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Diagnostic X-Ray Machines Quality Control Parameters Analysis in Some Major Hospitals in Benue State-Nigeria

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Abstract - ***The purpose of this work is to evaluate the quality control parameters and status of diagnostic X-ray machines with respect to ascertaining production of quality image and estimation of inappropriate radiation exposure to patients in all the X-ray units. The quality control assessment of the diagnostic X-ray machines were carried out using Radiographic/Fluoroscopic kit, model Gammex 184D, in the Radiological Departments of some major Hospitals in Benue State. Three X-ray machines in the Radiological departments were monitored and the Hospitals were abbreviated as H-1, H-2 and H-3. Three quality control Test Tools were employed in this research work, and they include; mAs Linearity Test, Collimator and Beam Alignment Test, and kVp Reproducibility Variance Test. The mAs linearity test for H-1 was found to be within the acceptable tolerance limit of 0.1 (10%) as recommended by American Association of Physicist in Medicine (AAPM) while H-2 and H-3 were above the tolerance limit; the Collimator and Beam Alignment Test show that H-1, H-2 and H-3 were within the tolerance as defined by National Center for Devices and Radiological Health (NCDHR) to be 1.5^0 from the perpendicular. Finally, the kVp Reproducibility Test and coefficient of variance were found to be 0.1% at H-1, 0% at H-2 and 0.3% at H-3 which are within ±5% as recommended by Conference of Radiation Control Program Directors (CRCPD). This quality control parameters were to ensure that exposure to radiation from X-ray machines is justified and optimized in keeping with ALARA principle and to also ensure that high quality image are produced.***

Keywords -***focal spot, X-ray machine, radiation exposure, beam alignment, quality control parameters***

I. INTRODUCTION

Quality control in diagnostic radiology is essential to ensuring accurate diagnostic information at optimal radiation doses (Sonawane*et al., 2010*), thereby making it possible to reduce unnecessary radiation hazard to patients, workers and the public. In Benue State of Nigeria, many X-ray machines are installed and commissioned, ignoring radiation protection aspects and safety consideration, and are operated without a proper quality control program. This results in contributing to a large radiation dose to human beings and also affects diagnostic image quality which may not provide accurate diagnostic information. Though X-rays are extensively used in the diagnosis of diseases and injury all over the world, improper use of X-rays can produce biological damage

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because of its ionizing nature (Ajayi and Akinwumiju, 2000).

Diagnostic X-ray machines are designed to provide accurate diagnostic information for the clinician to ensure that the correct treatment is employed. X-ray machines used for radiological diagnosis must therefore satisfy quality control standards, in order to obtain radiographs at reasonably low radiation exposure to patients.

In the past in Nigeria, the responsibility of monitoring facilities using ionizing radiation and the environmental test of the facilities rested solely on the Federal Radiation Protection Service (FRPS). However, because of increased radiation risk to children, adults and medical personnel, radiation monitoring program is essential and required especially in Nigeria with more than 5000 X-ray units, out of which less than 5% are under regulatory control, thereby posing serious challenges (Oluwafisoye*et al.*, 2010).

Without appropriate quality control (QC) measures for X-ray machines in place, the benefits of reduced dose to the patient and early diagnosis will not be realized. Quality control also makes it possible to unify X-ray-imaging practices in the country using international image quality guidelines. The impetus for this work resulted from the concern that with the current number of X-ray machines in Nigeria that are not under any form of regulation, coupled with limited technical support to maintain and operate them, increased radiation risk to patients and lower diagnostic accuracy are very high. The aim of this work is to report on the current status of diagnostic X-ray machines in Benue state in order to produce the data needed to formulate QC policies and strategies. These policies and strategies are needed to ensure that patients receive the lowest possible radiation risk and maximum health benefits from X-ray examinations.

Thus the aim of this work is to determine the quality control and status of diagnostic X-ray machines in Radiological Departments and to ensure that a high quality diagnostic image is produced with a minimum radiation dose administered to the patients in all the X-ray units visited to be consistent with the Nigerian Nuclear Safety and Radiation Protection Act of 1995.

II. MATERIALS AND METHODS

A. Methodology

The materials used include the PTW Diavolt Universal kV Meter, Collimator and Beam Alignment Test Tool, mathematical set, X-ray films, measuring tape with Three and Single Phase X-ray machines.

a) Procedure for measurement of mAs Linearity using PTW Diavolt Universal kV Meter:

A dosimeter was placed on the radiographic table on a lead apron or strip of lead vinyl.Five exposures were made using 80kVp, 0.1 second, and mA stations between 50 and 800 at a field size of 9×15.5cm. Each reading was recorded and µGy/mAs for each exposure are determined along with the maximum, minimum and average µGy/mAs values (Papp, J., 2011), which are then placed into the following equation:

$$Linearity\ variance = \frac{\frac{\mu Gy}{mAs}(\max) - \frac{\mu Gy}{mAs}(\min)}{\frac{\mu Gy}{mAs}(average)} / 2 \qquad (1)$$

b) Beam Alignment and Collimator Test:

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This experiment was done using Beam Alignment and Collimator Test Tool before exposure; the couch was levelled and the X-ray tube was centered at a distance from the focal spot at 100 cm. The collimator shutters were then adjusted such that the edges of the light field coincided with the rectangular outline of the collimator test tool. The film for the experiment was 10 × 8 cm cassette at approximately 60kVp and 10mAs.

c) Determination of kVp Reproducibility variance:

A lead apron was placed on top of a radiographic table-top, a dosimeter was placed on top of the lead apron in the center of the table-top material. The central ray of the X-ray beam was centered to the dosimeter; using an SID distance of 40 inches. Three to five separate exposures were made at 80 kVp, 100 mA, and 100ms. The readings were used to obtain and determine the reproducibility variance (Papp, J., 2011) using the following equation:

$$\text{kVp reproducibility variance} = \frac{\mu Gy_{max} - \mu Gy_{min}}{\mu Gy_{max} + \mu Gy_{min}} \quad (2)$$

III. RESULTS AND DISCUSSION

A. The results of mAs Linearity for H-1, H-2, and H-3

Linearity means that sequential increases in mAs should produce the same sequential increase in the exposure measured. Generally, doubling the mAs should produce a dose which is doubled as expected. For H-1, H-2 and H-3, the variation in dose with increase in mAs was non-linear as seen in figures 3.1, 3.3 and 3.5. These variations in output could be attributed to the wave form, anode material, filtration, tubeage and anode surface damage. (Papp, 2011 and Begum et al., 2011)

Table 3.1: The results of mAs linearity test

Hospital	mAs	PPV	Dose (µGy)	Dose/mAs
H1	5	85.8	96.5	19.30
	10	87.6	386.7	19.03
	20	87.4	773.4	19.34
	40	88.0	1219.0	19.35
	80	87.9	1544.0	19.30
				Avg = 19.26
H2	5	81.6	317.0	63.40
	10	82.0	1268.0	63.40
	20	81.5	2503.0	62.58
	40	81.2	3907.0	62.02
	80	81.1	4984.0	62.30
				Avg = 62.74
H3	5	78.9	26.55	5.33
	10	78.1	108.0	5.40
	20	66.6	309.0	7.73
	40	61.6	318.7	5.31
	80	69.8	426.0	5.33
				Avg = 5.82

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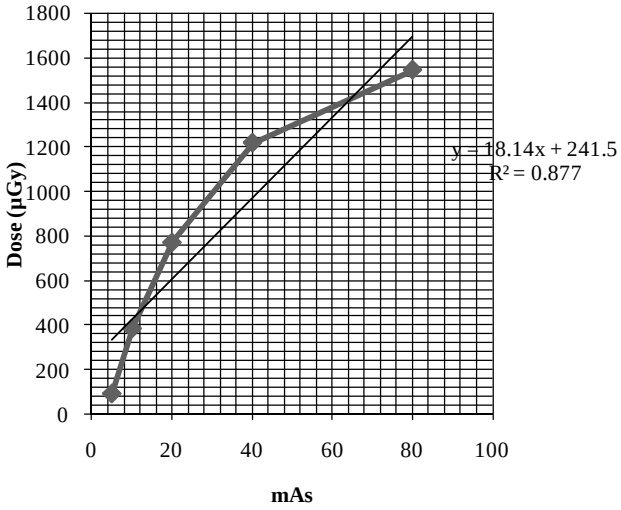

Figure 3.1: The relationship between Dose and mAs for H1

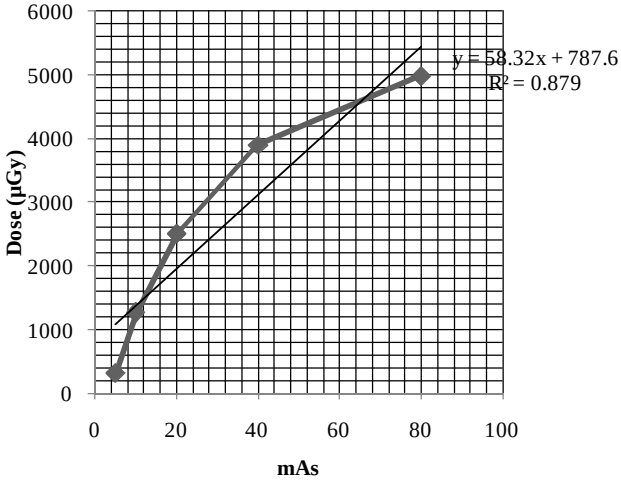

Fig. 3.3: the relationship between Dose and mAs for H2

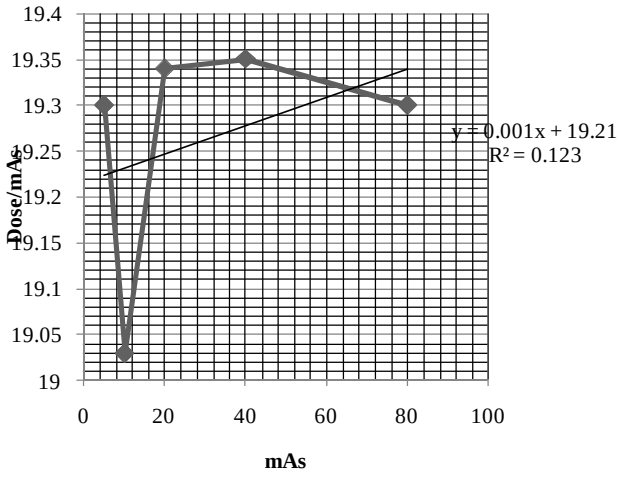

Figure 3.2: The relationship betweenmAs and Dose per unit mAs for H1

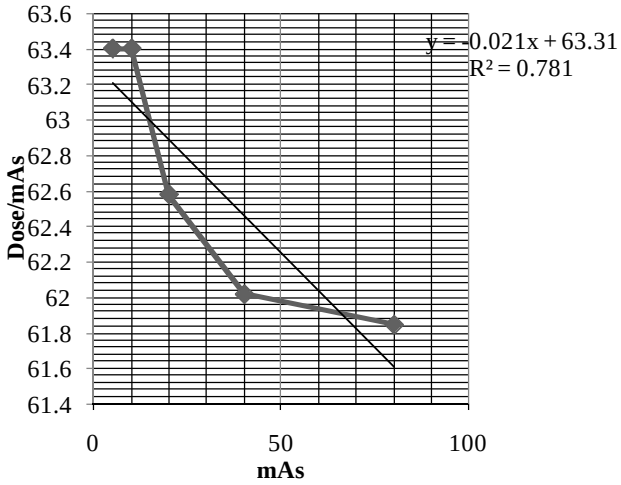

Fig. 3.4: the relationship between Dose/mAs and mAs for H2

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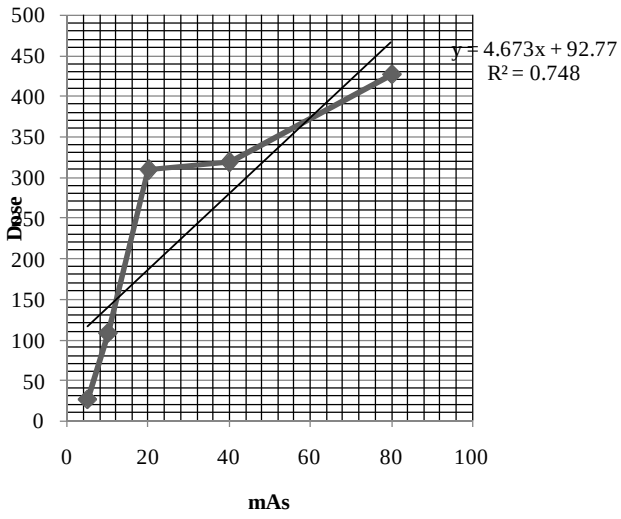

Fig. 3.5: the relationship between Dose and mAs for H3

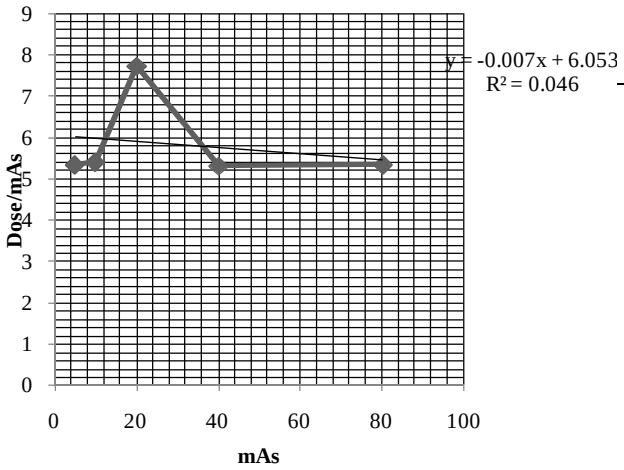

Fig. 3.6: the relationship between Dose/mAs and mAs for H3

B. The results for Collimator and Beam Alignment Test for all the facilities used

The exposure films are shown in figures 3.7, 3.8, 3.9 and Table 3.4 summarizes the results of the test; the maximum outside and inside misalignment ratios of all the three X-ray machines were not above the tolerance limit of ±2cm of FFD according to FDA and NCRP standard. The perpendicularity misalignments were 0.7^{o}, 1.5^{o} and 4.5^{o} for H-1, H-2 and H-3 which indicates that H-3 is above the set standard of 1.5^{o} according to the Center for Devices and Radiological Health (CDHR) specification. The misalignment reduces diagnostic image quality and lead to exposure of non-targeted areas. It is caused by the shifts in the relative positions of the light bulb, reflecting mirror or anode focal spot.

Table 3.4: Results of congruency between Optical and X-ray field (2%) for H-1, H-2 and H-3

Hospital Code	Right		Left		Up		Down	
	In	Out	In	Out	In	Out	In	Out
H-1	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0
H-2	1.0	0.0	0.0	0.0	0.0	1.0	1.5	0.0
H-3	0.0	0.5	1.5	0.0	1.0	0.0	0.5	0.0

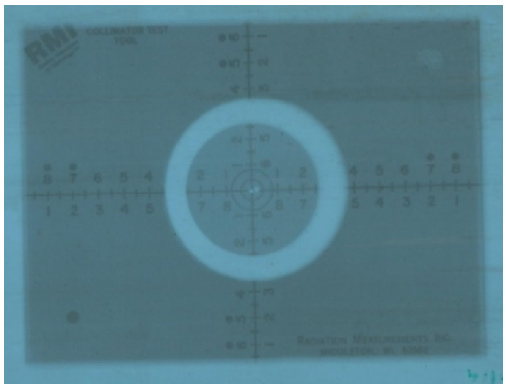

Fig. 3.7: Collimator and Beam Alignment Radiograph of H-1

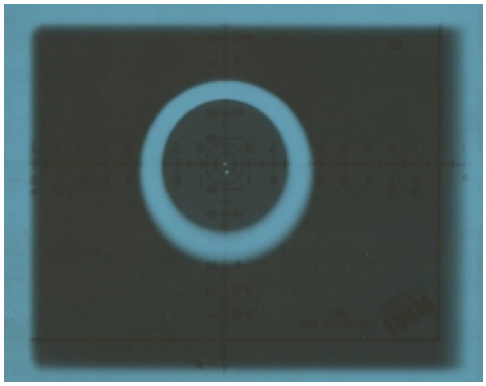

Fig: 3.8: Collimator and Beam Alignment Radiograph of H-2

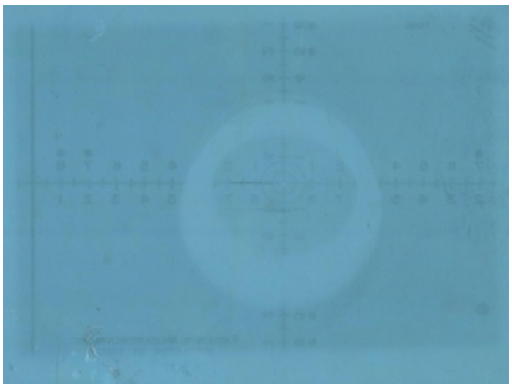

Fig. 3.9; Collimator and Beam Alignment Radiograph of H-3

C. The results for kVp Reproducibility Variance Test for H-1, H-2 and H-3

Table 3.7 summarizes the kVp reproducibility variance which was calculated using the formula in equation (2) that gives the coefficient of variance (CV) 0.1%, 0.0% and 0.3% which is far less than the stipulated ±5% limit for a properly functioning X-ray generator according to FDA.

Table 3.7: The results for kVp Reproducibility Variance Test for H1, H2 and H3 at constant kVp of 180 and constant mAs of 20

Hospital	PPV	Dose (µGy)	Dose/mAs
H1	87.6	386.7	19.34
	87.4	387.1	19.36
	87.5	387.4	19.37
	87.6	387.1	19.36
	87.5	386.7	19.34
		Avg = 387	Avg = 19.35
H2	82.1	1276	63.8
	82.1	1272	63.6
	82.1	1271	63.6
	82.1	1272	63.6
	82.1	1272	63.6
		Avg = 1272.6	Avg = 63.65
H3	77	185.3	9.265
	76.9	191	9.55
	76.8	175.5	8.77
	76.6	179.7	8.985
	77.2	over range	over range
		Avg = 182.88	Avg = 9.14

IV. CONCLUSION

Results from the study show that the sequential increase in measured exposure is nonlinear for all three X-ray units. However, the light and X-ray field congruency and kVp

reproducibility variance were found to be within acceptable limits. The perpendicularity between the X-ray beam and image receptor for H-1 and H-2 were within limit while H-3 exceeded the limit.

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