JOURNAL OF RADIOGRAPHY AND RADIATION SCIENCES

A SURVEY OF DIAGNOSTIC X-RAY ROOM DESIGN AND SHIELDING INTEGRITY OF LEAD APRONS IN A STATE IN NORTH EASTERN NIGERIA.

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Received: October 25th 2020 Received in revised form: November 9th, 2020 Accepted: November 10th, 2020

ARTICLE INFO

Keywords: X-ray unit, Accessories, Lead aprons.

ABSTRACT

Background: X-ray facility design and shielding integrity is meant to optimize radiation safety of patients, staff and the general public.

Objectives: To determine the conformity to x-ray room design standards and the functional efficacy of lead aprons in the surveyed facilities.

Materials and Method: The survey was conducted in six radio diagnostic centers in Gombe State Nigeria, labeled A to F for anonymity. The building layout of the radiology departments was sketched to show the dimensions (L x B x H) and adjoining structures. Data sheets were also used to record information about radio-diagnostic facility. Lead aprons were inspected for defects by physical observation and by x-ray exposure.

Results: The x-ray room dimension of the six radio diagnostic centers with A (24 m^2), B (14.8 m^2), C (30 m^2), D (36 m^2), E (21.2 m^2) and F (25 m^2). All the walls of radio-diagnostic room of facility A, B, C and D were lined with 2 mm lead equivalent, whereas E and F were not. About 7 (38.8%) of lead aprons inspected were defective, while 11 (61.1%) were not defective.

Conclusion: There are compromises noted in the design of facility B and majority of the lead aprons inspected showed good functional efficacy.

Introduction

"Structural design and equipment layout of x-ray rooms is a very important factor in radiation protection. Structural design is easier when x-ray facilities are not designed as standalone rooms and are planned as part of an integrated radiology/imaging department with its supporting areas and services [1]. Structural design for radiation sources should satisfy the required minimum radiation protection specifications. The Nigerian Nuclear Regulatory Agency (NNRA) recommends a minimum radiographic room area of at least 16m^2 [2]. A study jointly sponsored by the International Labour Organization (ILO), International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) recommend a radiographic room dimension of not less than 6 x 4 x 3 in length, breath and height [2].

Therefore, this gives a room area of at least 24 m^2. Radiation Protection practices are aimed simply at keeping all-radiation risks to health to as low as reasonably achievable, social and economic considerations being taken into account, under the constraint that no individual will be subjected to undue risk. Steps have been directed towards protecting of staff, patient and general public. These steps and measures have not yielded significantly positive results due mainly to compromise which includes lack of radiation monitoring, lack of adequate training of radiation workers, absence or use of sub-optimal or faulty radiation protection devices or accessories such as lead apron, gonad shield and radiation trefoil signs among others. To achieve desired results, various professionals such as radiographers, radiologists and medical physicists should, alongside the architect and engineers, are expected to be part of the design and construction of diagnostic facilities [2]. According to the published International Basic Safety Standards of International Atomic Agency (IAEA 2014) and local legislation in Nigeria, Nigerian Nuclear Regulatory Authority (NNRA 2006) both facility design and accessories of radio-diagnostic units, should be such that provides safety of patients, staff and the general public [3,4]. Observation has shown the proliferation of radio-diagnostic facilities in Gombe state. It is however not clear what recommendations were used in the establishment of some of these centers, some of which are in modified residential buildings. This paper undertakes to assess the results of a survey of these facilities to underscore the appropriateness of their designs and integrity of their radiation shielding provisions.

Materials and Method

The study was a cross sectional survey, conducted in six private and public hospitals in Gombe state, northeastern Nigeria. The names of the hospitals were coded as A, B, C, D, E and F for anonymity. Center B and C were private radio-diagnostic centers while center A, D, E and F were government owned hospitals. They were selected because their x-ray machines were functional at the time of this study and they consented to participate in the study. Ethical clearance was obtained from research and ethical committee of Federal Teaching Hospital Gombe. The researchers embarked on an on-site visit to assess facility design and procedural data while noting area of compromises in the following ways; The building layout of the radiology departments was sketched using coral draw to show the dimensions in meters and adjoining structures (such as offices, waiting area, toilets etc). These X-ray room dimensions will be compared to standards dimensions of Nigerian Nuclear Regulatory Authorities (NNRA), International Atomic Energy Agency (IAEA) and The Atomic Energy Regulatory Board (AERB). The position of the chest-stand, x-ray table and the control panel, were respectively shown in the sketches and the distances between them were also indicated. The shielding materials used were recorded in the data captured sheet. The data sheet included information about: Type of machine working (stationary or mobile x-ray machine), dimensions of radio-diagnostic rooms, width of the room walls, material of the room walls,
material of the control panel wall, thickness of lead lining in the room walls and control panel, the distance between the radiation source and control panel, thickness of lead lining used on the room doors and number of radiological procedures in the radio-diagnostic room per day. Secondary shielding devices (apparels): lead apron and gonad shield, were inspected for holes, crack and other defects using x-ray machine to ascertain their shielding integrity. The lead apparels, both front and back, were exposed to x-rays using a 35 cm x 43 cm film to detect defect. Figure1-6 are sketches of the layout of facilities studied. Table 1a, 1b and 2 showed the various parameters of the facilities studied while table 3 shows the result of analysis of the shielding/radiation protection integrity of the apparels studied.

Results

Facility A

Facility A (figure 1) had two x-ray room, with functional and non-functional x-ray machine. The room with functional x-ray machine had a dimension of 24m^2 with distance of 1.9m from the x-ray tube to the control panel (Tables 1a). A 2.0 mm lead sheet bonded to plywood was used as the shielding material.

Figure 1: Radiology department layout for facility A

Facility B

Facility B (figure 2) had an x-ray room dimension of 14.8m^2 with distance of 1.6m from the x-ray tube to the control panel (Tables 1a). A 2.0mm lead sheet bonded to plywood was used as the shielding material.

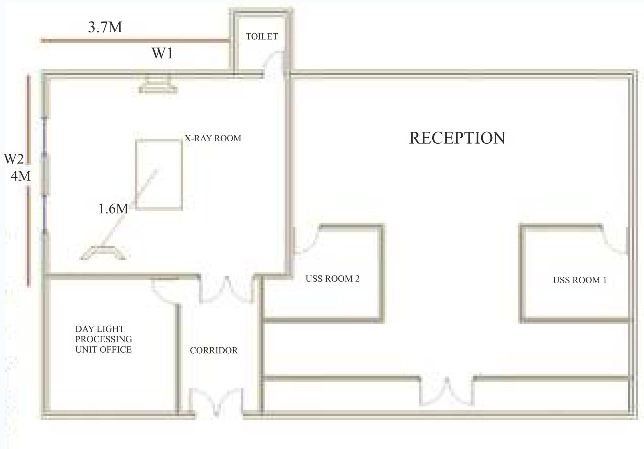

Figure 2: Radiology department layout for facility B

Facility C

Facility C (figure 3) had an x-ray room dimension of 30m^2 with distance of 2.6m from the x-ray tube to the control panel (Tables 1a). A 2.0mm lead sheet bonded to plywood was used as the shielding material.

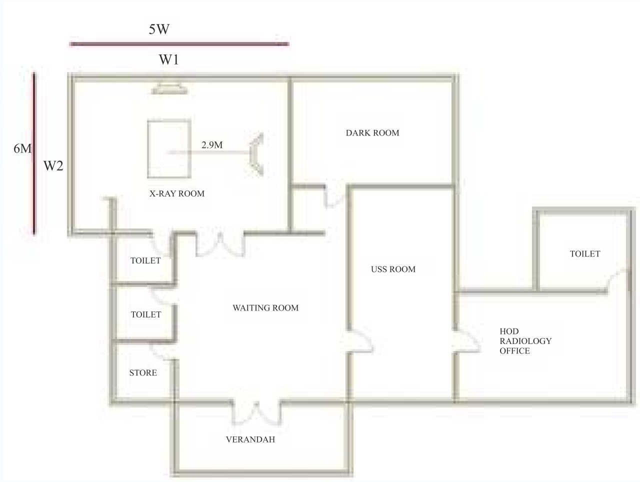

Figure 3: Radiology department layout for facility C

Facility D

Facility D (figure 4) had an x-ray room dimension of 36m^2 with distance of 2.9m from the x-ray tube to the control panel (Tables 1b). A 2.0mm lead sheet bonded to plywood was used as the shielding material.

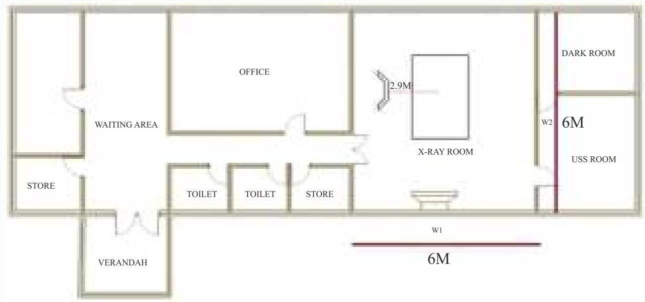

Figure 4: Radiology department layout for facility D

Facility E

Facility E (figure 5) had an x-ray room dimension of 21.2m^2 with no control panel (Tables 1b). The wall was not lead lined, but however a block/cement with a thickness of 0.45m is used instead.

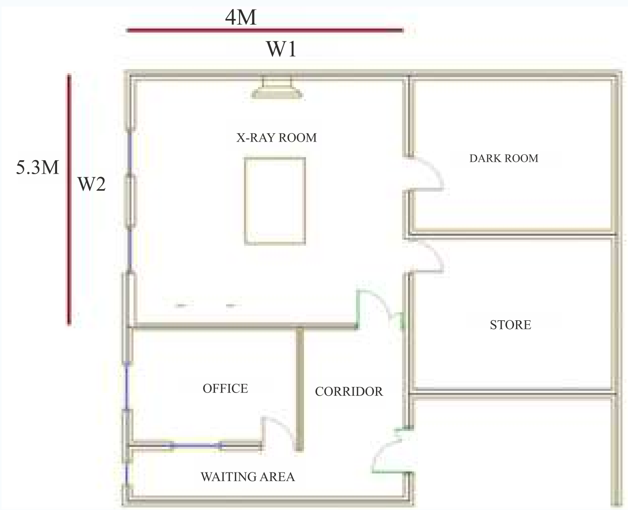

Figure 5: Radiology department layout for facility E

Facility F

Facility F (figure 6) had an x-ray room dimension of 25m^2 with distance of 1.7m from the x-ray tube to the control panel (Tables 1b). The wall was not lead lined, but however a block/cement with a thickness of 0.3m is used instead.

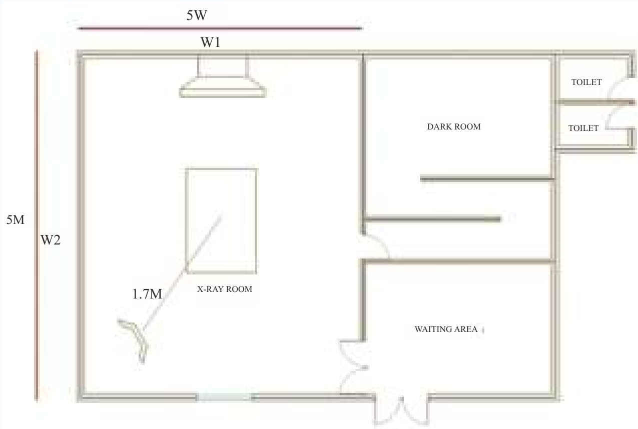

Figure 6: Radiology department layout for facility F

Table 1a: The x-ray room design and layout parameters for the facilities A-C

Facilities **PARAMETERS**	**A**	**B**	**C**
X-ray room size area (m)^2	24	14.8	30
Wall			
Material of room wall	Block/Cement	Block/Cement	Block/Cement
Thickness of wall (m)	0.3	0.3	0.3
Thickness of lead lining the room (mm)	2	2	2
Door			
Type of material	Wooden board 2- leaved	Wooden board 1- leaved	Wooden board 2- leaved
Thickness of the lead lining the door (mm)	2	2	2
Ceiling			
Type of material	Wooden board	Wooden board	Wooden board
Height from floor (m)	3	3	3
Control panel			
Type of material	Metal	Wooden board & Lead screen	Wooden board & Lead screen
Thickness of lead lining(mm)	2	2	2
Window			
Window numbers	None	2	None
Lead lining of windows (mm)	Nil	Lead lined	Nil
Distance			
Operator-tube (m)	1.9	1.6	2.6
Litter level	Low	High	Low

Table 1b: The x-ray room design and layout parameters for facilities D-F

Facilities **PARAMETERS**	**D**	**E**	**F**
X-ray room dim ension $(m)^2$	36	21.2	25
Wall			
Material of room wall	Block/Cement	Block/Cement	Block /Cement
Thickness of wall (m)	0.3	0.45	0.3
Thickness of lead lining the room (mm)	2	No leading	No lead lining
Door			
Type of material	Wooden board 2- leaved	Wooden board 1- leaved	Wooden board 2- leaved
Thickness of the lead lining the door (mm)	2	No lead lining	No lead lining
Ceiling			
Type of material	Wooden board	Wooden board	Wooden board
Height from floor (m)	3.1	3.1	3.3
Control panel			
Type of material	Lead screen	Nil	Lead screen
Thickness of lead lining(mm)	2	Nil	2
Window			
Window numbers	None	2	2
Lead lining of windows (mm)	Nil	Not lead lined	Not lead lined
Distance			
Operator-tube (m)	2.9	_______	1.7
Litter level	Low	Low	Intermediate

Table 2: Radiation protection parameters for all the facilities

Facilities **PARAMETERS**	**A**	**B**	**C**	**D**	**E**	**F**
Warning systems						
Exposure signals	Present	Present	Present	Absent	Absent	Absent
Local rules	Absent	Absent	Absent	Absent	Absent	Absent
Shielding						
Lead apron	Present	Present	Present	Present	Present	Present
Gonad shield	Absent	Absent	Absent	Present	Present	Present
Lead rubber gloves	Absent	Absent	Absent	Absent	Absent	Absent
Protective goggles	Absent	Absent	Absent	Absent	Absent	Absent
Monitoring						
Are workers provided with TLD?	No	No	Yes	No	No	No
Is there survey meter in the center?	No	No	No	No	No	No
Machine						
Type of machine	Mobile	Fixed	Fixed	Fixed	Mobile	Mobile
Number of procedure per day	25	15	7	3	3	6

Table 3: Shielding integrity of apparels

Facility	No. of lead aprons	Types of aprons	Lead equivalent (mm)	Status of apron (new/old)	Types of defect	Condition
	A1	Lead apron	0.35mm	New	None	Not defective
	A2	with separate	0.35mm	New	None	Not defective
A	A3	thyroid shield	0.35mm	New	Crack	Defective
	A4		______	Old	Crack	Defective
	A5		______	Old	Crack	Defective
	B1	Lead apron	0.35mm	New	Crack	Defective
B	B2	with separate	______	New	Breakage	Defective
		thyroid shield				
	C1	Lead apron	0.35mm	New	None	Not defective
C	C2	with se parate	0.25mm	New	None	Not defective
		thyroid shield				
	D1	Lead apron	0.35mm	New	None	Not defective
	D2	with separate	0.35mm	New	Crack	Defective
D		thyroid shield				
		Gonad shield				
	D3		0.35mm	New	None	Not defective
	E1	Lead apron	0.35mm	New	None	Not defective
E	E2	with separate	0.35mm	New	None	Not defective
		thyroid shield				
		Gonad shield				
	E3		0.35mm	New	None	Not defective
	F1	Lead apron	0.35mm	New	None	Not defective
F	F2	with separate	0.25mm	Old	Crack	Defective
		thyroid shield				
		Gonad shield				
	F3		0.35mm	New	None	Not defective

Figure 8: Result on Checks of some Apparel

Discussion

The findings of this study as shown in Tables 1a and 1b showed that facilities A, C, D and F met all the standards in terms of minimum x-ray room dimension. The Nigerian Nuclear Regulatory Agency (NNRA) recommends a minimum radiographic room area of at least 16m2. International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) recommend a radiographic room dimension of not less than 6 x 4 x 3 in length, breath and height [2]. Therefore, this gives a room area of at least 24 m^2. The Atomic Energy Regulatory Board AERB recommended a minimum room dimension ranging from 16 m2 to 20 m2 [2].. Facility E did not meet the WHO standard but met NNRA recommendation.

Facility B however, did not meet any of the standards. According to the inverse square law, the larger the room dimension; the more distance would be between the x-ray tube and the control panel, the lesser the radiation that will reach the operator and the wall of the radiographic room. Some corrective measures such as enlarging the size of x-ray room etc. are recommended for facility B, to prevent increased radiation exposure to personnel. Time, distance and shielding are well-established dose reduction strategies in radiography. Measurement of distances in diagnostic radiography is of great significance, as the intensity of radiation decreases as the square of its distance from the source, according to the inverse square law [6]. Apart from decreasing the intensity of radiation, maximized distance also helps to minimize the cost of shielding, and also has clinical significance as it aids in proper patient positioning and geometric display of anatomy of interest and pathology on radiographs [6]. All the walls of radio-diagnostic room of facility A, B, C and D involved in this study as shown in table 1a and 1b were lined with 2 mm lead equivalent which satisfied the recommendations of NNRA. Facility E and F are not lead lined; this is contrary to recommendations for operating such facilities. Immediate closure, for necessary remedial action is advised. The findings of this study are similar to Nilantha *et al*., (2015) who showed that 89% of X-Rooms studied in Sri Lanka, were larger than the recommended size of 20 m^2 (AERB standard) and 64 % had sufficient wall thickness [7]. There were lead aprons in the x-ray rooms of all the facilities. Radiation monitoring devices (thermo-luminescent dosimeter) was not provided to the staff in facility A, B, D, E and F, only facility C staff were provided with such device. Radiation survey meter was absent in all the facilities as shown in table 2.

These results are similar to those of Eze *et al.,* (2013) on Assessment of radiation protection practices among radiographers in Lagos, Nigeria except on the use of apron [8]. They find out that most modern radiation protection instruments were lacking in all the centers studied. Application of shielding devices such as gonad shield for protection was neglected mostly in government hospitals. Most x-ray machines were quite old and evidence of quality assurance tests performed on such machines were lacking. The results of this study is also similar with a study conducted by Okaro *et al.,* (2010) they show that personal radiation monitoring is available only in a few hospitals and in most cases does not cover all the radiographers on employment [9]. The result of this finding agrees with the result of a survey which was carried by Okpala (2004) that covered 28 x-ray centers in two states of south eastern Nigeria. The survey result showed that radiation monitoring was almost non-existent in the centers [10]. The results compare with studies in Erbil by Younis et al, Nepal by Adhikari et al 2014 and 2012 respectively who confirmed that up to 65% of radiation workers were not monitored owing to insufficient numbers of monitoring devices

TLD are Personnel dosimeter that monitors individual's exposure to radiation during the course of their work. Monitoring of radiation doses received by staff in radiology department is of great importance in efforts to protect them from the effect of excessive radiation during and after radiological examinations of patients. It is advisable to assess radiation doses received by radiology workers at periodic intervals to ensure their occupational safety.

The result in table 3 showed that 7 (38.8%) of apparels (lead aprons) inspected were defective, while 11 (61.1%) were not defective. The finding of this study is similar to the study conducted by Nkubli *et al.,* (2013) on quality control in radiology units' of tertiary healthcare centers in north eastern Nigeria.

They found out that regarding their (aprons) internal structures, 31 (65.96%) aprons were not defected (free of defect) and 16 (34.04%) were defected. Cracks accounted for 9(56.25%) and hole 7(43.75%) of the total 16 defected lead aprons [14]. This implies that greater percentage of the total apparels inspected were protective.

Conclusion

The study has discovered that facility B did not conform to x-ray room design standards, while facility E and F were not lead lined. These indicate poor radiation safety and hence, subjecting the patient and personnel to unnecessary radiation exposures, with the potential of causing radiation induced effects on the body. Majority of the lead aprons (61.1%) inspected across all the facilities showed good functional efficacy.

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