

Research Article

Assessment of Some Selected Conventional Diagnostic X-Ray Facilities at Cape-Coast in the Central Region of Ghana

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Abstract

The aim of the present paper is to assess some of the factors affecting on quality assurance of some conventional X-ray facilities such as reproducibility of tube voltage, dose output, X-ray tube consistency, accuracy of kVp, and half value layer. Examinations of these factors were studied using noninvasive kV meter of RMI 24A Multi-function meter. The quality assurance tests of X-ray diagnostic examination are measured and compared with the international tolerance. The half value layer of the radiation beam is an essential component of the assessment program. It is a measure of the beam hardness which relates to the type and thickness of shielding required in the facility and it also determines to a reasonable extent how much soft radiation is present in a beam. This soft radiation is absorbed in the surface tissue and results in unnecessary radiation being absorbed by the patient. In addition, it also contributes to unnecessary scatter within the patient which detracts from the desired image. The half value layer of a machine should not change for the lifetime of a machine unless someone removes the filter and as such it should be measured at least during the installation of a new machine.

Keywords: X-rays; Quality assurance; Half value layer; Radiation beam and examination

Introduction

In 1895 Wilhelm Rontgen was studying the effects of cathode rays passing through various materials and noticed a nearby phosphorescent screen glowing vividly in the darkened room. Rontgen soon realized he was observing a new kind of ray, one that, unlike cathode rays, was unaffected by magnetic fields and was far more penetrating than cathode rays bombarding the glass walls of his vacuum tube. Rontgen studied their transmission through many materials and even showed that he could obtain an image of the bones in a hand when the X-rays were allowed to pass through. This experiment created tremendous excitement, and medical applications of X-rays were quickly developed and still used today.

X-rays play an important role in modern technology, especially in the field of medical imaging purposes and treatments. Medical sources of ionizing radiation are the largest contributor of radiation doses from artificial sources and most of this radiation comes from diagnostic X-rays [1-3]. X-rays are produced when electrons strike or hit a metal targets.

The main goal of quality assurance of X-ray machine is to obtain accurate and timely diagnosis. The secondary goals are minimization of radiation exposure and to obtain high image quality. This can be assessed by testing the X-ray machine's 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 [4,5].

An adequate diagnostic Quality Assurance (QA) program

involves periodic checks of the components in a diagnostic X-ray imaging system. The optimum QA program for any individual facility will depend on a number of factors which include but may not be necessarily be limited to, items such as the type of procedures performed, type of equipment utilized, and patient workload. The quality assurances of diagnostic X-ray are based on the Basic Safety Standard -BSS [4] and International Commission of Radiological Protection, for the use of Diagnostic Reference Levels (DRL for patients, ICRP- Report No. 1966 [2,6].

For the purposes of this test procedure like the kVp test, accuracy will mean the degree of agreement between the measured and



Figure 1: RMI Multi -functional meter.

indicated kVp values. The X-ray kVp is the most critical. A small error of this variation will have a greater effect on the final radiographic image.

The beam quality test verifies that the Half-Value Layer (HVL) is sufficient to reduce patient exposure to low-energy radiation and assures that filters, which may have been removed for tube inspection, are in place for normal radiography [7-9].

In this study, the various tests were performed in diagnostic X-ray facilities for image quality by using appropriate equipment. Image quality and patient dose are dependent on any variation in the generator kilo Voltage (kV) of the X-ray set. Therefore an accurate kV calibration is always required [10-14].

The aim of this paper is to assess some factors affecting the quality assurance of conventional X-ray machines such as reproducibility of tube voltage, dose output, accuracy of kVp, and half value layer or radiation beam quality.

Material and Method

The assessment was performed using a checklist developed by the Radiation Protection Board of Ghana Atomic Energy Commission which lists the general radiation provision such as radiation warning light, shielding, protective clothing, output consistency and beam quality.

The following parameters were tested for at the selected X-ray facilities: kVp accuracy and reproducibility, beam quality, beam collimation and alignment and the radiation dose output consistency. The RMI 241 meter was used to measure the kVp and timer accuracy; and the Red check was used to measure the radiation output consistency and the Half Value Layer (HVL) by using aluminum absorbers or filters. The beam alignment and collimation test was done using the collimator and beam alignment tools.

The kilovoltage (kVp) accuracy test

Firstly the RMI meter was set at a distance of 100 cm from the X-ray tube focus and was centered using the laser. Then 20mAs was set on the machine control panel. The kVp was then measured from 60-120 kVp in increment of 10. At every set kVp on the control panel, the measured kVp was recorded. The percentage difference between the kVp set on the control panel and measured kVp values were



Figure 2: Rad Check Plus meter.



Figure 3: A set of Aluminum absorbers.

calculated. This should be within ± 6% for acceptance (Figure 1).

Tube output measurement

This test checks that the radiation output [mGy/mAs] remains constant as the mA is varied. For this test, the dose Victoreen Red check Plus meter was used as shown in Figure 2.

Half value layer (HVL) measurement

The half-value layer measures the quality of the X-ray beam. The apparatus used are the Aluminum (Al) attenuator set, Victoreen Rad Check Plus meter and lead vinyl. The meter was placed at 100 cm from the tube focus on the lead vinyl to standardize backscatter. The kVp was set at 80 and fixed value of 20mAs. The X-ray beam was collimated to the size of the meter. Three exposures were taken and the resulting doses were recorded. Another set of exposures and dose measurements were taken after placing a 1.0mm thick Al attenuator on the collimated area of the Rad Check Plus meter. Further exposures and dosage measurements were taken for after adding varying thicknesses of Al attenuators until the dose has fell to below 50% of the initial unattenuated value.

A graph with the dose against the aluminum attenuator thickness was then plotted. From the graph, the thickness of Al required to reduce the unattenuated dose by 50% is the Half Value Layer (HVL) of the radiation beam.

Mathematically, the HVL could also be determined by using the relation (Figure 3).

$$HVL = \frac{\ln 2}{\mu} \tag{1}$$

$$HVL = \frac{0.693}{\mu} \tag{2}$$

Where μ is the linear attenuation coefficient.



Figure 4: Beam alignment tool.

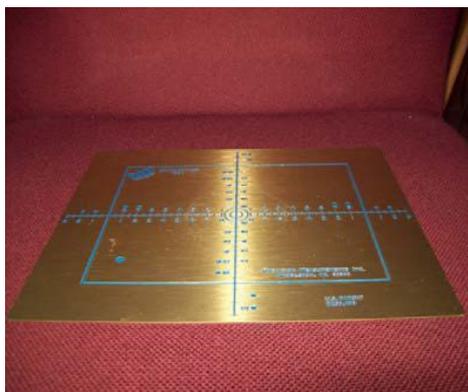


Figure 5: Collimator tool.

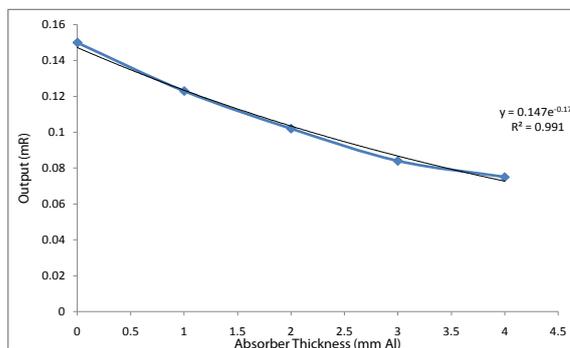


Figure 7: A graph showing the variation of absorber thickness and output for Case 2.

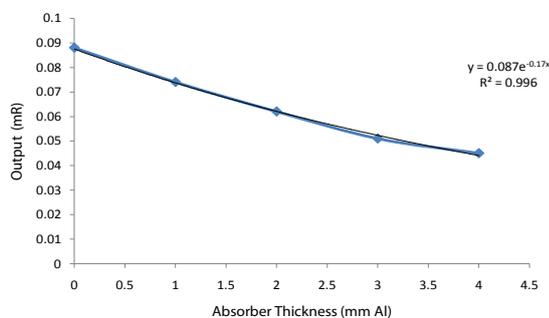


Figure 6: A graph showing the variation of absorber thickness and output for Case 1.

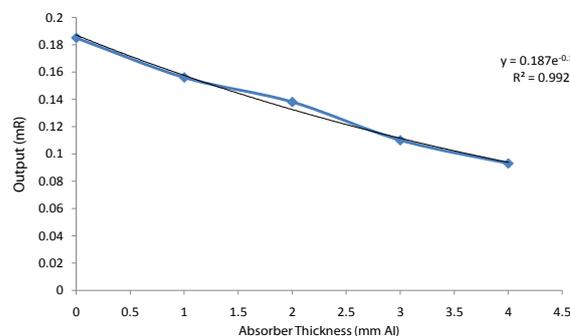


Figure 8: A graph showing the variation of absorber thickness and output for Case 3.

Beam collimation

The following apparatus were used: beam alignment tool as shown in Figure 4, collimator tool shown in Figure 5, cassette and film.

The collimator tool was placed at a distance of 100cm from the tube focus with a cassette loaded with a radiographic film placed underneath. The beam alignment tool was then placed at the center on the collimator tool. The collimator shutters were adjusted so that the edges of the light field coincide with the rectangular outline on the collimator tool. Then the cassette was exposed and later the film was developed to visualize the image produced.

If the X-ray field falls just within the image of the rectangular frame there is good alignment. If an edge of the X-ray field falls on the first spot, ± 1.0cm, on either side of the line it shows that the edges of the X-ray field are misaligned by a percentage of 1% (Figure 6,7,8).

Results and Discussion

Some of the model and serial numbers that could not be identified were due to embossment either removed or peeled off from the machines as observed in facilities 3, 4 and 6 in Table 1 respectively. The reason was that, some of the machines are very old in the system. From the graphs for Cases 1, 2 and 3 it was observed that the regression $R^2 \approx 0.9936$ which was almost equal to 1.0 which shows a good fit. From the graphs for cases 1, 2 and 3 it was observed that, the HVLs were 4.05, 3.92 and 4.03 mmAl respectively (Table 2,3,4). These show a very good agreement with the stated values [15,16] (Table 5,6,7).

The following shows the results of the experiments conducted in each of the facilities selected.

Table 1: Facilities and radiation beam characteristics.

No of Facilities	Manufacturer	Type of machine	Model No	SerialNo.	KVp	mAs	HVL (mmAl)	Remarks
Facility 1	Shimadzu	mobile	Art Eco	3YCF3BOBO2E	60	4	3.47	Pass
Facility 2	Philips medical system	Fixed	Optimus	06011166	81	40	4.5	Pass
Facility 3	Carestream	mobile	ODYSSEYHF Series	-----	80	20	5.0	Pass
Facility 4	Philips Medical Systems	Fixed	-----	-----	80	25	3.65	Pass
Facility 5	Chonging medical equipment factory	Fixed	Fx 50	790	70	50	1.8	Pass
Facility 6	Philips Medical Systems	Fixed	MRS	-----	70	20	2.9	Pass
Facility 7	SIEMENS	mobile	1804298X0381	01398 S16	81	16	4.5	Pass

Table 2: A table showing the indicated kilo-voltages and average kilo-voltages with the corresponding remarks for Case 1.

Indicated kV	Measured kV Readings			Average kV ±%	Remarks
60	57.7	57.4	57.6	57.56±4.07	Pass
70	67.2	67.4	67.2	67.26±3.91	Pass
80	76.9	76.9	77.0	76.93±3.83	Pass
90	87.5	88.0	87.0	87.50±2.78	Pass

Table 3: A table showing the indicated kilo-voltages and average kilo-voltages with the corresponding remarks for Case 2.

Indicated kV	Measured kV readings			Average kV ±%	Remarks
60	64.4	63.9	63.9	64.06±6.76	Fail
70	74.5	75.4	75.4	75.10±7.28	Fail
80	82.7	82.4	82.5	82.25±2.81	Pass
90	85.6	86.0	86.0	85.86±4.60	Pass

Table 4: A table showing the indicated kilo-voltages and average kilo-voltages with the corresponding remarks for Case 3.

Indicated kV	Measured kV readings			Average kV ±%	Remarks
60	59.8	59.6	59.8	59.73±0.45	Pass
70	69.6	69.8	69.7	69.70±0.43	Pass
80	77.9	77.8	77.5	77.73±2.84	Pass
90	81.8	81.5	81.2	81.50±9.44	Fail

Table 5: A table showing the variation of absorber thickness with average output for Case 1.

Absorber thickness (mmAl)	Average Output (mR)
0	0.088
1	0.074
2	0.062
3	0.051
4	0.045

Table 6: A table showing the variation of absorber thickness with average output for Case 2.

Absorber thickness (mmAl)	Average Output (mR)
0	0.150
1	0.123
2	0.102
3	0.084
4	0.075

Conclusion

The quality assurance tests of X-ray machines under study of the selected facilities in Cape Coast of Central Region have obtained accurate and timely diagnosis. The measured output doses were within the international reference doses. The quality assurance program should be generalized for all hospitals to ensure the quality of the X-ray machines under services and the hospitals should try to procure the quality control kits for use.

Table 7: A table showing the variation of absorber thickness with average output for Case 3.

Absorber thickness (mmAl)	Average Output (mR)
0	0.185
1	0.156
2	0.138
3	0.110
4	0.093

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