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Evaluation of X-ray Machines in Gezira State: Based Quality Control

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Abstract
Implementation of quality control in diagnostic x-ray facilities is essential to provide high quality images which are lead to proper diagnose with minimum hazard in diagnostic radiology departments. Adequate quality control (QC) program should be in place to optimize the practice of diagnostic radiology. About 20 units of x-rays distributed in Gezira state, only 6 x- ray units considered for this study because most of the machines are not functioning or the rooms under reconstruction. The evaluation covers Kvp reproducibility, Kvp and time accuracy, mAs linearity and coincidence between light beam and radiation beam. The result was compared with some international standard such as American Association of Physicists in Medicine (AAPM) No. 74. The results of kvp accuracy mean value a ranged from 0.84 % to 1.83 %, timer accuracy ranged between 0.06% to 4.06%, and Coincidence of light beam and radiation beam ranged between (L1+L2 (0-3) % and W1 + W2 (0-1.9) %, kvp reproducibility variance coefficient ranged between 0.004 % and 0.02%. The results were within the acceptable limits. Linearity coefficient for each machine ranged from 0.1 to 0.20, which indicates that these units need urgent calibration. The results indicate that most of the x-ray units in Gazira state need a calibration. The study recommends that the quality control of the radiological devices should be performed periodically and regularly

Keywords: *Quality control, Beam alignment,* X-ray, Radiology, quality control, quality assurance, unfors Mult-O-Meter

1. Introduction

Since the discovery of X-rays by Sir Wilhlem Conrad Roentgen in 1895, their applications in the field of medicine have been of profound values. Majority of crucial decisions in medicine directly depend on X-ray diagnosis and it plays a vital role in the early diagnosis of many diseases. X-rays are used in the diagnosis of many diseases and disorders, and they help clinicians confirm or rule out a diagnosis. The risk to individuals from the radiation used in diagnostic X-rays is small compared to the benefits that accurate diagnosis and treatment can provide. The widespread use of X-ray in the diagnosis and management of patients has led to increased radiation exposure. Although the clinical use of X-ray is governed by dose optimization and as-low-as-reasonably achievable (ALARA) principle, more invasive methods have been proposed (1). Quality Assurance is a vital part of radiological protection "Because most procedures causing medical exposures are clearly justified and because the procedures are usually for the direct benefit of the exposed individuals, less attention had been given to the optimization of protection in medical exposure than in most other applications of radiation sources. As a result there is considerable scope for dose reduction in diagnostic radiology (2). QA include both quality control (QC) techniques and quality administration procedures. QC is normally part of the QA program and quality control techniques are those techniques used in the monitoring (or testing) and maintenance of the technical elements or components of an X-ray system. The quality control techniques thus are concerned directly with the equipment that can affect the quality of the image. The quality assurances of diagnostic X-ray are based on the Basic Safety Standard – BSS and International Commission of Radiological Protection, and use of diagnostic reference levels (DRL for patients, ICRP- Report No. 46, 1966).

Quality Control Series of standardized tests developed to verify that the equipment is operating satisfactorily and to detect changes in x-ray equipment function from its original level of performance, this can be assessed by performance the X-ray machine using optimum operating parameters such as reproducibility of tube voltage, dose output, time, X-ray tube efficiency, Accuracy of KVp, mA, time, focal spot size and half value layer.

The aim of this paper is to investigate some factors affecting on quality assurance of conventional x-ray such as reproducibility of tube voltage, dose output, time, x-ray tube efficiency, Accuracy of kVp, time and Beam alignment, are measured and compared with the international tolerance, (4).

2. Material & Methods

To perform this work 6 radiographic units used in radiology departments in Wad Medani, Gezira state Hospitals (H1) NCI, (H2) Renal Hospital, (H3) Alia Specialized Hospital), (H4) Police Hospital, (H5) Pediatric Medicine & Surgery Hospital, (H6) traumatology hospital were evaluated to evaluate the accuracy of kV, timer accuracy, linearity between exposure and mAs, and repeatability of exposure. Table 1 presents the radiographic equipment information at various hospitals investigated. The years of manufacture of the equipment range from 6 to 14 years the effect of age on the output of an X-ray machine is well documented meanwhile, each of the X-ray facilities was used for both pediatric and adult examinations.

Table 1: Margin specifications

Location	***Date***	***Manu. date***	***Model***	***SN***
H1	9/2017	2005	1/2P13DK	50976
H2	10/2017	2005	ShimadzuR-20	503-55050
H3	11/2017	2005	Eco Ray SMS-Ts-2	150718
H4	12/2012	2013	Shimadzu 2P18DE-85	035009
H5	11/2017	2005	Shimadzu-R20J	0166M1424 5
H6	3/2018	2008	Shimadzu-class1	0266M1394

In all the hospitals there was no previous exposure and QC data available. The data manipulation done using Microsoft Excel, 2010

Mult- OMeter (Model 302, Unfors, Sweden) was used. The Mult-O-Meter family has been designed to fulfill "The Unfors Concept". The measuring procedure is always the same; Turn on the Mult-O-Meter, position the detector in the expected X-ray beam, make an exposure and read the measured parameters that are installed. To determine the accuracy of the tube voltage Mult-O-Meter was placed on the X-ray unit bed at a distance of 100 cm in the center of the field and kV and exposure time were given to the units in a way that did not increase the tube load. Accuracy of tube voltage was examined for each machine. The % error was calculated using the formula:

$$Voltage\ Accuracy = \frac{Kv\ measured - Kv\ nominal}{Kv\ nominal} \qquad (1)$$

KVp variations should not be greater than ±% 5[1, 2].

To check The KVP Reproducibility, the detector was placed at 100 cm SSD on a lead apron while kVp station was kept at 80. Three exposures were done and kVps were measured by detector as shown as table 4.3. The Coefficient of variance was calculated using the formula:

$$Reproducibility = CV = \frac{SD}{X} \qquad (2)$$

CV must be less than 5% , Results recorded and trend lines established.kVp variations should not be greater than ±% 5 The linearity of mas or Exposure reproducibility was checked using the following equation: Coefficient of linearity (CL)

$$CL = \frac{\left(\left(avg\frac{x}{Mas}\right)max - \left(avg\frac{x}{Mas}\right)min\right)}{\left(\left(avg\frac{x}{Mas}\right)max + \left(avg\frac{x}{Mas}\right)min\right)} \qquad (3)$$

Timer accuracy the % error was calculated using the Formula

$$\text{Time accuracy} = \frac{time\ (measuerd) - time\ (nominal)}{time\ (nominal)} \qquad (4)$$

The beam alignment was measured by using cassette was loaded on table at 100 cm FFD (focus-film distance), then set up light beam for ~ 20 x 20 cm field, metal markers was placed (eg. coins) at each field edge plus one at anode end, and one at top of field and exposure was taken Beam alignment = the distance between light and X-ray field.

$$Beam\ alignment = \frac{l1 + l2}{SID} * 100 \qquad (5)$$

Where l is the length

3. Result and Discussion

3.1 KVP accuracy

At fixed mAs, six kVp stations (50, 70, 80, 90, 100, and 110) were selected and exposures were done, as shown in table 3.1

Table 1: KVP accuracy

Hospital	***Mean KVp error%***
1	1.24
2	1.10

3	0..96
4	0.45
5	0.84
6	1.83

KVp accuracy is good for all the machines the tolerance limit (± 5%) (5, 6)

3.2 KVp reproducibility

Table 3.2 KVP Reproducibility for X-ray Machines

Hospital	***Reproducibility(CV) %***	US Letter Paper
1	0.008	
2	0.004	
3	0.0012	
4	0.0121	
5	0.020	
6	0.0128	

The kVp linearity test for X‐ ray unit were within acceptable limit of ± 5% at all selected tube potential from 50 to 120 kVp

3.3 mAs linearity

Detector was placed at 100 cm SSD. Three exposures were made at fixed time of 0.1 sec (100 ms), 80 kVp, and various mAs 3.3 the linearity was checked using the following equation.
X1-X2/X1+X2*100
Where X1 and X2 are two successive readings
Coefficient of linearity (CL) =
(D/X)max − (D/X)min/ (D/X)max + (D/X)min < 0.1

Table 3.3 mAs linearity coefficient is (LC)

Hospital	***Linearity Coefficient (LC)***
1	0.1
2	0.2
3	0.1
4	0.1
5	0.2
6	0.1

The mAs linearity in this study for x-ray units is vary from 0.1 to 0.2 which indicate that this units need urgent calibration, but if we take Action Level 0.1< L ≤ 0.2 or Rejected Level L > 0.2 that mean is good with in action level.

3.4 Coincidence of light beam and radiation beam

cassette was loaded on table at 100 cm FFD (focus-film distance),then set up light beam for ~ 20 x 20 cm field, metal markers was placed (eg. coins) at each field edge plus one at anode end, and one at top of field and exposure was taken (L1 + L2)/SID x 100
(Length) and (W1 + W2)/SID x 100 (w: width) was calculated as shown as table 4.6 Recommended Tolerance L1 + L2 < 2% SID distance; W1 + W2 < 2% SID distance

Table 3.4 Difference between light field and radiation field

Hospital	***Difference between light field and radiation field***	
	L1 + L2	W1 + W2
1	1 %	1.2 %
2	3 %	1.9 %
3	1.4 %	1.7 %
4	2.5 %	1%
5	0 %	0 %
6	1.3 %	1.5 %

The result shown good alignment between radiation beam and light beam for unit which is below the limit (2% of FFD or ±2cm), (7).

4. Conclusions

The results obtained in this study that x-ray machines under study is within acceptable limit . Performing strict quality control on all radioactive devices is one of the radiation protection priorities that should be done periodically. If we do not have good accuracy and precision of X-ray units and periodic quality control programs, it is possible that patients and personnel take extra doses. The radiographs image quality could be improved by improving the working condition ,the results confirm the need for the propagation of quality assurance (QA) in Algeziera state

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