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ASSESSMENT OF KV$_P$ ACCURACY AND REPRODUCIBILITY AS RADIATION PROTECTION MEASURES IN TERTIARY HOSPITALS IN YOLA, NORTH-EAST NIGERIA

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ABSTRACT

Background: Conventional x-rays radiography over the years has been and remains one of the vital methods of diagnosing ailment within some internal organs of human. This is however, not without problems due to machine factors. Patients usually undergo repeated x-ray examinations, after their initial radiographs are rejected due to poor image quality which subjects the patient to excessive radiation. Assessment of kVp accuracy and reproducibility as part of Quality Control parameters is an important practice that ensures high image quality with minimal radiation dose to both patients and personnel.

Purpose: To measure the quality of radiographs from some tertiary hospitals based on x-ray machines kV$_P$accuracy and their reproducibility.

Materials and Method: The kV meter RMI 245 was used to measure the kVp accuracy and kVp reproducibility on three conventional x-ray machines from three hospitals in Yola represented as M-1, M-2 AND M-3.

Results: The result for kVp accuracy shows average percentage error for M-1 was 4.2 % calculated through the range from 2.38 % – 6.2 % while that for M-2 was 9.71 % calculated from 5.8 % – 15.0 %. The average percentage error for M-3 was 4.4 % calculated from 1.17 % – 8.1 %. M-1 and M-3 are within the tolerance limit of ±5 % while M-2 was outside the tolerance limit. For kVp reproducibility, M-1, M-2 and M-3 were 2.28 %, 10.35 % and 4.47 % tolerance respectively. M-1 and M-3 are within normal limit less than the tolerance ±5 % recommended. However, for M-2 the reproducibility is above the recommended limit.

Conclusion: All the machines show high percentage error in kVp accuracy at higher exposure factors which necessitated kVp calibration. Machine M-2 was deficient in kV$_P$ reproducibility.

Introduction

The discovery of x-ray has proved to be beneficial to man. These benefits have been greatly utilized for medical diagnostic and therapeutic purposes. The most widespread use of radiation in medicine remains diagnostic radiology procedures (1) many studies have shown that the process is associated with some hazards (2).

A study of a number of general radiography facility by the Daleware USA (DU) cited in (3) revealed that an average of 9 % of the radiographs taken had to be repeated. An analysis of the reason for rejection and hence repeat led to the conclusion that poor equipment performance made a significant contribution. Similarly, in optimization of radiation protection checks on diagnostic radiology equipment in some Nigerian hospitals, it was found that equipment malfunctioning and human factor contribute to reject or retake of radiographs (3).

In most of our tertiary hospitals patients usually undergo repeated x-ray examinations, after their initial radiographs are rejected due to poor image quality. These situation subjects the patients to excess radiation exposure and extra cost is also incurred on the hospital which leads to lost in revenue in the organization (4). As part of the system of radiation protection the International Commission on Radiation Protection comes up with justification and optimization of practice to mitigate unusual exposure of patients through machine error (5).
Quality Control (QC), the process through which the actual quality performance is measured and compared with existing standards (6), has become very important for machines used for the purpose of radiological examinations.

The tube peak kilo voltage (kVp) is one of the most important parameter affecting both radiation exposure and image contrast (7). If the peak energy of the output beam is not same (accuracy) as the set kVp or the kVp applied cannot be reproduced (reproducibility) then important details of the image can be lost and results to retake of the image, which gives more doses to patient. The exposure made at same kVp and with various mA stations should produce same kVp as set on the machine (8AAPN, 2002). In this way a radiographer wishing to reproduce a good quality image can be confident that same technique settings will produce the same result (9). Assessment of x-ray equipment QC parameters is an important practice that ensures high image quality with minimal radiation dose to both patients and personnel (optimization of practice) (10).

Material and Methods of Measurement

Material

Three tertiary hospitals namely Federal medical Centre Yola, Adamawa State Specialist Hospital and Adamawa-German medical Centre Yola were chosen for this investigation and the choice was made based on their patronage and volume of patients handled on daily basis. The specifications of the x-ray machines found in the hospitals are given I the table 1 as M-1, M-2 and M-3 but not in order of their listing above.

Table 1. Specifications of various Machines in the facilities

S/No	Manufacturer	Type of machine	Serial No	Model	Year of manufacture	Date installed	Country of manufacture
Machine 1	Italray	Fixed	20-767-06	GEN+IR20 1/A-C	2006	2017	Made in Italy
Machine 2	Siemens Protec	Fixed	2042	05893404	2010	2011	Made in Germany
Machine 3	American Medithec incorporation AMI – HX	Fixed	2K121150 002-X/HF	HX-50	2012	2014	Made in Japan

Figure 1. kVp Meter RMI 245

kVp meter test tool

The kV-meter Gammex RMI 245 enables the user to measure the kVp given in figure 1, The device is designed for measurements of kVp during quality control and acceptance testing in diagnostic radiology. It is used for non-invasive measurement of the tube voltage of x-ray systems in the range 50 kV to 200 kV.

Method of Measurements

The film focus distance (FFD) was set at 100 cm from the X-ray table, the kVp meter was placed on the table and the beam is collimated to cover the meter. Five exposures were made using 16 mAs, and the kVp was then varied from 60 to 110 kVp in step of 10 kVp. At every set kVp on the control panel, the measured kVp was recorded. The meter was cleared (reset to zero) after each exposure. The readings obtained were used to determine the percentage error for the tube potential accuracy using equation (1):

$$\text{Percentage kVp error} = \frac{Vo - Vs}{Vs} \times 100 \qquad (1)$$

where Vo is the measured value, Vs is the set value and kVp is peak kilo voltage

To measure the kVp reproducibility the kVp meter RMI 245 was used also for this test. The kVp meter was placed in the center of the table. The central ray of the x-ray beam was directed to the meter, using an FFD of 100cm. The beam was collimated so that the x-ray field is just slightly larger than the meter, five (5) exposures were made at 80 kVp, and varying mAs. The meter was cleared after each exposure. The result obtained was evaluated using equation below.

$$kVp\ reproducibility = \frac{\sqrt{(X - X_1)^2 / (n-1)}}{N}$$

where X is the set kvp, X_1 is the recorded kVp, N is the average kvp recorded and n is the number is exposure.

Results

The result for kVp accuracy is given in Table 2. The dial kVp is the kVp set on the machine, while the actual kVp is the result recorded on the meter after exposure. The kVp accuracy is calculated using equation (1). The average % error for M-1 = 4.2%, using the range of 2.38% – 6.2%. Similarly, average % error for M-2 = 9.71% with range from 5.8% – 15.0% and average % error for M-3 = 4.4% with range from 1.17% – 8.1%.

Table 3 shows the result for kVp reproducibility, the dial kVp which is the input kVp for M-1 and M-3 was 80 kVp while that of M-2 was 90 kVp. Since the machine M-2 operated at high kVp and it is the kVp used for common radiographic procedures, while the recorded kVp for the various machines are also given. Using equation (2) the kVp reproducibility was calculated for machines M-1, M-2 and M-3 as 2.28%, 10.35% and 4.47% respectively.

Discussion

From the result presented in table 2 above for machines M-1 and M-3 the dial kVp starts from 60 kVp while for machine M-2 the dail kVp starts from 70 kVp as the minimum accepted kVp on the machine; to obtain five exposures it is extended to 110 kVp. The result shows that the average kVp accuracy are 4.2, 9.71 and 4.4 for M-1, M-2 and M-3 respectively, with machine M-2 falling outside the recommended limit ±5% ICRP recommendation for the safe exposure of patients and could pose as hazard to patients by adding to photon absorption. It can also lead to repeat radiograph for personnel not used to the machine because the kVp applied is not exactly what the machine gives.

Table 2. kVp Accuracy Parameters (13 mAs)

Dial kVp	Machine M-1		Machine M-2		Machine M-3	
	Actual kVp	Percentage error (%)	Actual kVp	Percentage error (%)	Actual kVp	Percentage error (%)
60	63.4	5.67	-	-	60.7	1.17
70	71.8	2.57	74.1	5.80	71.8	2.60
80	81.9	2.38	85.4	6.75	83.4	4.30
90	93.6	4.00	99.2	10.20	95.3	5.90
100	106.2	6.20	111.8	10.80	108.1	8.10
110	-	-	126.5	15.00	-	-

Table 3. kV_Preproducibility for machined M-1, M-2 and M-3

Dial mAs	Recorded kVp M-1 (at 80 kVp)	Recorded kVp M-2 (at 90 kVp)	Recorded kVp M-3 (at 80 kVp)
10	81.9	99.1	80.3
12.5	81.5	99.1	83.3
16	81.5	99.2	84.0
20	81.7	99.3	83.7
25	81.7	99.2	83.8

All the machines at higher kVp shows increase in exposure, the reasons for higher deviation in kVp could be due to lack of kVp calibration. If the peak energy of the output beam is not same as the set kVp the important details of the image can be lost and results to retake of the image. When the percentage of kVp error lie between ±5%, the kVp value is acceptable (11). Moreover, the excessively high deviation between the set and the measured kVp could reduce the image contrast (11).

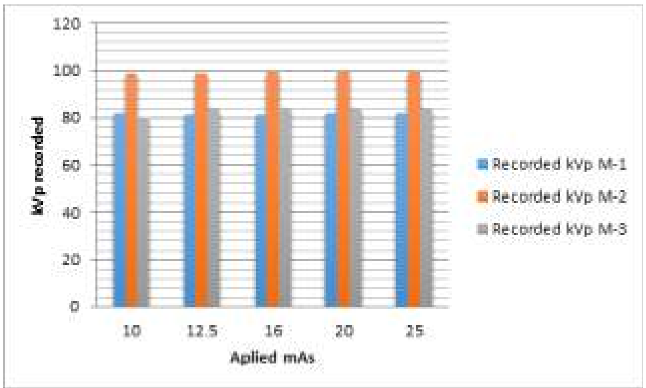

Figure 2: A bar chart of the recorded kVp with applied mAs in test for kVp reproducibility

The kVp output of an X-Ray machine at a given setting should be reproducible. A graphical plot of the recorded kVp for each applied mAs for the three machines is also given in Figure 2. Poor reproducibility may lead to repeated exposure for a procedure that needs more than one exposure. From the calculation of the kVp reproducibility from values in Table 3 the kVp reproducibility for machines M-1, M-2 and M-3 been 2.28%, 10.35% and 4.47% respectively showed that M-1 and M-3 have kVp reproducibility within normal limit which is less than the tolerance ± 5%. For M-2 however, the result falls outside the ICRP recommended value for reproducibility but the reason could be due to slight variation in kVp accuracy as shown in the result for kVp accuracy in table 2. The result is in accordance with the studies conducted by (10,3).

Conclusion

The results for kVp accuracy and reproducibility for the machines used for medical diagnosis in the tertiary hospitals in Yola investigated were within normal limits except machine M-2 that fell outside the recommended limits and required urgent calibration to ensure maximum compliance and radiation safety.

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