan modality during exposure. The secondary radiation (scattered and leakage) released by the CT scan can spread all over the CT scan room and other areas around. This includes control area, patient waiting room, corridors, toilets and other offices attached to the room. Therefore, this necessitated the use of some principles and techniques to reduce the detrimental effects of ionizing radiation released during the procedure. The distance from the source should be maximized in accordance with the inverse square law. The time spent during exposure should be reduced. The use of shield to attenuate the radiation from reaching the uncontrolled areas should also be applied (Shah and Platt, 2008; IAEA, 2000).

The term radiation shielding connotes the interposed of protection material between the radiation and an object to reduce the radiation intensity and damage to the object. This is the prepared and standard method of controlling radiation which results in safe working conditions of personnel and non-personnel (Moores and Regulla, 2011). The type of shielding used and thickness most meet the standard of National Commission on Radiation Protection and Management (NCRP, 2005). For the proper shielding of radio-diagnostic room as well as the safety of the patients, personnel and the other members of the public, two kinds of radiation must be taken into account. Primary radiation which is the useful radiation intensity emitted from the source and secondary radiation is the radiation intensity from the patient's body (scatter) and leakage from the CT gantry (Akintunde, 2005). Both the two kinds of radiation requires primary barrier for primary radiation intensity and secondary barrier for secondary radiation intensity in order to protect patient, occupational workers and members of the public (Potts et al., 2008; Wallace et al., 2011). Various materials can be used as a shield, this includes lead, concrete, gypsum, glass and wood (Shah and Platt, 2008).

The main principles to achieve radiation safety in radio-diagnostic practices are justification of practice, optimization of procedure and dose limitation (ICRP, 2004; Dixon et al., 2005). A good practice of radiation protection recommends that all practice should be at ALARA (as low as reasonably achievable) (Shah and Platt, 2008; Lanser, 2014).

In 2009, Aniko et al. conducted a study on Optimization of Radiation Protection in Diagnostic Radiology in Jos Teaching University Teaching Hospital, Nigeria (Anikoh, 2014). The study assessed the shielding evaluation of general radiology room using Xraybarr software. The results of the study showed that the ratio of the calculated shielding barrier thickness from the Xraybarr to the designed shielding barrier thickness was less than 1. This showed that the shielding barrier thickness was adequate.

A recent study conducted by Abubakar and Sidi on the determination of X-ray Shielding Thickness of Two Tertiary Hospitals in Kano (Abubakar and Sidi, 2018). The study was carried out using Xraybarr software to determine the minimum barrier thickness required. The results obtained showed that the shielding barrier thicknesses were within the recommended standard.

Another study conducted by Verdun et al. on the Criteria for Establishing Shielding of Multi-Detector Computed Tomography (MDCT) Rooms (Omouni et al., 2015). The shielding barrier thickness of the walls was calculated using dose length product (DLP) of the CT scan modalities. The results obtained showed that the all the shielding barrier thickness was adequate.

Nkasah et al, (2013), performed a study on the Assessment of the Integrity of Structural Shielding of Four Computed Tomography Facilities in the Greater Accra Region of Ghana. The study re-evaluated the shielding integrity using dose length product (DLP). The results obtained showed that the shielding barrier thickness is accepted. The area monitoring survey of the rooms was carried out using radiation survey meter. The results obtained were within the recommended dose limit.

Ionizing radiation can cause detrimental effects to the patient, occupational workers and other members of the public as a result of poor shielding of the radio-diagnostic rooms. Some radio-diagnostics rooms were awarded to contractors which were not expert in that field. The contractors are using sub-standard materials in shielding the radiographic rooms in order to maximize their gains. So also some radiographic rooms were converted from the existing buildings which are not originally designed for radio-diagnostic purposes.

The CT scan room of General Amadi Rimi Specialists Hospital (GARSH), Katsina has already been designed and constructed. The criteria for the shielding design and occupational exposure monitoring have not been made public as it's the norm.

It is therefore, important to evaluate the CT scan room shielding barrier design and integrity. So also the area monitoring survey of strategic locations in the CT scan unit to ensure the safety standard of the patient, occupational workers and other members of the public.

MATERIALS AND METHODS

This study was carried out in August, 2019 to November, 2019 in CT scan unit of General Amadi Rimi Specialist Hospital, Katsina, Nigeria. The CT room had an area of 7m x 7m as shown in figure 1. The CT machine was Siemens 64 slice Somatom Perspective with a maximum tube potential and tube current of 140kVp and 500mA, respectively. The machine was manufactured in Germany in 2013. The materials used included: XRAYBARR software, calibrated survey meter and tape rule.

The XRAYBARR software is a software developed by Douglas J. Simpkin in 1996 and upgraded in 2001 (Simpkin, 2007). The software was used to determine the thickness and type of shielding material used. To determine the minimum required thickness for each barrier (wall) of the CT scan room, the following variables are inserted in the XRAYBARR: The distance (D) of each wall from the CT Gantry, the average number of patient (N) per week, the total workload (Wtot) which was obtained by the product of average number of patient and normalized workload, occupancy factor (T) which was the fraction of time that the exposed individual is present when the x-ray procedure is ON, the use factor (U) which was the fraction of primary beam that is directed towards a given primary barrier . The design permitted dose (P) provided by the software for controlled (occupied by personnel) and uncontrolled (occupied by non-personnel) area. The annual radiation dose limit used was 1 mSv/yr and 5 mSv/yr for uncontrolled and controlled area, respectively. The scattering angle of 90^0 was used. The occupancy factor of 1 was used for controlled and uncontrolled area. While the use factor of 1 and 0 was used for primary and secondary barrier, respectively (NCRP, 2005). All barriers were considered primary as they are exposed to primary beam of radiation. The room measurement was done using calibrated tape rule. Five barriers were evaluated and labeled as wall 1,2,3,4 and 5 (control area). The floor and ceiling of the room were also evaluated. After inserting all the variables, the calculate button was clicked.

A calibrated radiation survey meter (RDS-120) obtained from Center for Energy Research and Training, Zaria, Nigeria was used for area monitoring of various strategic locations around the CT room when the CT modality was working at maximum capacity. The locations were control area, reception, at the CT room door, corridors and behind the CT room. The readings were collected at an interval of 3 minutes at each locations. There readings were taken repeatedly before exposure, during exposure and after the exposure. The readings were measured in μSv/hr.

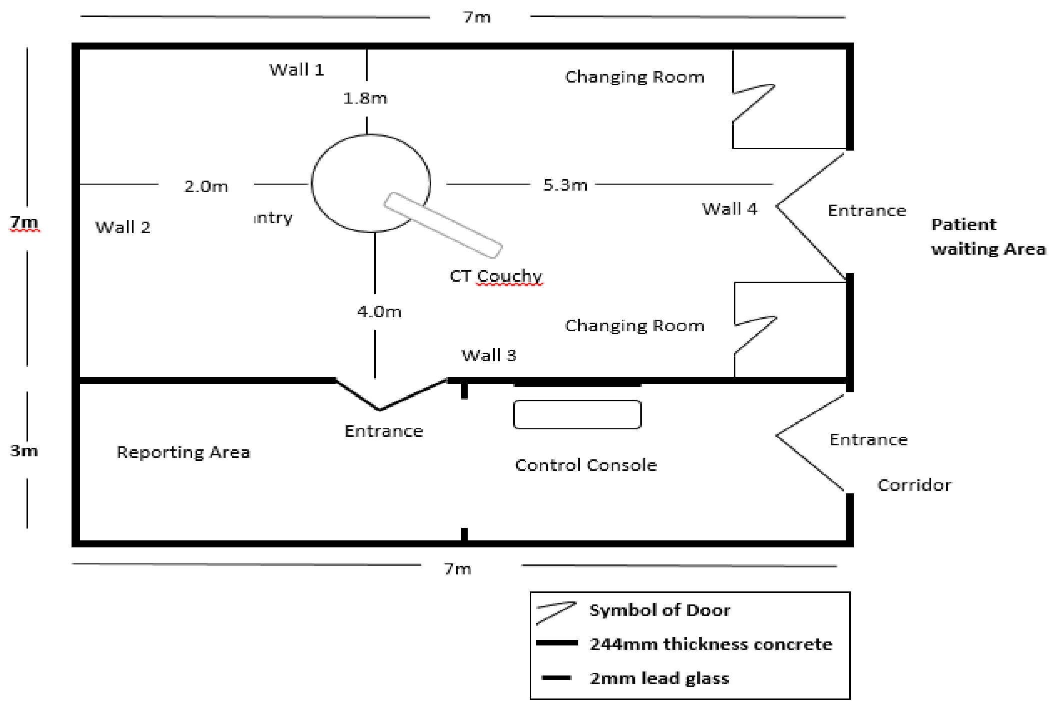

Figure 1. CT scan room layout

RESULTS

The results of the evaluation of the shielding barrier thickness and area monitoring survey of the CT scan unit of General Amadi Rimi Specialists Hospital (GARSH), Katsina were carried and the results obtained were presented on the tables. The shielding barriers thickness was evaluated using Xraybarr software. The type of materials and their equivalent thickness were also calculated using the software. The area monitoring survey of some strategic places around the CT scan room was carried out using calibrated radiation survey meter.

Table 1. Shielding Barrier thickness of the CT room as calculated from XRAYBARR software

Barrier	Distance from the CT Tube (m)	Calculated Dose (mSv/wk) Unshielded area	Shielded area	Minimum Barrier thickness Concrete (mm)
Wall 1	1.80	57.76	0.0200	155.1
Wall 2	2.10	42.44	0.0200	146.8
Wall 3	4.00	11.70	0.0200	112.5
Wall 4	5.00	6.662	0.0200	98.10
Control Area	5.00	6.662	0.0200	98.10
Floor	0.90	231.00	0.0200	193.0
Ceiling	3.00	20.79	0.0200	128.0

The table 1 shows the minimum required shielding barrier thickness for wall 1, 2, 3, 4, control area, floor and ceiling. The required thickness calculated from the Xraybarr software was done using the average number of 32 patients per week, total workload of

48.30 mAmin/week, use factor (U) of 1 and 0 for primary and secondary barrier, respectively, occupancy factor of 1 for controlled and uncontrolled area as recommended by NCRP. The calculations were carried out at the scattering angle of 90^0 and field area of 4900 cm^2. All barriers (walls) were considered primary barriers in the calculation.

Wall 1, 2, 3 and 4 had a distance of 1.80, 2.10, 4.00 and 5.00 m, respectively from the CT tube (gantry). The calculated unshielded radiation dose at wall 1, 2, 3 and 4 was 57.7600, 42.44, 11.70 and 6.662 mSv/week, respectively for the uncontrolled area. The shielded radiation dose in the controlled area was 0.02mSv/week for all the four (4) barriers. The minimum required shielding barrier to attenuate the unshielded radiation in the uncontrolled area for wall 1, 2, 3 and 4 was calculated to be 155.1, 146.8, 112.5 and 98.10 mm thickness concrete, respectively. The Control area had a distance of 5.00 m from the CT scan (Gantry). The calculated unshielded radiation dose in the uncontrolled area was 6.662 mSv/week and 0.0200 mSv/week for the controlled area. The minimum required shielding barrier to attenuate the unshielded radiation in the uncontrolled area was 98.10 mm thickness concrete. The Floor and ceiling had a distance of 0.90 and 3.00 m, respectively from the CT gantry. The calculated unshielded radiation dose in the uncontrolled area were 231.00 and 20.79 mSv/week for the floor and ceiling, respectively. The calculated radiation dose for the controlled area was 0.020 mSv/week for both floor and ceiling. The minimum required shielding barrier to attenuate the unshielded radiation in the uncontrolled area was 193 and 128 mm thickness concrete for the floor and ceiling, respectively. The results supported by the findings of Abubakar and Sidi (2019) reported the occupancy factor of 1 and 0 for primary and secondary barriers respectively. The calculated unshielded in the controlled area to be 0.02 mSv/week. However, the results of unshielded radiation in the uncontrolled areas contradicted by the findings of Abubakar and Sidi (2019) reported the unshielded radiation for wall 1, wall 2, wall 3 and wall 4 to be 14.10, 1.720, 0.220 and 0.169 mSv/week. This contradiction occurs due to the distance between the X-ray tube and the walls. So also in their study, they consider only wall 1 to be primary barrier. While in the present study all barriers were considered primary.

Table 2. Comparison of calculated shielding barrier thickness from XRAYBARR to the design shielding barrier thickness of the CT room.

Position	Wall 1	Wall 2	Wall 3	Wall 4	Control	Floor	Ceiling
Calculated Barrier Thickness Concrete(mm)	155.5	146.8	112.5	98.10	98.10	193.0	128.0
Design Barrier Thickness Concrete(mm)	244	244	244	244	244	244	244
Ratio of Calculated to Design Barrier Thickness	0.6357	0.6016	0.4611	0.4020	0.4020	0.7720	0.5246

Note. Design barrier thickness refers to the already constructed barrier thickness

Table 2 shows a comparison of the calculated shielding barrier thickness from the Xraybarr software to the design shielding barrier thickness of the CT scan room. Simple ratio was used to make a comparison between the calculated shielding barrier thickness and the design shielding barrier thickness of the room. It can be observed that the ratio of the calculated shielding barrier thickness from the Xraybarr software to the designed shielding barrier thickness was less than one (<1). This shows that the shielding barriers in the CT room were adequate. Therefore, the uncontrolled area and controlled area were adequate shielded and safe based on the NCRP recommendation.

The results contradicted by the findings of Anikoh et al., (2009) which reported the results of calculated dose when compared to the design dose is greater than or equal one (≥1). The contradiction occurs due to poor shielding of their study area. Similarly, the result supported by the findings of Abubakar and Sidi (2019) which reported the comparison of calculated barrier shielding thickness to that of design barrier shielding to be less than one (<1).

Table 3. Equivalent thickness in (mm) of different materials used for barrier shielding estimated from XRAYBARR.

Type of Material	Wall 1	Wall 2	Wall 3	Wall 4
Lead	2.03	1.909	1.412	1.209
Concrete	155.1	146.8	112.5	98.10

Gypsum	480.00	455.5	353.5	310.1
Steel	20.00	18.62	13.17	10.97
Glass	167.00	158.6	125.3	110.9
Wood	1123.00	1078	892.7	812.1

Table 3 shows the equivalent thickness of different materials that can be used for shielding the CT scan room. The required materials designed by the Xraybarr software were lead, concrete, gypsum, steel, glass and wood. The required thickness for the primary barrier with a distance of 1.80 m from the CT tube were 2.03 mm, 155 mm, 480 mm, 20 mm, 167 mm and 1123 mm respectively. The required thickness for other barriers were stated as shown in table 3. The material used for shielding the CT scan room of GARSH, Katsina was combination of lead and concrete.

The results supported by the findings of Nkasah et al., (2013) reported the minimum barrier thickness for the shielding of radio-diagnostic room was 102 to 152 mm thickness concrete.

Table 4. Area monitoring results of the strategic locations around the CT room at maximum exposure

Location	Measured Dose Rate (µSv/h)		
	Before Exposure	During Exposure	After Exposure
Background	0.09	0.10	0.09
Control area	0.10	0.12	0.10
Reception	0.10	0.11	0.10
ECG Room	0.09	0.13	0.09
CT room door	0.10	0.56	0.10
Behind CT room	0.09	0.10	0.09
Corridor	0.10	0.11	0.10

Table 4 shows the measured dose of some strategic places around the CT scan room before, during and after exposure. The results obtained for the background, control area, reception, ECG office, behind the CT room and the corridors were within the permissible dose limit of 1 mSv/y and 5 mSv/y for members of the public and occupational exposure, respectively. High radiation dose of 0.56 µSv/hr was measured at the entrance door of the CT room. The result is supported by the findings of Joseph et al., (2017) which recorded 0.12, 0.14, 0.10 and 0.10 µSv/hr for background, control area, reception and behind x-ray room, respectively.

CONCLUSION

Based on the comparison of the calculated shielding barrier thickness from Xraybarr software to that of the constructed shielding barrier thickness, the ratio was found to be less than 1. This revealed that the shielding barrier thickness of the CT scan room was adequate and safe. From the study, it was found that various materials could be used in shielding radio-diagnostic rooms if they have meet the recommended thickness. The. The area monitoring survey was excellent as the recorded radiation dose was within the permissible dose limit. Precautions should be taken by a proper use of thyroid shield, lead apron and light-lead glasses by the occupational workers. Despite the aforementioned results from the area monitoring survey, there is need for protection measures to strongly be implemented.

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