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QUALITY CONTROL ANALYSIS OF DIAGNOSTIC RADIOLOGY EQUIPMENT IN 44 NIGERIAN ARMY REFERENCE HOSPITAL KADUNA, KADUNA STATE, NIGERIA

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ABSTRACT

In this study, quality control analysis of radiographic equipment used in Radiology unit of 44 Nigerian Army Reference Hospital Kaduna was carried out in order to ensure that both workers and patients were within the minimum recommended radiation exposure level. The dose rate at the operator stand, X-ray table, corridor, change cubicle, offices and reception were measured with survey meter (RADOS, model, RDS-120). Generally, the result obtained indicated that both parameters assessed showed good level of compliance, with only digital radiography that was found to have failed Half Value Layer (HVL) test. The exposure reproducibility, kV_p test, beam alignment and HVL could not be assessed for Mammographic equipment because its non-availability in the QA/QC kit. Visual inspection showed that, the X-ray Machines and rooms dimensions are adequate, with exception of personal monitoring badges (TLD) that were not available. The background radiation dose level was found to be safe for the patient, staff and general public. The measured leakage radiation and entrance skin dose also showed a very good level of compliance with both National and International regulations.

Keywords: *radiographic equipment; X-ray; QA/QC kit; exposure reproducibility*

INTRODUCTION

Since its discovery by Roentgen in 1895, X-rays has continue to play a vital role in Medical Sciences. X-rays are used by equipment in all aspects of diagnostic and therapeutic radiology, such as General radiography, Fluoroscopy, Computed tomography and Mammography (Assmus, 1995). X-ray remains the most favorable radiographic technique due to its low cost and easy operation, despite discovery of some other imaging techniques such as Ultrasound and Magnetic Resonance Imaging, MRI which utilizes non-ionizing radiation which deliver zero or no risk to patients (UNSCEAR, 2000).

X-ray is the major contributor to the effective dose of both patients and personnel, even at low doses it is associated with the risk of cancer induction and other stochastic radiation effects (Patni *et al.*, 2017). Due to the radiological risk involved, it is pertinent that, radiation doses to patients should kept as low as reasonably achievable (ALARA). As such regular quality control checks and assessment on radiographic equipment could help in minimizing unwanted radiation exposure to patients and help in assuring the best quality images with the least amount of radiation exposure received and ensured best compliance to standard practice(Valentin, 2000; Oluwafisoye *et al.*, 2010). This studies assessed the radiographic equipment used in 44 Nigerian Army Reference Hospital Kaduna in order to determine the level of compliance to the standard recommended National and International Practice using QA/QC kit available at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria.

MATERIALS AND METHODS

Materials

The materials used in this study are listed below and they were obtained from the Health Physics unit of the Centre of Energy Research and Training, Ahmadu Bello University, Zaria.

Survey meter (model RDS-120), kV meter (RMI) model 245,HVL Attenuator set model 115A, Aluminum HVL sets, X-ray film size 24 x 30 cm, Metallic markers, Thermoluminescent dosimeters (TLD), Beam alignment test tool, TLD reader, Measuring Tape.

Methodology

Measurement of radiation levels

Radiation dose levels were measured at the X-ray room, operator's stand, reception, adjoining offices, corridors, changing cubicle, and the processing room using RADOS survey meter (model RDS-120) with three readings taken in

each location and the average dose rate was recorded in order to minimize error.

Leakage radiation test

Leakage radiation if any was measured using RADOS survey meter (RDS-120) with the collimator completely closed. The measurements were taken at a distance of 1m from the X-ray tube at four different positions, the average of both readings was taken to give the dose rates for each position. The values obtained were compared with the acceptance limit value of 0.25 mSv/h(EPA, 2000).

Half Value Layer (HVL) test

Aluminum sheets of different thicknesses in conjunction with a dosimeter (model DR0393) were used for this test. The dosimeter was placed in primary beam at 40 cm from the cone. The first exposure was made without filters. 0.1 mm filter was taped over the open end of the cone and exposed. Exposures were repeated with increasing thickness of aluminum filters. Three exposures were made in each case and the dosimeter reading was recorded. The average value of the readings was obtained as HVL and compared with acceptance limit.

Beam Alignment test

The loaded cassette was located on the Couch, the collimator test tool was placed on the cassette and the Beam Alignment test tool was placed at the center of the collimator test tool. The tube was adjusted to 100 cm focus film distance (FFD). The beam alignment tool was adjusted until its center coincided with the center of the collimator test tool. And it was exposed with about 70 kV_p and 20 mAs and the film was processed.

Peak Kilovoltage (kV_p) Reproducibility test

Measurements were done with the kV meter. The kV meter was positioned at 2.5 cm from the X-ray tube in the primary beam. Five exposures were made and the kV_p was measured and recorded in each case. The coefficient of variation was calculated using Equation 1(EPA, 2000).

$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Average}} \qquad 1$$

Exposure Reproducibility

The dosimeter Radcheck ion chamber (DR0393) was used for this test. It was placed in the primary beam at 10 cm from the cone. Five exposures were made and the dosimeter reading was recorded in each case. The coefficient of variation was calculated using Equation 1 and compared with tolerance level value of 0.05 (Rehani, 1995).

Entrance Skin Dose (ESD)

Three TLDs were used for this test. Each TLD was placed in the primary beam at 10 mm from the end of the cone and exposed. The ESD was assessed for molar view and compared with the recommended value of 2-3 mGy (IAEA, 2013).

RESULTS AND DISCUSSION

Equipment Specification and Room Dimension

The specifications of equipment used in the study area are presented in presented in Table 1.

Table 1: Equipment Specification

Parameter	Digital Radiography	Fluoroscopy	Mammography
Machine Type	Fixed	Fixed	Fixed
Manufacturer	Toshiba electron and devices, Co. LTD.	Eenerd Electronics DE VZW2930FC2-32	GE medical system societe.
Model	E7843	006/2310	2323449-5
Serial No.	10B588	January 2010	D2S1029
Manufactured	February 2010		April 2010

Large space is required in an X-ray room for easy movement of patients on trolley and beds, for easy manipulation of equipment and for radiation safety of staff and public (IAEA, 2000). The smaller the size of an X-ray room the more important extra shielding for radiation protection is required (Simpkin and Dixon, 1998). The measured room dimensions in the study area is presented in Table 2. It can be seen in the table that, the measured room dimensions meet the NNRA minimum requirement 16 m^2 for the size of an X-ray system room (NNRA, 2003).

Table 2: Measured Room Dimensions

Equipment	Room Dimension (m^2)	NNRA Minimum Requirement (m^2)
Digital Radiographic	28.5	16
Mammography	22.0	16
Fluoroscopy	38.0	16

Visual Inspection of the X-ray Machines and Rooms

Table 3 shows the result of the visual inspection of the X-ray system equipment and machines room. Personnel monitoring badges (TLD) were not available indicating that personnel dose monitoring was non-existent.

Table 3: Visual Inspection of X-ray System Machines and Rooms

Inspection	Remarks
Tube stability	Yes
Radiation warning sign displayed	Yes
Lead Apron Available	Yes
Personal monitoring	No
Qualified Personnel available	No
Space of X-rays System Room adequate	Yes

Radiation Dose Levels

The measured radiation dose levels before, during and after exposure at specified locations within the X-ray unit is presented in Table 4.

Table 4: Measured Radiation Dose Rates

Location	Dose Rate (µSv/h)		
	Before Exposure	During Exposure	After Exposure
Background	0.10	0.10	0.10
X-ray Table	0.11	0.86	0.12
Operator's Stand	0.12	0.18	0.13
X-ray room door	0.11	0.12	0.12
Adjoining Offices	0.11	0.11	0.11
Reception	0.10	0.10	0.10
Corridor	0.10	0.10	0.10
Changing Cubicle	0.11	0.11	0.11
Processing Room	0.10	0.10	0.10

The measured radiation dose levels before, during and after exposure of each of the specified location indicated that the dose rates measured during exposure at the X-ray table are found to be slightly higher, which is expected. The dose rates measured at the remaining locations are found to be low and similar in trend which is safe for members of staff, patients and the public.

Leakage Radiation

This test shows the amount of radiation that leaked from the X-ray tube through other areas than the window. A high level of leakage radiation contributed to the increase in dose to patient and operator. Leakage radiation should not exceed 1.0 mSv/h at a distance of 1m from the X-ray tube (EPA, 2000). From Tables 5, it can be seen that the level of leakage radiation is far below the acceptance limit. The results show high level of compliance to this test.

Table 5: Result of leakage radiation test

Position	Dose Rate(µSv/h)			ToleranceLimit (mSv/h) (Rehani, 1995)
	Digital Radiography	Mammography	Fluoroscopy	
Front	0.14	0.13	0.25	1.0
Right	0.13	0.13	0.25	1.0
Back	0.12	0.12	0.24	1.0
Left	0.12	0.11	0.22	1.0

Beam Alignment test

The acceptance limit of beam alignment is 1.5^0 (Rehani, 1995) beyond this value, distortion could be seen on the image produced. This could lead to wrong diagnoses and perhaps increased patient dose due to repeat exposures. The beam alignment of the equipment under study was found to be within normal as presented in Table 6.

Table 6: Result of Beam Alignment test

Equipment	Beam Alignment (^{0})	Tolerance Limit (Rehani, 1995)
Digital Radiography	1.5	< 1.5
Mammography	-	< 1.5
Fluoroscopy	0.5	< 1.5

kVp Measurements

The measured kVp for digital radiographic and fluoroscopic equipment in the study area are presented in Table 7 and 8 respectively.

Table 7: Measured kV_p for Digital Radiography

kV_p Station		Coefficient of Variance	Tolerance (Rehani, 1995)
kV_p	mAs		
60	10	0.00	0.05
70	10	0.00	0.05
80	10	0.00	0.05
90	10	0.00	0.05
100	10	0.01	0.05
110	10	0.00	0.05
120	10	0.00	0.05

Table 8: Measured kV_p for Fluoroscopy

kV_p Station		Coefficient of Variance	Tolerance (Rehani, 1995)
kV_p	mAs		
50	40	0.00	0.05
60	40	0.00	0.05
70	40	0.00	0.05
80	40	0.00	0.05
90	40	0.00	0.05
100	40	0.00	0.05
110	40	0.00	0.05
120	40	0.00	0.05

Exposure Measurement

The measured exposure coefficients are presented in Table 9 and 10 for digital radiography and fluoroscopy respectively.

Table 9: Measured Exposure for Digital Radiography

kV_p Station		Coefficient of Variance	Tolerance (IAEA, 2013)
kV_p	mAs		
60	50	0.02	0.05
60	40	0.00	0.05
60	30	0.00	0.05
60	20	0.01	0.05
60	10	0.01	0.05

Table 10: Measured Exposure for Fluoroscopy

kV_p Station		Coefficient of Variance	Tolerance (IAEA, 2013)
kV_p	mAs		
60	5	0.01	0.05
70	10	0.00	0.05
80	15	0.00	0.05
90	20	0.01	0.05
100	25	0.00	0.05
110	30	0.01	0.05

Half Value Layer (HVL) Test

The HVL of an X-ray beam is used to judge the adequacy of filtration. Proper filtration is necessary to remove low-energy (soft) X-ray from the beam. Too low HVL will allow low-energy X-ray to fall on the patient, increasing patient dose without any enhancement on diagnostic information. The measured HVL of the equipment in the study area is presented in Table 11. It can be observed that fluoroscopy has a HVL of 1.6 mmAl while digital radiography has a value 1.4 mmAl which are within the acceptable limit value of 1.5 mmAl (IAEA, 2013), this implies that the filtrations of both machines are very adequate.

Table 11: Half Value Layer (HVL) Test Results

Equipment	kVp	HVL (mmAl)	Limit (mmAl) (IAEA, 2013)
Digital Radiography	50	1.4	> 1.5
Fluoroscopy	60	1.6	> 1.5

Entrance Skin Dose

The measured Entrance Skin Dose (ESD) is presented in Table 12.

Table 12: Measured Entrance Skin Dose (ESD)

Equipment	kVp	Measured Dose (mGy)	Tolerance (mGy) (NRPB, 1992)
Digital Radiography	50	0.17	3.0
Mammography	50	0.16	3.0
Fluoroscopy	60	0.29	3.0

The results shows a good level of compliance with the standard value. The doses delivered to patients by the machines at the point where the X-ray beam enters the patient body were found to be lower than the recommended limit values of 3 mGy set by NRPB (NRPB, 1992), as such it won't pose any immediate effect to the exposed patients expect after

a prolonged exposure which could lead to accumulation of doses.

CONCLUSION

Quality control assessment of diagnostic radiology equipment at the 44 Nigerian Reference Hospital Kaduna was carried out. In general, the parameters assessed showed good level of compliance to the quality control tests (exposure reproducibility, kV_p test, beam alignment test entrance skin dose and HVL) performed with only digital radiography found to have failed HVL test. Visual inspection of X-ray system Machines and rooms were found to be adequate except that personal monitoring badges (TLD) were not available. The measured radiation dose level, leakage radiation and entrance skin dose were found to be in good compliance with the standard regulations governing the practices.

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