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X-Ray Barrier Estimation - A Case Study of the General Radiography Room of a Major Nigerian Teaching Hospital

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ABSTRACT

Background: The observation that the designing rules and calculations on shielding barrier thickness estimation for most general radiographic rooms are not being practised made the evaluation of the already existing shielding barrier of the General Radiography Room of Ahmadu Bello University Teaching Hospital, Shika - Zaria to ascertain its shielding adequacy very necessary.

Materials and Methods: The General Radiography Room with an area of 6.36m x 5m houses a Silhouette General X-ray machine; model MS-185N with serial number 0877 manufactured by General Electric (GE) Medical Systems in September, 2004. The evaluation was based on the method by NCRP Report No. 147, and used the number of patients examined in this room per week for shielding calculations.

Results: The results showed that the barrier thickness required varied from 0.10 to 0.46mm of lead for the secondary barriers and 1.36mm of lead for the primary barrier. The ratio of the calculated to the current (already contructed) barrier thickness ranged from 0.09 to 0.23 for the secondary barriers and 0.68 for the primary barrier .

Conclusion: Based on the results from this study, the shielding barrier already provided in the General Radiography Room of Ahmadu Bello University Teaching Hospital, Shika - Zaria is adequate and in the event of public access to the surrounding area, the dose rates are at acceptable limits.

INTRODUCTION

The Ionizing Radiations Regulations 1999 require that work involving exposure to external radiations should be performed in rooms which are provided with adequate shielding [1]. In the event of public access to the surrounding area or access to employees who are not directly involved in the radiation work, the shielding should be designed to reduce dose rates to the shielding designed dose limits [1]. The amount of shielding in a barrier between an x-ray source and the adjacent area depends on the allowed shielding design dose limit, the distance from the x-ray source to the occupied area, the workload on the x-tube, the kVp on the tube, the occupancy and the use factors [2, 3].

The National Council on Radiation Protection and Measurements (NCRP) provides the standard guidelines on the design and determination of shielding barriers for diagnostic x-ray rooms in the Reports No.49 and 147, which form the basis for the design and shielding of radiographic rooms in most countries. The NCRP Report No.49 recommends 50mGy as the annual dose limit for radiation workers and 5mGy for the general public [4, 5]. This annual dose limit was reduced for both radiation workers and general public in the NCRP Reports No.116 and 147, to 5 mGy for controlled areas and 1 mGy for non-controlled areas [4, 5]. The NCRP Report No.49 assumptions for shielding design did not reflect the present existing conditions and may underestimate or overestimate the scattered and leakage radiation respectively from modern x-ray units [6-9]. Therefore new guidelines reflecting existing situations for designing and shielding based on the number of patients determined by weekly mean, kVp distribution, with new values for occupation factors and use factor was presented in the next NCRP Report No. 147

Generally it has been observed that the designing rules and calculations on shielding barrier thickness for most radiographic rooms are not being practiced. What happens is that after constructing the radiographic room some thickness of lead is knocked on the wall. This is the case in the General Radiography Room of Ahmadu Bello University Teaching Hospital commissioned in 2005. Since any radiation exposure may have associated level of risk, it is important that the already existing shielding barrier thickness be evaluated to ensure that all the exposures meet the ALARA principle [10]. Also some rooms adjoining the general radiography room which were originally used as stores were converted to offices thereby necessitating a review of the barrier thickness in place [11].

This study will attempt to evaluate the already constructed structures of the General Radiography Room of Ahmadu Bello University Teaching Hospital, Zaria using NCRP Report No. 147 as this Report is intended for use in planning and designing new facilities and in remodeling existing facilities [12] by

i. Manually calculating the shielding barrier thickness required to reduce

radiation exposure at occupied areas to the design dose limit.

ii. Comparing the calculated barrier thickness to that already in place in the general Radiography Room of Ahmadu Bello University Teaching Hospital, Zaria.

Materials and Methods

Workload determination

This study was carried out in the General Radiography room of Ahmadu Bello University Teaching Hospital, Shika-Zaria. The workload was earlier surveyed for 12 calendar weeks. For instance using[13] determination of workload and use factor for this facility, the number of patients examined/week (190 patients/week)[3] was chosen for the manual calculation of the shielding barrier thickness for this room.

Room Layout

The General Radiography Room has an area of 6.36m x 5m while the operator console in the room has an area of 1.52m x 2.35m and 2m high. The x-ray machine is a Silhouette General X-ray machine; model MS-185N with serial number 0877 manufactured by General Electric (GE) Medical Systems in September, 2004. It has a minimum inherent filtration of 1.5mmAl equivalent at 100kV. It also has a leakage radiation of 0.876mGy/h dose (100 mR/h exposure) at 1m (150 kVp, 3mA). The layout of the General Radiography Room is shown in figure 1.

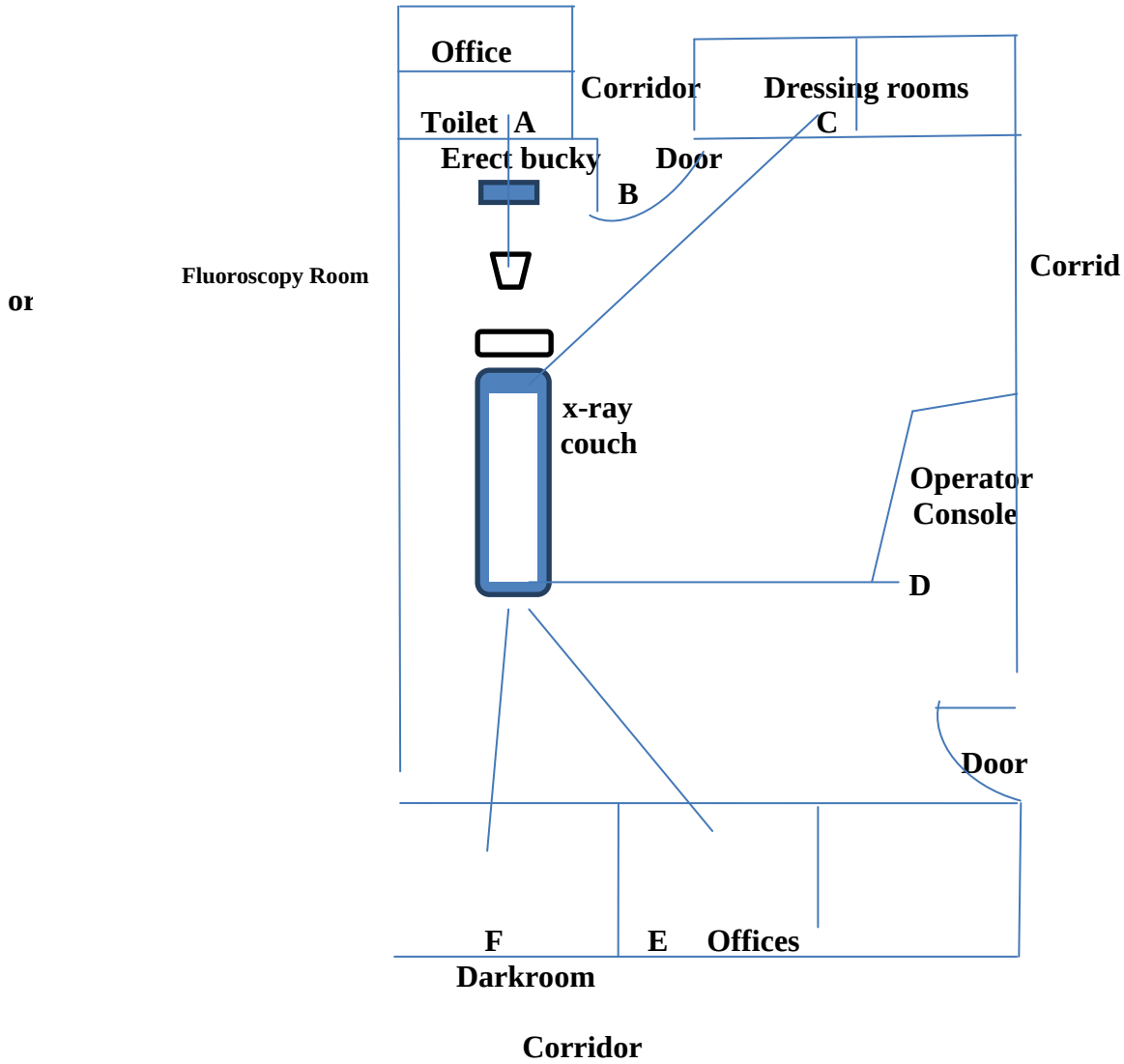

Figure 1: Layout of the General Radiography Room of Ahmadu Bello University Teaching Hospital, Shika- Zaria

Wall A is a primary barrier while the rest of the walls (B, C, D, E and F are secondary barriers. These were the only barriers considered in this study. The building does not have a basement and second floor.

Calculation of shielding barrier thickness

The primary and secondary barrier's thicknesses of the General Radiography room were separately calculated using NCRP Report No. 147 method. The estimation of the primary and secondary shielding barrier thickness were given by

$$\frac{NT}{Pd^2} \qquad (1)$$

Where N = number of patients examined per week
T = Occupancy factor
P = Design dose limit
d = distance from source to occupied area of interest

Table 2 lists the assumptions used in the calculation of the shielding barrier thickness.

Table 2 Assumptions used to calculate the barrier thickness by NCRP Report No. 147 method

Position	**Type of barrier**	**d_{pri}**	**d_{sca}**	**d_{leak}**	**T**	**Design dose limit (mGy)**
Toilet B Door	Primary	2.98	1.15	2.98	0.2	0.02
C Changing Room	Secondary	-	3.19	3.19	0.2	0.02
D Operator's Console	Secondary	-	4.15	4.15	0.2	0.02
E Office	Secondary	-	3.18	3.18	1.0	0.1
F Darkroom	Secondary	-	3.80	3.80	1.0	0.02
			3.10	3.10	1.0	0.02

Number of patients/week = 190

RESULTS

Table 3: The calculated and Current barrier thickness for the General Radiography Room

Position	Type of barrier	Calculated barrier thickness mm of lead	[a]Current Barrier thickness mm of lead	Ratio of Calculated to current barrier thickness
A (Toilet)	Primary	1.36	2	0.68
B (X-ray room Door)	Secondary	0.18	2	0.09
C (Changing) Room)	Secondary	0.10	2	0.05
D (Operator's Console)	Secondary	0.18	2	0.09
E (Office)	Secondary	0.37	2	0.185
F (Darkroom)	Secondary	0.46	2	0.23

[a] *Current barrier thickness refers to the barrier thickness already constructed in the walls of the General Radiography Room*

Table 2 presents the assumptions used to calculate the thickness required for the different barriers. Positions A, B and C were given a conservately safe occupancy factor assumptions of 0.2 while the other positions were given occupancy factors of 1 [3]. The average number of patients examined in this room was 190patients/week

Table 3 presents the results of the manual calculation of the barrier thickness required for the different Positions in the Radiography room. The calculated barrier thickness ranged from 0.10mm of lead for Position C (Changing room) to 0.46mm of lead for Position G (Darkroom) for secondary barrier thickness. The calculated barrier

thickness for the primary barrier behind the chest/erect bucky is 1.36 mm of lead. This calculation ignored the preshielding provided by the chest/erect bucky hardware because a conservatively safe assumption was used. The thickness of lead knocked on the walls surrounding the General Radiography Room and it's doors is 2mm of lead while the Operator console is protected by a 2 mm of lead glass. The ratio of the calculated to the current barrier thickness varied from 0.05 to 0.23 for secondary barriers and 0.68 for the primary barrier indicating that the barrier thickness required for the different barrier positions were highly variable.

The design dose limit recommended by the National Council on Radiation Protection and Measurements (NCRP) is 0.1mGy week^{-1} in controlled areas and 0.02mGy week^{-1} in uncontrolled areas for new facility operations [3]. The operator's console is the only controlled area while the other positions are uncontrolled areas. The results of the shielding calculations (Table 3) shows that both controlled and uncontrolled areas beyond the primary and secondary barriers are adequately shielded.

DISSCUSSION AND CONCLUSION

In this study, the operator's console is the the only controlled area considered while the other areas are uncontrolled. Also Position A (Toilet) behind the chest/erect bucky is the only primary barrier and the other positions are secondary barriers. The shielding at Position A (Toilet) behind the erect/chest bucky must protect against primary radiation from the x-ray tube and secondary radiation from the couch while shielding at the other positions must protect against secondary radiation from the erect/chest bucky and the x-ray couch. These concerns were included in the calculation of the barrier thickness for this Room. It can be seen that from Table 3 that the calculated barrier thickness ranged from 0.10 mm of lead for Position C (Changing room) to 0.46 mm of lead for Position G (Darkroom) for secondary barrier thickness and 1.36mm of lead for Position A. This variation in the barrier thickness required can be attributted to the differences in distances to the occupied area, varying occupancy and use factors and design dose limits for the different positions. The ratio of the calculated to the current barrier thickness varied from 0.05 to 0.23 for secondary barriers and 0.68 for the primary barrier indicating that the barrier thickness required for the different barrier positions were highly variable. The lower the calculated barrier thickness compared to the current barrier thickness indicates that the structure already in place can accomodate future increases in number of patients examined in this room per week.

The walls of General Radiography Room are made up of 12 inches hollow cement blocks, followed by 13.2 mm of gypsum screwed to metal studs on the blocks, 2 mm of lead is then glued to the gypsum and another 13.2 mm of gypsum is used to cover the lead. Based on this fact, it

can be said that the shielding design rules and calculations were never carried out for this room.

In spite of these concerns, the evaluation of the already existing shielding barrier of the General Radiography Room of Ahmadu Bello University Teaching Hospital,Shika - Zaria showed that the barrier thickness is adequate. The ratio of the calculated to the current barrier thickness is less than 1 (<1). It can therefore be concluded that based on NCRP Report No. 147 method, the shielding barrier thickness of the General Radiography Room of Ahmadu Bello University Teaching Hospital, Shika - Zaria might have been overestimated with attendant waste of scarce financial and economic resources.

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