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Quality control test of conventional X-Ray systems in Delta State, South-South, Nigeria

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ABSTRACT

The quality assurance (QA) and quality control (QC) programmes of imaging equipment are key ingredients of a quality system. This study is aimed at measuring X-Ray machine parameters and comparing them with the American Association of Physicists in Medicine (AAPM) report No. 74. Also, this study made comparison with similar articles locally and internationally. The study was conducted in 12 X-Ray unit (A-L) located in Delta State. A MagicMax Universal Basic Unit was used alongside an XR Multidetector (silicon photodiode) to measure dose, dose rate, practical peak voltage (PPV), exposure time, current in milliampere (mA) and quantity (Q) in milliampere seconds (mAs). The XR Multidetector was positioned at 100 cm from the focus to image distance (FID) to make most measurements. Six (6) X-Ray units were above 20 years, accounting for 50% of the total X-Ray units used. 30% of X-Ray units > 20 years failed the QC test, which was 2.3 times higher than X-Ray units < 10 and 10-20 years respectively. On the average, 55% pass mark was achieved in the 12 X-Ray units across the state, while 26.11% of the test could not be done due to bad knobs and other challenges. Two (2) X-Ray units with an average age of 3 years, passed all the test. The study showed that many of the X-Ray units were old and certain machine parameters could not be assessed. The study also reveal that most X-Ray specifications manual were either misplaced or missing. Continuing QC programme is highly recommended in the studied areas.

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***Keywords*:** Quality Assurance, Quality Control, Silicon Photodiode, Focus to Image Distance (FID), Half Value Layer (HVL), Practical Peak Voltage (PPV), Digital Radiography (DR)

1. INTRODUCTION

X-Ray equipment are used by imaging experts to get the desired results in the diagnosis of any anomaly in the patient's body [1-3]. This is usually the overall aim while trying to solve the patient's health problem, however these equipment may malfunction if there no quality management programmes put in place from the time of purchase, commissioning (acceptance testing) and the daily use (quality control) of the machine. This has the capacity to increase the patient radiation dose and invariably the cancer risk [4, 5].

In Nigeria, the Nigerian Nuclear Regulatory Authority (NNRA) is saddled with the responsibility of ensuring that all radiological equipment meet the minimum requirements before X-Ray equipment are used by the employer. This is through authorization and licensing to operate the facility, which require that individual facilities present their acceptance testing results, quality assurance and control results among others, which are usually verified by the regulators [6-8].

Quality Assurance (QA) means the planned and systematic actions that will produce consistently high quality images with minimum exposure of the patients and workers. Quality Assurance actions include both "Quality Control Techniques" and "Quality administration procedures" [9].

Quality control (QC) in medical imaging is an ongoing process and not just a chain of rare evaluations of medical imaging equipment. The QC process involves designing and implementing a QC program, collecting and analyzing data, investigating results that are outside the acceptance levels for the QC program, and taking corrective action to bring these results back to an acceptable level. The QC process involves key personnel in the imaging department, including the radiologist, radiologic technologist, and the qualified medical physicist (QMP). The QMP performs detailed equipment evaluations and helps with oversight of the QC program, the radiologic technologist is responsible for the day-to-day operation of the QC program [10-14].

A reason for this study was to ascertain the state of conventional X-Ray equipment in Delta State through equipment testing, using basic QC kits. A pilot from our interaction with radiologist and radiographer show that there is either no personnel (medical physicist) to perform these tests and there are no QC kits to perform these tests.

The purpose of this study was to determine the accuracy and reproducibility of X-Ray machine parameters in 12 X-Ray units in the State and comparing our obtained values with the American Association of Physicists in Medicine (AAPM) report No. 74.

2. MATERIALS AND METHODS

The study is a prospective cross-sectional design. The target population for this study was X-Ray facilities in Delta State (Asaba, Warri, Ughelli, Eku, and Abraka). A convenient sampling method was used. A sample size of twelve (12) X-Ray facilities that met the inclusion criteria were used for the study. The following criteria was met:

1) The X-Ray facility must be owned by the government or by a qualified radiographer
2) It must be a functional X-Ray unit
3) It can be a mobile, floor mounted or ceiling mounted X-Ray unit
4) The operator of the X-Ray unit must be licensed

Ethical approval was obtained from the Faculty Ethical and Research Committee of the Nnamdi Azikiwe University, Nnewi Campus and permission was obtained from the managements of the X-Ray facilities where the study was carried out.

The following materials were used for this study: X-Ray machine (floor mounted, ceiling mounted or mobile unit), a MagicMax universal basic unit and a XR solid state multi-detector was used to determine dose, dose rate, practical peak voltage (PPV), duration (s), Half-value layer (HVL) and filtration, a MagicMax current probe, which is capable of measuring milliampere (mA) and milliampere-seconds (mAs) was used, an Inspector USB survey meter was used which was calibrated using Caesium-137, with a calibration factor (CF) of 3340 cpm/mR/hr from the National Institute of Radiation Protection and Research (NIRPR) Ibadan, Oyo State, Nigeria, eight coins, measuring tape and X-Ray film (analog or digital film).

The study was carried between November and January 2021 in Delta State. A total of 11 centres were visited to perform quality control test of conventional X-Ray units in Delta State.

The personnel involved in this study was the 2 Medical Physicist, and at least 2 radiographer from each facility and 1 radiologist. A quality control programme is recommended by the Nigerian Nuclear Regulatory Authority (NNRA) to be performed regularly on all imaging equipment.

2. 1. The XR Multi-Detector

The XR multi-detector was attached to a MagicMax Universal basic unit, which plug to a computer for the display of results (Figure 1). From a single exposure at a field to focus distance (FFD) of 100 cm from appropriate selected parameters the following was determined:

I. Dose (mGy)
II. Dose rate (mGy/s)
III. Practical peak voltage (PPV), (kV)
IV. Duration (s),
V. Half-value layer (HVL)
VI. Filtration

Figure 1. Set up with the XR Multidetector

2. 2. The Current Probe-Detector

In order to determine mA and mAs, the MagicMax current probe was attached to the cable of the cathode (Figure 2). After the selection of appropriate machine parameter and exposure, the followings detector parameters were determined:

I. mA

II. mAs

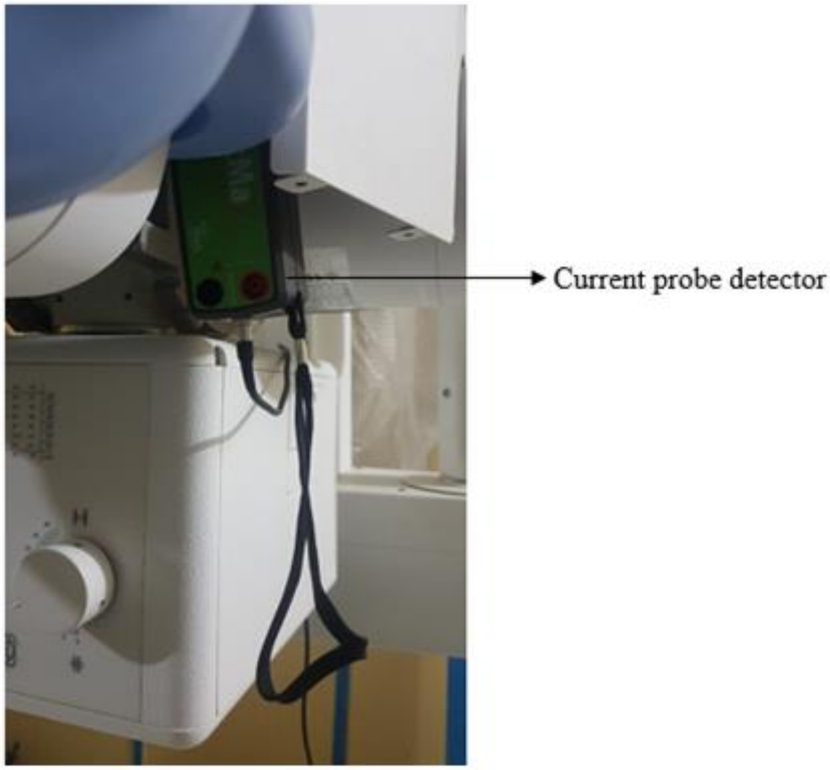

Figure 2. Attachment of the current probe detector to the cathode cable

2. 3. The survey meter

A calibrated (Cesium-137) Inspector USB survey meter (with energy response of 10 keV – 2.0 MeV, which is capable of measuring alpha, beta, gamma and X-Ray, with unit of measurement in CPM, CPS, mR/hr, µSv/hr, Bq, or DPM. The accuracy is ±10%, typically ±15% maximum in mR/hr, µSv/hr and count per minute (CPM) modes; manufactured in 2013 by S.E. International, Inc. USA) was used to measure the tube head leakage radiation (Table 1 and Figure 3).

Table 1. Survey meter specification

Specifications	
Detector	Geiger Muller Tube
Operating range	0 - 350,000 CPM, 0-5,000 CPS, 0.01-1000 µSv/hr, 0.001-100 mR/hr
Accuracy (Cs-137)	0-100 mR/hr ±15%, 0.01-1000 µS/hr ±15%, 0-350,000 CPM ±15%
Energy sensitivity	3340 CPM/hr (Cs-137)

Photon energy response	10 - > 1000 keV
Power requirement	9V
Temperature range	10 °C to 50 °C
Weight	273g

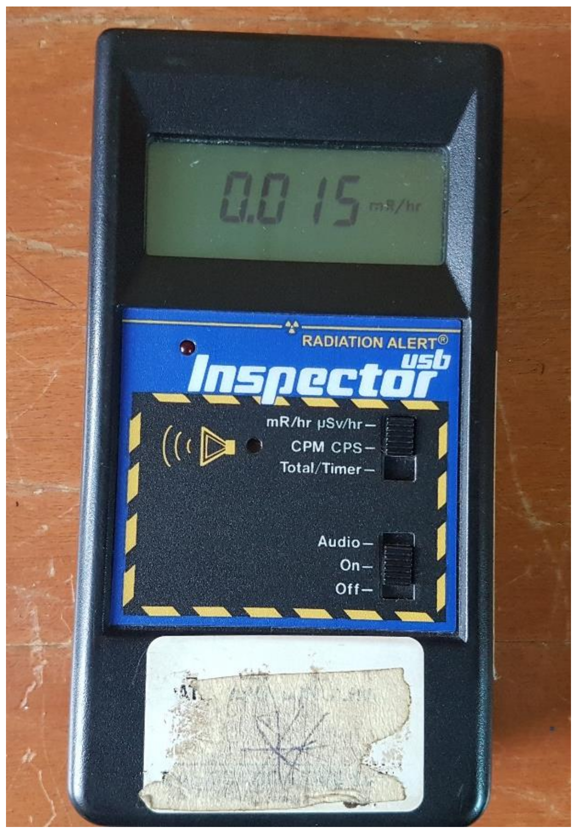

Figure 3. Calibrated survey meter used for leakage test

2. 4. The data collection

The data collection was done as outlined below:

1) The specification of the X-Ray facility were written out in a workbook. 10 of the centres did not have operational manuals for their machines so, the specification of each machine was written out from the body of the X-Ray machine.

2) The XR Multi-detector was positioned at 100 cm FFD with a 20 by 20 field size, covering the entire detector on the table bulky. In order to determine kVp accuracy, a range of kV (depending on the capacity of the X-Ray unit) was selected at constant mAs. At least 5 measurements was made to determine corresponding kV from the

detector readout through a MagicMax software from a computer. The same approach was used for the mAs accuracy, at constant kV and by changing the mAs.

$$kV\ accuracy = \frac{kV_{measured} - kV_{set}}{kV_{set}} \tag{1}$$

$$mAs\ accuracy = \frac{mAs_{measured} - mAs_{set}}{mAs_{set}} \tag{2}$$

Other parameters that were determined using similar approach was the exposure (sec) and mA accuracy. The recommended accuracy of the kVp and mAs should be within ±5% [15].

3) For generators that display the selected time prior to the exposure, accuracy should be within ±5% (for times greater than 10 msec) and ±10% for times less than 10 msec [15].

4) The exposure (s), kVp and mAs reproducibility was determined using the following formula:

$$\text{Coefficient of variation (CV)} = \frac{SD}{M} \times 100 \tag{3}$$

where SD = Standard deviation, M = mean of the values
The exposure reproducibility should be < 0.1 and the kVp and mAs reproducibility be < 0.05 [15].

5) The tube leakage was determined by closing the collimator diaphragm and making exposure between 100-150 kV (this was difficult to achieve for some X-Ray machine). The survey meter was positioned towards the anode, cathode, upper and lower ends of the tube at a distance of 10 cm from the tube head. Measurements was recorded in mR/hr, which was converted to μSv/hr. It is however recommended that tube leakage should be < 1000 μSv/hr [15].

6) The X-ray field alignment was determined with 8 coins, positioned at the edges of the X-Ray light beam and area just outside it. A cassette larger than the collimated beam was used. In some cases, a flat panel system was used for DR technology. The acceptance level was L1 +L2 ≤ 2% SID and W1 +W2 ≤ 2% SID [15].

7) The mA linearity test was determined using the relation below:

$$\text{Linearity coefficient} = \frac{X_{max} - X_{min}}{X_{max} + X_{min}} \tag{4}$$

8) The HVL was determined without external filter at 75 kV. The IEC-60601-1-3 recommends that at 80 kV, HVL should be 2.3 mmAl.

3. RESULTS

Machine specifications are indicated. A total of 7 X-Ray unit were floor mounted, 4 X-Ray units were mobile and 1 unit was ceiling mounted. The minimum and maximum kVp was 100-150 and the mAs ranged from 200-630. The inherent filtration ranged from 0.83-2 mmAl, while the additional filter ranged from 0.5-2.3 mmAl. The total filtrations ranged from 2.5-2.5

mmAl. Ten (10) X-Ray units were single phases, while 2 X-Ray units were three-phases. The machine ages ranged from 2- >30years, with half of the X-Ray units above 20 years (Table 2)

Table 2. X-Ray machine specification for X-Ray unit A-L

Unit	Manufacturer	Type	Serial No	Machine model	kVp range	mAs range	Max current	I.F (mmAl)	A.F (mmAl)	Focal Spot	T.F (mmAl)	Phase	Age (yrs)
A	WATSON & SON	Floor	41514	XE 1253	150	500	300	1.5	2	0.5	3.5	1φ	> 20
B	LISTEM	Floor	618	CSC-21	125	200	-	1.5	0.5	-	2.5	1φ	18
C	DEAN	Mobile	2845	-	130	500	300	1.5	2.5	1.8	4	1φ	>30
D	GE	Floor	128154BC2	5331186	150	625	-	1.3	2.3	1.2/0.6	3.3	3φ	4
E	Yanyzhou	Floor	XS-1	DX4-29	100	-	100	1.5	-	-	-	1φ	>20
F	Tanka	Floor	TP-30	-	-	-	-	-	-	-	-	1φ	>20
G	RMS	Mobile	BY5111015	MDX-100D	-	-	-	-	-	-	-	1φ	6
H	GE	Mobile	4133	46-270615	125	-	-	0.83	1.8	0.8	2.63	1φ	12
I	GE	Mobile	MDYS-4893	46-270615	125	-	-	0.83	1.8	0.8	2.63	1φ	11
J	GEC	Floor	AH 2248/C	BXT-150W	100	-	-	-	-	-	-	1φ	24
K	RADIOLOGIA	Ceiling	19030007	Polyrad CS	150	630	1600	2	1.3	1.2/0.6	3.3	3φ	2
L	DEAN GEC	Floor	62823012	R-20MC	150	300	500	1	1.5	-	2.5	1φ	>20

I.F = Inherent filtration, A.D = Additional filtration, T.F = Total filtration

The quality control (QC) tests in X-Ray unit A indicated that only 40% of the total test were within the acceptable limits, however, 60% of the test were below the required mark for acceptance. The parameters that failed the test were the kVp, mAs and mA accuracy, kVp/mAs reproducibility and the mA linearity tests. In X-Ray unit B, the quality control (QC) tests indicated that 60% of the total test were within the recommended values, however, 40% of the test were below the required mark for acceptance. In X-Ray unit C, the quality control (QC) tests indicated that 62.5% of the total test were within the recommended values, however, 37.5% of the test were below the required mark for acceptance. The parameters that failed the test were the exposure and mA accuracy and the exposure reproducibility of the X-Ray machine. X-Ray unit D, which is a U-arm, floor mounted DR X-Ray machine with a fully incorporated dose area product (DAP) meter, show that all (100%) quality control (QC) tests were within the recommended values.

The quality control (QC) tests in X-Ray unit E, indicated that 33.33% of the total test were within the recommended values, while 66.67% failed the test. In X-Ray unit F, only 2 test could only be performed. The exposure reproducibility test was below the recommended, while the tube leakage test was within the acceptable range. The quality control (QC) tests in X-Ray unit G, indicated that 33.33% of the total test were within the recommended values, however, 66.67% of the test were below the required mark for acceptance.

The parameters that failed the test were the kVp accuracy, exposure accuracy and exposure and kVp reproducibility of the X-Ray machine. The quality control (QC) tests as seen in X-Ray unit H, indicated that 100% of the total test were within the acceptable limits. The quality control (QC) tests in X-Ray unit I, indicated that 71.43% of the total test were within acceptable limits and 28.57% were above the acceptable limits. In addition, the quality control (QC) tests in X-Ray unit J, indicated that only 50% of the total test were within the recommended values, however, half (50%) of the test were below the required mark for acceptance. The parameters that failed the test were the mAs and kVp accuracy, mA reproducibility and the mA linearity tests. The unit (K) comprise of a ceiling mounted DR system. The quality control (QC) tests indicated that 100% of the total test were within the recommended limits. The quality control (QC) tests in X-Ray unit L, indicated that 62.5% of the total test were within the recommended values, however, 37.5% of the test were below the required mark for acceptance. The parameters that failed the test were the mAs accuracy, mAs reproducibility and mA accuracy of the X-Ray machine (Table 3).

Table 3. Quality control test on X-Ray unit in centre A-L

Parameters	A	B	C	D	E	F	G	H	I	J	K	L	Limit
kVp accuracy	7.01	5.1	4.62	1.73	7.34	-	6.18	1.71	7.68	15.06	0.06	2.85	±5
mAs accuracy	37.98	-	-	1.93	-	-	-	2.4	0.66	51.06	0.27	19.58	±5
Exposure accuracy	3.25	-	39.86	0.38	-	-	16.76	-	-	-	0.96	-	±10
mA accuracy	36.95	-	11.06	2.34	-	-	-	-	-	-	0.35	-	±10
Exposure reproducibility	0.0271	0.1443	0.661	0.0012	0.022	0.451	0.923	0.0005	0.193	0.027	0.098	0.018	< 0.1
kVp reproducibility	0.057	0.0018	0.012	0.013	-	-	0.085	0.014	0.05	0.026	0.0001	0.0014	0.05
mAs reproducibility	0.43	-	-	0.017	-	-	-	0.014	0.0035	0.676	0.0004	0.156	0.05
Tube leakage	9.07	14.6	0.51	0.76	1.23	0.94	5.04	2.49	4.02	3.17	1.14	7.23	1000µSv/hr
HVL @80kV	2.4	3.7	2.9	4.7	-	-	2.55	2.9	3.5	2.6	3.1	3.1	2.3
mA linearity	0.407	-	0.068	0.0015	-	-	-	0.00	0.008	0.333	0.016	0.144	? 0.1

Table 4. Light beam test among the X-Ray units

Centres	L1+L2	Outcome (< 2% SID)	W1+W2	Outcome (< 2% SID)
A	0.5	Pass	1.6	Pass
B	0.4	Pass	0.9	Pass
C	1.8	Pass	11.4	Fail
D	0.3	Pass	0.5	Pass

H	0.4	Pass	1.4	Pass
I	0.5	Pass	0.4	Pass
K	0.3	Pass	0.4	Pass
L	1.15	Pass	0.95	Pass

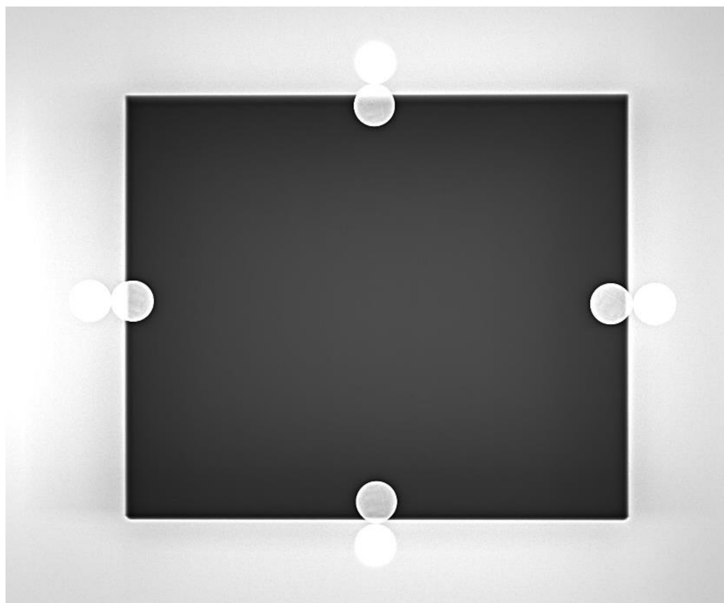

Figure 4. Light beam test from one of the X-Ray unit

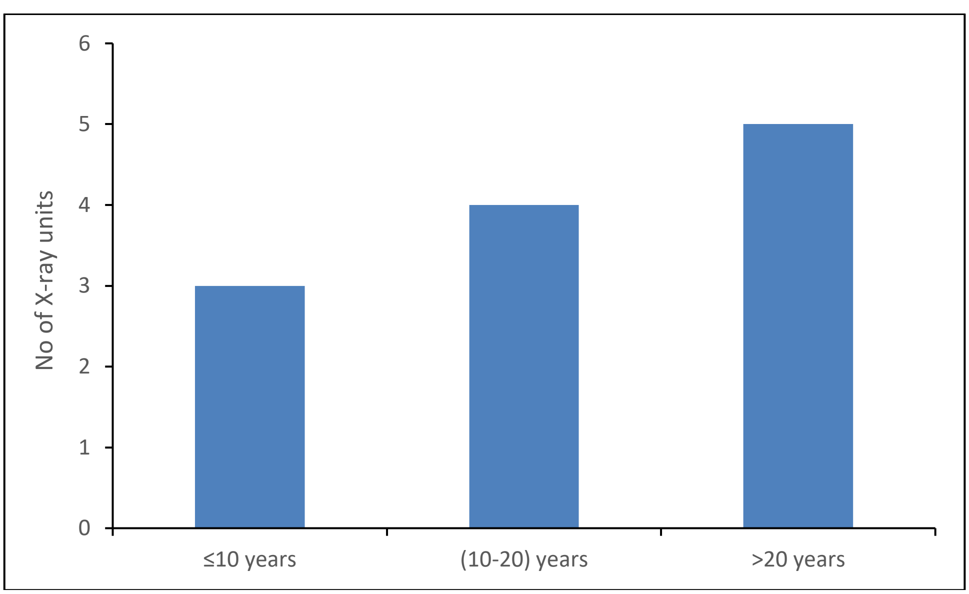

Figure 5. Number of X-Ray units against age (years)

The light beam test was performed with 8 X-Ray unit. All facilities passed the congruency test along the length (L1+L2) axes. Similarly, 7 X-Ray units passed the test along the width (W1+W2), axes, except for X-Ray unit C, which failed the test (Table 4 and Figure 4).

The distribution of the X-Ray machine according to 3 major age groups is represented. Three (3) of the X-Ray units were below 10 years, 3 were within 10-20 years, while 6 were above 20 years (Figure 5).

4. DISCUSSION

A study to determine the quality control test of 12 X-Ray units in Delta State, South-South Nigeria have been determined using some test tools to determine kVp, mAs, mA and exposure accuracy, kVp, mAs and exposure reproducibility, X-Ray tube leakage, HVL at 80kVp and mA linearity test.

Six (6) X-Ray units were above 20 years, accounting for 50% of the total X-Ray units used. 30% of X-Ray units > 20 years failed the QC test, which was 2.3 times higher than X-Ray units < 10 and 10-20 years respectively. On the average, 55% pass mark was achieved in the 12 X-Ray units across the state, while 26.11% of the test could not be done due to bad knobs and other challenges. Two (2) X-Ray units with an average age of 3 years, passed all the test.

Out of 12 X-Ray units, 5 passed the kVp accuracy test (45.45%) with 5 X-Ray units (centre A, B, E, G and I) failing the test.

The kVp could not be determined from centre F because the knob for the kVp control was faulty and could only be operated on very few kVp only. Also the age of 6 X-ray machine was > 20 years, which indicated that most parts are likely to malfunction. The aspect of radiation protection in Centre F would be compromised since the knob was bad. Similarly, only 4 X-Ray units passed the mAs accuracy test (57.14%). Two units failed the test and 5 X-ray units either had faulty knobs (centre B, E and F) or the power cable supplying the cathode could not be accessed for mAs measurements (centre C and G).

The kVp accuracies from a study by Khoshbin-Khoshnazar et al, show that 25.9% from 44 X-Ray equipment failed the machine QC tests [16]. Similarly, a study by Mehrdad et al, showed that 35% failed the test, while Akpochafor et al, showed 20% [17, 18]. Other studies like Asadinezhad et al (38.6%), Gholamhosseinian et al (27%), Jomehzadeh et al (25%), Rasuli et al (6.7%) and Akpochafor et al (30.43%) showed similar trend [19-23]. The results from the 9 studies were lower than our study, where 54.5% of the X-Ray units failed the kVp accuracy test. Machine age could be a contributory factor in our study, where 50% of the X-Ray units were over 20 years. The kVp accuracies from studies by Esmaeilli et al (55%) and Saghatchi et al (57%) were slightly above our study [24, 25].

Also, 60 % from 3 X-ray units passed the exposure (timer) accuracy test, while 40% from 2 X-ray units failed the test (centre C and G). Failed exposure accuracy from our study was the highest compared to Khoshbin-Khoshnazar et al (37%) [16], Asadinezhad et al (34.5%) [19], Jomehzadeh et al (29%) [21], Esmaeilli et al (30%) [24] and Saghatchi et al 2006 (14%) [25]. However, Gholamhosseinian et al (45%) was higher than our study [21]. The exposure accuracy could not be performed in 7 X-Ray units (centre B, E, F, H, I, J and L) because the control console configurations for mA and exposure parameters were not separated.

In addition, 50 % from 2 X-Ray units passed the exposure accuracy test, while 50% from 2 X-ray units failed the test (centre A and C).

The exposure accuracy could not be performed in 8 X-Ray units (centre B, E, F, G, H, I, J and L) because the control console configurations for mA and exposure time parameters were not separated. While in some X-Ray unit, the current probe could not be used because the cathode cables could not be accessed.

The exposure reproducibility was performed in all the X-Ray units. 7 (58.33%) out of 12 passed the test. However, 5 (41.67%) X-Ray units failed the test. The number of X-Ray units from our study that failed the test was higher compared to Asadinezhad et al (19.4%), Gholamhosseinian et al (30%), Jomehzadeh et al (39%), Esmaeilli et al (30%) and Saghatchi et al (7%).

In the same vain, 80% passed the kVp reproducibility test with only 2 X-Ray units failing the test, while 40% passed the mAs reproducibility test from 5 X-Ray units. The mAs reproducibility could not be carried out in 6 X-Ray units because of either faulty knobs from the console, inability to access the cathode cable entering the tube head.

All the X-Ray units passed the tube leakage test. The mean leakage radiation from our study (0.00418 mSv/hr) was lower to a study in Iraq by Kareem et al, where their mean leakage radiation was 0.03 mGy/hr [26]

Similarly, all the X-Ray units passed the HVL test at 80 kVp. Although, the HVL could not be accessed from X-Ray unit E and F because both facility could not be operated on 80 kVp. Also 3 facility failed the mA linearity test but 5 (62.5%) passed the test. The mA linearity could not be determined from X-Ray unit E, F and G. 94% of the facilities passed the light beam test, except for the widths of centre C. A reason for this could be the machine age which was > 30 years. On the average 65% of the total test was passed by the 12 X-Ray units. The result can be said to be above average.

The study reveals that there was statistically significant difference between kVp accuracy ($P = 0.003$), exposure reproducibility ($P < 0.001$), kVp reproducibility ($P < 0.001$), mAs reproducibility ($P = 0.001$), tube leakage ($P < 0.001$), HVL ($P = 0.001$) and mA linearity ($P = 0.001$) against the machine ages. Parameters that didn't affect the machine ages were the mAs ($P = 0.731$), exposure accuracy ($P = 0.987$) and mA accuracy ($P = 0.906$). The average age (15.58 ± 8.56) of the X-Ray machines was similar to what was obtained by Khoshbin-Khoshnazar et al, where machine age average was 15.78 ± 12.83 years [16].

A study from in Lagos, Nigeria by Akpochafor et al, showed that there was no difference in kVp accuracy and machine age ($P = 0.770$) with a maximum machine age of 11 years [18]. Another study from in Jos, Nigeria by Akpochafor et al, showed a statistically significant difference in machine age and kVp ($P < 0.05$). This outcome was similar to our study ($P = 0.003$) [23]. In general, there was no correlation between machine age and QC test performed.

5. CONCLUSION

A study to assess the QC testing of 12 conventional X-Ray units have been carried out in Delta State. The study shows that 50% of the total X-Ray units investigated were above 20 years and with highest failure (30%) compared to < 10 (13.33%) and 10-20 (13.33%) years respectively. They also accounted for the highest number of QC test that could not be performed mostly as a result of bad kVp and mAs knobs. Sensitization and training on the need for regular X-Ray machine QC test is imperative in Delta State.

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References

[1] Toppenberg MD, Christiansen TEM, Rasmussen F, Nielsen CP, Damsgaard EM. Mobile X-ray outside the hospital: a scoping review. *BMC Health. Serv. Res.* 20 (2020) 767

[2] Howell JD. Early clinical use of the X-ray. *Trans Am Clin Climatol Assoc.* 127(2016) 341-349

[3] Chen H, Rogalski MM, Anker JN. Advances in functional X-ray imaging techniques and contrast agents. *Phys. Chem. Chem. Phys.* 14(39) (2012) 13469-13486

[4] Park MY, Jung SE. Patient Dose Management: Focus on Practical Actions. *J Korean Med Sci.* 31(2016) Suppl 1(Suppl 1) S45-S54

[5] Rasuli B, Mahmoud-Pashazadeh A, Ghorbani M, Juybari RT, Naserpour M. Patient dose measurement in common medical X-ray examinations in Iran. *J Appl Clin Med Phys.* 17(1) (2016) 374-386

[6] Akpochafor MO, Omojola AD, Adeneye SO, Aweda MA, Ajayi HB. Determination of reference dose levels among selected X-ray centers in Lagos State, South-West Nigeria. *J Clin Sci* 13 (2016) 167-72

[7] Nigerian Nuclear Regulatory Authority (NNRA). Nigerian Safety and Radiation Protection Act (1995 No. 19): Nigerian Radiation Safety in Diagnostic and Interventional Radiology Regulations, (2006) B661-B692

[8] Nigerian Nuclear Regulatory Authority (NNRA). Nigeria Basic Ionizing Radiation Regulation. (2003) B165-B247.

[9] Mohan C. Quality program in radiology: Persue or perish. *Indian J Radiol Imaging* 27(1) (2017) 1-3

[10] Jones AK, Heintz P, Geiser W, Goldman L, Jerjian K, Martin M et al. Ongoing quality control in digital radiography. *Med Phys.* 42(11) (2015) 6659-6669

[11] Sharma R, Sharma SD. A quality control programme for medical X-ray films in India. *Radiat Prot Dosimetry* 148(1) (2012) 51-57

[12] European Commission, European Commission. European Guidelines on Quality Criteria for Diagnostic Radiographic Images. EUR 16260 EN, Luxembourg. (1996).

[13] General X-ray QA and QC Guideline, Version 1. The Royal Australian and New Zealand College of Radiologists. (2013).

[14] International Atomic Energy Agency. Dosimetry in Diagnostic Radiology: An International Code of Practice, Technical Reports Series No. 457, IAEA, Vienna. (2007).

[15] American Association of Physicists in Medicine (AAPM). Quality control in diagnostic radiology. AAPM Report No. 74. (2002)

[16] Khoshbin Khoshnazar A, Hejazi P, Mokhtarian M, Nooshi S. Quality control of radiography equipment in Golestan Province of Iran. *Iranian Journal of Medical Physics* 10(1) (2013) 37-44

[17] Mehrdad G, Fataneh N, Vahid K. The evaluation of conventional X-ray exposure parameters including tube voltage and exposure time in private and governmental hospitals of Lorestan Province, Iran. *Iran J Med Phys.* 2 (2015) 85-92

[18] Akpochafor MO, Omojola AD, Soyebi KO, Adeneye SO, Aweda MA, Ajayi HB. Assessment of peak kilovoltage accuracy in ten selected X-ray centers in Lagos metropolis, South-Western Nigeria: A quality control test to determine energy output accuracy of an X-ray generator. *J Health Res Rev.* 3 (2016) 60-65

[19] Asadinezhad M, Toossi MTB, Ebrahiminia A, Giahi M. Quality Control Assessment of Conventional Radiology Devices in Iran. *Iran J Med Phys.* 14(1) (2017) 1-7

[20] Gholamhosseinian-Najjar H, Bahreyni-Toosi MT, Zare MH, Sadeghi HR, Sadoughi HR. Quality control status of radiology centers of hospitals associated with Mashhad University of Medical Sciences. *Iranian J Med Phy.* 11(1) (2014) 182-7

[21] Jomehzadeh Z, Jomehzadeh A, Tavakoli MB. Quality Control Assessment of Radiology Devices in Kerman Province, Iran. *Iranian Journal of Medical Physics* 3(1) (2016) 25-35

[22] Rasuli B, Pashazadeh AM, Tahmasebi Birgani MJ, Ghorbani M, Naserpour M, Fatahi-Asl J. quality control of conventional radiology devices in selected hospitals of Khuzestan province, Iran. *Iranian Journal of Medical Physics* 12(2) (2015) 101-108

[23] Akpochafor MO, Adeneye SO, Akpolile FD, Omojola AD, Aweda MA. Evaluation of kilovoltage failure in conventional X-ray machines among selected X-ray Centers in Jos North Local government area of Plateau State, Nigeria. *Nig Qt J Hosp Med.* 27(2) (2017) 768-775

[24] Esmaeili, S. Measurement of patient skin dose of common techniques in diagnostic radiology in 15 radiology centers and quality control of those units in Mashhad, in Medical Physics. Mashhad University of Medical Sciences (2006).

[25] Saghatchia F, Saloutib M, Bahreinic MT. QC of X ray machines in the hospitals of the Medical Sciences University of Zanjan. QANTRM, Vienna, 13–15 November. IAEA-CN-146/095 (2006)

[26] Kareem AA, Hulugalle SN, Al-Hamadani HK. A Quality Control Test for General X-Ray Machine. *World Scientific News* 90 (2017) 11-30