Original Article

Determination of X-ray shielding thickness in two tertiary hospitals in Kano metropolis, Nigeria

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Abstract

Background: Radiation dose depends on the total workload (Wtot) which is affected by the number of patients, tube potential, and tube current. Despite the increment in patients visiting the X-ray units under study and X-ray tube revolutions, changes have not been made in the shielding material to suit the current situation.

Aims: This study aims to evaluate the thickness of X-ray shielding barriers in two tertiary hospitals in Kano Metropolis using XRAYBAR software.

Materials and Methods: This was a prospective, cross-sectional study and was undertaken from March 2017 to October 2017. A purposive sampling technique was employed to select two hospitals out of five. The two were named A and B, respectively. The minimum required thickness in each barrier was determined by XRAYBAR software.

Results: The Wtot (workload) for room I, II and III was found to be 199.9, 146, and 149.1 mA-min per week. The shielding barrier thickness required to reduce the unshielded radiation dose to the design dose limit for wall 1, 2, 3, 4, and operating console of the Room I was found to be 17.5, 5.5, 0.2, 0.00, 3.3 cm, that of wall 1, 2, 3, and 4 of room II was found to be 9.1, 3.4, 0.02, 2.3 cm, while for the wall 1, 2, 3, 4, and operating console of room III was found to be 12.3, 4.8, 3.8, 3.2, and 26.5 cm, respectively.

Conclusion: The calculated shielding barrier thickness from XRAYBARR code when compared to the design barrier thickness was found to be adequate.

Keywords: Shielding, X-ray, XRAYBARR

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INTRODUCTION

The sole aim of radiation protection is to prevent deterministic and reduce nondeterministic biological effects of ionizing radiation.[1] Shielding is a term that implies deliberate introduction of a material between the radiation and an object to reduce the radiation intensity and damage to the object.[2] If individuals are not properly shielded, such that only the intended body part exposed to ionizing radiation, there could be potential health hazards to the workers and members of the public.[1,3] Primary radiation is the useful beam emitted directly from the X-ray tube and requires a primary barrier to intercept the beam. Secondary radiation emanates from patients as a result of scatter. Leakage from a tube head could also be responsible for this radiation type. Both primary and secondary radiation types require barriers to protect patients, personnel, and the public.[4] The barriers that are commonly used in the clinical

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practice include lead sheet, concrete, cement blocks, bricks, gypsum, and wallboard. The minimum required thickness in each barrier was determined using radiologic statistical software XRAYBARR based on The National (American) Council on Radiation Prevention and Measurement (NCRP) recommendations. The software was developed by Doug Simpkin in Maryland, 1996-2001 as shown in Figure 1.[4] For each barrier, variables such as distances of each wall from a radiation source (D), average number of patients per week (N), total workload (Wtot) per week in each room, occupancy factor (T), and use factor (U) were inserted into the software together with the shielding design goal (P) provided by the software for areas adjacent to X-ray rooms populated by radiation workers (controlled areas) and those areas populated by nonradiation workers (uncontrolled areas) and the type of barrier in concern (primary or secondary). The use factor (U) is the fraction of the primary beam workload that is directed toward a given primary barrier and depends on the type of radiographic installations and the barrier of concern. The NCRP recommended U = 1 for primary barriers and U = 0 for secondary barriers for radiographic rooms.[5] The occupancy factor (T) is the fraction of time that the maximally exposed individual is present in that area while the X-ray beam is on. Radiation workers may be assumed to spend their entire work period in controlled areas. Therefore, controlled areas behind the X-ray rooms and control booths should be designed with an occupancy factor of unity (1).[4]

The two hospitals under study been established since the 1950s have gotten more patients' throughput probably due to increment in the population and patients awareness; more patients visiting the X-ray unit lead to more increment in the Wtot in the rooms; however, changes have not been made in the shielding material to suit the current situation. To the best of the researchers' knowledge, no study has been conducted in the centers under review to determine their shielding adequacy. The NCRP provides the widely accepted methodology for radiation shielding design, and this shall be adopted for this work.[5]

MATERIALS AND METHODS

The study design was prospective and cross-sectional, and a purposive was adopted to select two hospitals out of five. The study was conducted from March 2017 to October 2017. Two governmental tertiary hospitals were selected in Kano metropolis; the hospitals were named A and B. In hospital A, only two rooms out of four were selected named room I and II as they are the only rooms containing active X-ray machines at the time of the study. While in hospital B, only the conventional X-ray room was considered and was named as room III. Room I had an area of 31 feet × 27 feet (944.8 cm × 822.9 cm). The X-ray machine in the room was a conventional X-ray machine with a total filtration of 2.5 mmAl and a maximum tube potential and tube current of 130 kVp and 400 mA, respectively. Room II had an area of 21 feet × 20 feet (640.1 cm × 609.6 cm) housing an ITALRAY conventional X-ray, with total filtration of 2.5 mmAl and a maximum tube potential and tube current of 150 kVp and 500 mA, respectively. Room III had an area of 24 feet × 24 feet (731.5 cm × 731.5 cm). The conventional X-ray machine is Picker International with a total filtration of 2.5 mmAl and a maximum tube potential and tube current of 125 kVp and 350 mA, respectively. All room measurements were done using a retractable tape. A total of 14 barriers (walls) were evaluated in the two hospitals. In room I and III, five barriers were evaluated in each room labeled as wall 1, 2, 3, 4, and 5 (operating console), whereas in room II, four barriers were evaluated labeled as wall 1, 2, 3, and 4 (operating console). Wall 1 was considered as the primary barrier in all the rooms as they are exposed by the primary radiations, while the other walls were considered as secondary as they are exposed by secondary radiations.

The average number of patients per week (N) in each room was noted. The use factor (U) used was 1 and 0 for primary and secondary barriers, respectively, as recommended by the NCRP.[5] T factor used was 1 in all the rooms except in wall 4 in room I and III and wall 3 in room II, where 0.020 (1/40) was used.[4] The Wtot per week (mA-min/week) was determined by the product of average number of patients per week (N) and normalized workload (Wnorm) (Wtot = Wnorm × N).[4] The annual radiation dose permitted (P) used was 1 mSv/year and 5 mSv/week for uncontrolled and controlled areas, respectively, as recommended by the NCRP.[5] The scattering angle was 90° in all the rooms. All the parameters were inserted into the software and then "calculate button" was clicked.

RESULTS

All shielding barriers in the room I and II of hospital A were concrete with a thickness of 25 cm all. In room I, the distance (D) from X-ray source to wall 1, 2, 3, 4 and operating console was measured to be 12, 11, 21.2, 19, and 16 feet, respectively. However, in room II, the distance was 13, 10, 10, and 14 feet for wall 1, 2, 3, and 4, respectively. In room III, the barriers are union of lead, wood, and bricks with a total thickness of 25 cm. The distance (D) from X-ray source to wall 1, 2, 3, 4, and operating console was measured to be 12, 10, 14, 16, and 7 feet, respectively. The average number (N) of patients per week in room I, II, and III was 289, 72, and 224, respectively while the workload was 199.9, 146, and 149.1 mA-min/week in all the three rooms, as shown in Tables 1-4 respectively.

The software showed that in room I, the shielding barrier thickness required at the different positions to reduce the unshielded radiation dose to the design dose limit for primary barrier was 17.7 cm of concrete and a range 0.00–5.4 cm of concrete for the secondary barriers. In room II, 9.1 cm and a range of 0.025–3.3 cm of concrete needed to reduce the unshielded radiation dose to the design dose limit at the primary and secondary barriers, respectively. In room III, 12.2 cm and a range of 3.1–6.35 cm concrete needed to reduce the unshielded radiation dose to the design dose limit (0.02 mSv/week) at the primary and secondary barriers, respectively as shown in Tables 2-4.

DISCUSSION

In room I, the primary beam was directed at wall 1 for 45.67% of the Wtot, with the remaining 54.3% directed toward the other walls. In room II, 33.6% of the Wtot was directed toward the erect bucky and 66.4% to other barriers. In room III, 42.2% of the Wtot distribution was directed to the erect chest bucky and 57.8% to the floor and other barriers. The kilovoltage distribution of the Wtot and the total number of patients per week in room I, II, and III are shown in Table 1. The workload distribution was spread between the operating potentials of 55–100 kVp in the two hospitals. The Wtot distribution rooms were divided into the chest wall (Erect Bucky) and floor/other barriers (X-ray table); 45.7% and 54.3% Wtot were directed to the chest wall and the floor/other barriers in room I. In room II, 33.6% were directed toward the erect bucky and 66.4% to other barriers, while in room III, 42.2% was directed to the erect chest bucky and 57.8% to the floor and other barriers. Separating the Wtot into these two barrier-specific distributions provide a more accurate description of the intensity and penetrating ability of the radiation directed at primary barriers, and it is used

Table 1: Workload distribution in the two specialist hospitals

Workload mA-min/week	Room I		Room II		Room III	
	Average patients/week (289)		Average patients/week (72)		Average patients/week (224)	
	Barrier (kVp)					
	Primary	Secondary	Primary	Secondary	Primary	Secondary
<60 kVp	14.7	12.6	-	43.2	16.6	11.6
60-100 kVp	77.0	96.0	49.6	54.0	52.5	68.7
>100 kVp	-	-	-	-	-	-

Table 2: Shielding barrier thickness required, calculated from XRAYBARR at workload of 199.9 mA-min per week and scattering angle of 90° for room I

Barrier (feet)	D1	D2	D3	U	T	Calculated dose mSv/week		Minimum barrier thickness Concrete (cm)
						Unshielded area	Shielded area	
W1	12	5	12	1	1	38.17	0.090	17.50
W2	11	11	11	0	1	1.274	0.100	5.50
W3	21.2	21.2	21.2	0	1	0.342	0.090	0.20
W4	19	19	19	0	0.025	0.010	0.010	0.00
OC	16	16	16	0	1	0.601	0.100	3.30

Table 3: Shielding barrier thickness required, calculated from XRAYBARR at workload of 146.1 mA-min per week and scattering angle of 90° for room II

Barrier (feet)	D1	D2	D3	U	T	Calculated dose mSv/week		Minimum barrier thickness Concrete (cm)
						Unshielded area	Shielded area	
W1	13	7	13	1	1	1.70	0.02	9.10
W2	10	10	10	0	1	0.8345	0.02	3.40
W3	10	10	10	0	0.025	0.0208	0.02	0.020
W4	14	14	14	0	1	0.4258	0.02	2.030

Table 4: Shielding barrier thickness required, calculated from XRAYBARR at workload of 149.1 mA-min per week and scattering angle of 90° for room III

Barrier	D1	D2	D3	U	T	Calculated dose mSv/week thickness		Minimum barrier Concrete (cm)
						Unshielded area	Shielded area	
W1	12	6	12	1	1	14.10	0.020	12.30
W2	10	10	10	0	1	1.720	0.020	4.80
W3	14	14	14	0	1	0.220	0.020	3.81
W4	16	16	16	0	0.025	0.169	0.020	3.20
OC	7	7	7	0	1	3.534	0.020	6.55

Table 5: Comparison of calculated shielding barrier thickness to the design shielding barrier thickness for the general radiography room I

Position	Wall 1	Wall 2	Wall 3	Wall 4	Operating console
Calculated barrier thickness (cm of concrete)	17.5	5.5	0.02	0.00	3.3
Design barrier thickness (cm of concrete)	25	25	25	25	38
Ratio of calculated to design barrier thickness	0.696	0.216	0.0077	0.00	0.09
Type of barrier	Primary	Secondary	Secondary	Secondary	Secondary

Wall 1 - Primary barrier; Wall 2, 3, 4, and operating console - Secondary barrier

Table 6: Comparison calculated shielding barrier thickness to the design shielding barrier thickness for the general radiography room II

Position	Wall 1	Wall 2	Wall 3	Wall 4
Calculated barrier thickness (cm of concrete)	9.10	3.4	0.02	02.03
Design barrier thickness (cm of concrete)	25	25	25	25
Ratio of calculated to design barrier thickness	0.36	0.135	0.001	0.081
Type of barrier	Primary	Secondary	Secondary	Secondary

Wall 1 - Primary barrier; Wall 2, 3, 4 and - Secondary barrier

Table 7: Comparison calculated shielding barrier thickness to the design shielding barrier thickness for the general radiography III

Position	Wall 1	Wall 2	Wall 3	Wall 4	Operating console
Calculated barrier thickness (cm of concrete)	12.3	4.8	3.81	3.2	6.55
Design barrier thickness (cm of concrete)	25	25	25	25	25
Ratio of calculated to design barrier thickness	0.483	0.190	0.150	0.128	0.258
Type of barrier	Primary	Secondary	Secondary	Secondary	Secondary

Wall 1 - Primary barrier; Wall 2, 3, 4 and operating console - Secondary barrier

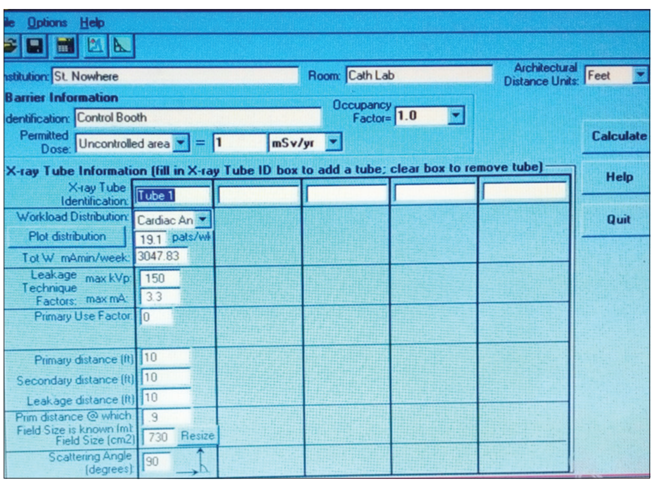

Figure 1: Image of XRAYBARR software v1.4[8]

for primary beam barrier calculations.[4] The comparison of design shielding barrier thickness to the calculated shielding barrier thickness from the software for room I, II, and III are shown in Tables 5-7. The ratio of the calculated shielding barrier thickness to design shielding barrier thickness was <1, indicating that the shielding barriers at the different positions were enough and that the uncontrolled and controlled area were adequately shielded.

CONCLUSION

The ratio of the calculated to the design dose limits was <1. It is hereby concluded that based on the NCRP recommendations, the design barrier thickness in the radiology department of all the room involved in the study was adequate.

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Conflicts of interest

There are no conflicts of interest.

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