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DOSE LINEARITY ASSESSMENT OF X-RAY EQUIPMENT FROM FOUR HOSPITALS IN LAGOS SOUTH-WESTERN NIGERIA

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ABSTRACT

The risk associated with the exposure to x-ray must always be weighed against the clinical benefits. This call for the assessment of dose linearity of the x-ray machines used in selected hospitals of Lagos State, to avoid careless and over exposure of patients. The measurements procedure for x-ray effective dose with varying kVp and mAs were carried out using RAD-CHECK PLUS 06-526. At constant mAs, the effective dose obtained at 70 to 100 kVp varies from one hospital to another. At constant 70 kVp, similar variation was also observed in the effective dose measured at 10 to 40 mAs. The dose linearity obtained fall below the acceptable limits recommended by international bodies, however, the linearity varies from one hospital to another. Hence, there is need to regularly monitor and check the linearity of x-ray machine in Nigeria hospitals with the view of reducing or eliminate unnecessary exposure of patients.

Keywords: Dose linearity, X-ray equipment, Radiographer, Hospital, Lagos.

1. INTRODUCTION

The use of x-ray equipment in both private and government hospitals is on the increase daily in developed and developing countries. As reported in the literature, x-ray is the major contributor to the effective dose of both the patient and personnel working in the radiographic unit. Because of the radiological risks involved, it is usually recommended that dose to patient from x-ray be kept as low as reasonably achievable with adequate image quality (IAEA, 1996). There are over 4000 x-ray machines in Nigeria and less than 5% are under regulatory control as reported by (Elegba, 2006). The patients and personnel are subjected to x-rays exposures during imaging and the allocation of personnel offices very close to radiological unit that were not built in line with recommended standard pose a great challenge to the Regulatory bodies in Nigeria. The frequency of exposure is a factor for an increase in the annual collective dose to individual. There are no short-term health effects from diagnostic exposures of x-radiation and the risk of potential long-term effects has a very broad uncertainty. To check and quantify these irregularities, dosimeters are used to evaluate the performance of x-ray equipment. However, the issue of how accurate and precise the measuring devices employed in assessing diagnostic exposure needs to be addressed. The radiologists have relied on their own best judgments concerning the types and frequencies of calibration for their instruments, as well as on the overall assessments of performance characteristics. Some of the existing instruments have been reported in literatures to be deficient in diagnostic application. (American Association of Physicists in Medicien, 1992)

With the knowledge about risks from exposures to low levels of ionizing radiations, there is need to assess absorbed dose from diagnostic x-ray examinations and in achieving this, the concept of dose linearity was introduced. Dose linearity assessment of x-ray equipment is a valid process for estimating radiation dose received by an individual or group of individuals. It is used in occupational epidemiological studies to determine the amount of radiation workers received when working in radiation environment. The use of radiation for medical diagnostic and therapeutic is hazardous especially when the patients are over expose. Improper use of radiography equipment and inexperience of radiographers in handling the equipment are major cause of over exposure of the patients. In most cases, different dose exposure values are applied for the same clinical examination because of incompetence of some radiographers. The International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), and other radiological agencies or institutes have been making publications in relation to guidelines for the use and handling of radiation for more than fifty (50) years on this same issue (International Commision on radiological protection, 1991; IAEA, 1996).

Although advances in medical imaging in the past few decades, using procedures such as computed tomography (CT), fluoroscopy, and nuclear medicine imaging examinations have improved health care but the frivolous use of ionizing radiation is detriment to human health. One of the advantages of ionizing radiation in medicine is that the depth of tissues within the body is easily accessed. Using these procedures permit radiologists to diagnose diseases that would have necessitated exploratory surgery (Wittenberg, et al., 1978). Other direct benefit of modern imaging procedures include effective surgical treatment (Godoy et al., 2011) potentially shorter delay in hospital (Battle, Hahn, Thrall, & Lee, 2010), safe discharge of patients (Littet, et al., 2012), better diagnosis and treatment of cancer (National Research Council of the National Academies, 2012), more efficient treatment of injury (Philipp, Kubin, Hormann, & Metz, 2003), better treatment of stroke and cardiac diseases (Saini & Butcher, 2009; Winchester, Wyner, Shifrin, Kraft, & A, 2010) and rapid diagnosis of life –threatening vascular diseases (Furukawa, et al., 2009). Hence, the aim of this research is to evaluate the dose linearity assessment of x-ray commonly used in hospitals with the objectives of measuring the precision of each x-ray machine in the hospital under study, the radiation output of the x-ray equipment and to provide appropriate recommendation for the safety of workers in the related environment.

2. MATERIALS AND METHODS

Radiographic measurements were carried out in four (4) randomly selected quality secondary for x-ray units from Governmental hospitals. Data were obtained from: one Nigeria army military hospital denoted (H_1), National Orthopaedic hospital denoted (H_2), one general government hospital denoted (H_3), and Psychiatric hospital denoted (H_4), all in Lagos Nigeria. A RAD-CHECK PLUS 06-526 model (Elimpex- Medizintechnik) ranges: 0.001 to 2 R, 0.001 to 20 R/min was used in the measurements including the peak tube voltage (kVp), mAs and linearity of x-ray output. The test carried out on the x-ray facilities were in accordance with guideline of the RAD-CHECK PLUS. The details of x-ray machines investigated at each hospital are presented in the Table 1.

Table 1: Specific data of x-ray machines investigated

Hospital Parameter	H_1	H_3	H_4
Manufacturer/Model	General Electric Company	Philips Medical	Genius HF
Name of Machine	Wattson	Practix 100	Villa Systemimedicali
Year of Manufacture	1977	1999	2001
Year of installation	> 35years	2001	2005

2.1 Measurement Procedure for X-Ray Effective Dose Variation with kVp

The RAD-CHECK PLUS dosimeter was positioned in the central beam axis such that the x-ray tube focal spot detector distance (FDD) was 100 cm for the measurement. The radiation field size was set to cover the RAD-CHECK PLUS meter in order to avoid the possible scattered radiation to the meter. In order to investigate effect of kVp to the dose in the H_1 the dosimeter was set at 10 mAs and 70 kVp values. An x-ray exposure was made and the meter reading was recorded. This step was repeated at same constant mAs and different kVp setting of 80, 90 and 100 kVp, and meter reading was determined. Similar x-ray dose measurement was determined for H_2 at the same mAs settings for kVp values of 50, 60, 70, 80, 90 and 100 kVp. For H_3, kVp reading were taken at the same mAs the reading settings of kVp of 60, 70, 80, 90, 100, and 120 kVp. Lastly at H_4, the kVp settings at the same mAs were 65, 70, 75, and 80 kVp.

2.2 Measurement Procedure for X-Ray Effective Dose Variation with mAs

The dosimeter was positioned at 100 cm FDD from focal spot of the x-ray tube. In order to determine the effect of mAs on the dose, the exposures were performed with constant 70 kVp, but with gradual increase of mAs of 10, 20, 30, and 40 mAs. All measurements were repeated for the remained x-ray unit of each hospital.

2.3 Calculation of Dose Linearity

According to Health Canada (2008), the dose linearity was checked using the following Equation (1).

$$X = \frac{mR}{mAs} \quad (1)$$

where X is the average of radius of exposure to indicate milliampere-seconds product (mR/mAs) obtained at any two consecutive tube setting. The expression for the dose linearity L is given by Equation (2)

$$L = \frac{X_1 - X_2}{X_1 + X_2} \; \square \; 0.1 \quad (2)$$

where X_1 and X_2 are the initial and final output dose respectively. The various output doses were determined by setting the machine operating conditions and the parameters were changed over diagnostic clinical range.

3. RESULTS AND DISCUSSION

Assessment of X-Ray Effective Dose with varying kVp

The results obtained for the measured effective doses by varying the kVp values are shown in Table 2. From the results obtained, it was observed that the effective dose values show wide distribution for each measurement and as the kVp increases the effective dose also increase. At each parameter setting, the effective dose also varies from one x-ray machine available at each hospital to another, this can be attributed to component that make up the x-ray machine and the years of their operations. This variation may affect the output of the image quality and further expose both the patient and personnel unnecessarily.

Table 2: Effective Dose (mSv) at 10 mAs and varying tube voltage (kVp)

Units	Tube Voltage Settings (kVp)														
	50	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**
H_1	-	-	-	-	53.98	-	61.53	-	69.02	-	77.90	-	-	-	-
H	30.77	-	60.13	-	121.67	-	245.87	-	297.32	-	345.12	-	-	-	-
H_3	-	-	36.60	-	63.55	-	90.80	-	117.20	-	143.20	-	-	-	135.90
H_4	-	-	-	65.12	70.22	75.39	81.07	-		-		-	-	-	-

Assessment of X-Ray Effective Dose with varying mAs

The effective dose obtained at constant tube voltage of 70 kVp and increasing current of 10, 20, 30 and 40 mAs at distance of 100 cm are as presented in Table 3. From the results obtained, it was observed that the values obtained for the effective dose also show wide distribution for each measurement and as the mAs increases the effective dose also increase. This also conform with the result obtained for the variation in kVp. The variation in the output among the hospitals could lead to variation in dose delivered to the patients during the examination.

Table 3: Effective Dose (mSv) at 70 kVp and varying tube current (mAs)

Units	Tube Current Settings (mAs)			
	10	**20**	**30**	**40**
H_1	51.28	76.92	153.84	205.12
H_2	121.67	182.51	304.18	425.85
H_3	37.56	76.13	151.62	299.89
H_4	75.25	80.38	120.50	180.75

Dose Linearity

The results obtained for the assessed dose linearity are as presented in Table 4. Comparing the results obtained with the international standard, it was observed that none of the radiological units estimated demonstrated deviance outside the accepted limits stated by Healing Arts Protection Act (2011). However, in the Clinical setting, it is essential that radiological units produce a proportional change in expose as millamperage (mA) varies. In case of H_1, the linearity in 10 mAs was 0.00056 , 20 mAs was 0.00028, but at 30 mAs and 40 mAs the linearity was the same as 0.00019, and this may be attributed to the tube age and anode surface damage of x-ray machine. In H_2 the linearity decreased from 10 mAs to 30 mAs then increased 40 mAs these were indication that the x-ray machine was out-dated as evidence from the years of productions. At $H_3$and H_4 linearity decreased progressively from 10 mAs to 40 mAs, these malfunction tends toward reasons gave above.

Table 4: Estimated dose linearity

Units	10 mAs			20 mAs			30 mAs			40 mAs		
	X_1	X_2	**L**	X_1	X_2	**L**	X_1	X_2	**L**	X_1	X_2	**L**
H_1	5.634	5.631	0.00056	5.6350	5.6345	0.00028	5.7477	5.7470	0.00019	7.7456	7.7425	0.00190
H_2	7.515	7.512	0.00075	7.5140	7.5130	0.00038	7.7747	7.7737	0.00026	12.7445	12.7438	0.00032
H_3	2.504	2.503	0.00025	2.5030	2.5030	0.00013	2.6360	2.6350	0.00009	2.74830	2.7477	0.00007
H_4	3.758	3.756	0.00038	3.7570	3.7217	0.00019	3.7217	3.7207	0.00012	3.79730	3.7970	0.00009

4. CONCLUSION

Quality control of different x-ray units have been undertaken with the purpose of safety and dose optimization in different government hospitals of Lagos State. For the x-ray machines investigated, there was deviation in the results obtained for the set of parameters considered. Although the results obtained in the four hospital fall within the acceptable limit of dose linearity but in ideal clinical setting, it is essential that all x-ray unit produce a proportional change in exposure. The quality control test carried out on kVp accuracy and consistency were not in compliance in the hospitals assayed and these variations may be attributed to various components that makes up the x-ray machine available at each hospital. The variation in the data obtained demonstrate the importance of educating and creating awareness for the radiographic staff about regular quality control of the equipment and standardization of protocols. The urgent need for intervention and appropriate actions in order to improve and standardize practice, so as to enhance the quality of the radiographs, and avoid unnecessary risks of increased radiation dose to patients and staff.

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