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Investigation of Some Regular X-ray Imaging Parameters in Suggestive Radiography of Four Hospitals in Bangladesh

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Received: *17 November 2022* / **Revised:** *23 February 2023* / **Accepted:** *19 April 2023*

Abstract

Analytic radiography is a normal image testing technique which has been utilized for quite a long time. It is recommended by specialists so they can identify any problem in patients' bodies without a cut. Thinking about its wide use, the principle objective of this investigation is to give a top notch picture by keeping the radiation portion as low as conceivable through identifying any variety in quality control (QC) boundaries. In this work, some standard quality control boundaries, for example, voltage exactness, time precision test, tube yield linearity, half value layer (HVL) of x-beam were measured. These quality control (QC) boundaries were estimated by a dosimeter keeping a distance of 100 cm from source. The voltage precision went from 0.31% to 4.67% and the time exactness test went from 0% to 2.29%. The consequences of this investigation show that all the QC boundaries are inside the acceptable level which guarantees the advancement of the low portion conveyed to the patients.

Keywords: Diagnostic radiography, Quality control (QC), X-ray, HVL, Dosimeter

1. Introduction

Diagnostic x-ray is a common and frequently used procedure in any accidental case to check fracture or to monitor progression of diagnosed disease all over the world. A report has been made that medical imaging tests are increased at a rate of 5% per year with the whole world annual per capital dose of 0.4 mSv. So, diagnostic imaging becomes the largest source of man-made exposure to ionizing radiation in medical science (Abdulkadir, 2020). As the use of x-ray in medical science has been grown up everywhere, the execution of quality control of x-ray machines is of most important for justification and optimization of exposures (Al-Kinani & Mohsen, 2014). Optimization of dose is of most important for the quality and quantity of QC test on x-ray machines (Gholami, Nemati, & Karami, 2015). The World Health Organization (WHO) characterizes a quality assurance (QA) program in symptomatic radiology as a coordinated exertion by the staff working an office to guarantee that the indicative pictures delivered are of adequately excellent so they reliably give sufficient analytic data at the most reduced conceivable expense and with the most un-conceivable openness of the patient to radiation (Inkoom, Schandorf, Emi-Reynolds, & Fletcher, 2011). The initial responsibility of a medical physicist is to design and supervise a QA program which is stated by AAPM. The European Commission of protection published a guideline for QC in 1997 and main components of QC programs have been reported by AAPM in 2002 (Asadinezhad, Bahreyni Toossi, Ebrahiminia, & Giahi, 2017). QC is part of the QA program that is used to test and maintain the technical component of x-ray units. So, quality control techniques mainly focused on the instruments that can play an important role in imaging (Ismail, Ali, Omer, Garelnabi, & Mustafa, 2015). Patients and radiation workers in diagnosis face an estimated lifetime cancer risk of between 1 in 3500 and 1 in 7000. So, it is very important to know the amount of radiation exposure used during diagnosis so that it may lessen excessive radiation to patients (Rubai et al., 2018). Minimization of radiation exposure to have a high quality image is the main aim of QA. This can be done by routine checkup of some parameters like voltage and time accuracy, linearity of output, half value layer (Abd-Alla, Salih, & Albashir, 2019). 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) (Taha, 2011). The main objective of this study is to decrease the delivered dose during imaging with a high quality image by investigating some important QC parameters which would also reduce the economic cost according to the IAEA Technical Report Series No. 457 (International Atomic Energy Agency [IAEA], 2007).

2. Materials and Methods

Three 500 mA digital x-ray systems (Shimadzu IEC60601-1-2-2001) of Delta Hospital Ltd., Mirpur, Dhaka, and KhwajaYunus Ali Medical College Hospital, Sirajgonj as well as one digital x-ray system (Siemens part8375545g2107) of National Institute of Cancer Research and Hospital (NIRCH), Dhaka, Bangladesh were used with inherent filtration 1.5 and 1 mm respectively in the present study. Dosimetry convention in this study was as indicated by the IAEA Specialized Report Arrangement No. 457 (IAEA, 2007). QC test were performed by using a dosimeter named DIAVOLT UNIVERSAL (T43014-001400) made by PTW-Freiburg. Its measuring quantities are practical peak voltages and air kerma. For making this, various quality control parameters such as output of x-ray, time accuracy, output linearity with mA, voltage accuracy, kV linearity with kV_p were investigated. The beam alignment was checked with field size of 10×10 cm^2. For measurements, the dosimeter was positioned in such a way that the focus to detector distance (FDD) was 100 cm.

Figure 1. Set-up representation of the radiation measurement geometry for 40, 50, 60, 80 and 100 kV.

2.1 Voltage accuracy test

For various tube currents which are commonly used in different organs image testing of the patients, tube voltage was tested. At field to surface distance (FSD) 100 cm kV_p was measured from 60-120 kV tube voltage for different currents in mA (Ranallo, 1998).

$$Voltage\ \ accuracy = \frac{kV(measured)-kV(nominal)}{kV(nominal)} \quad (1)$$

2.2 Time accuracy test

It was measured for 15 tube voltages at FSD 100 cm.

Linearity test with output

For mA linearity test 4 data was taken for using 80kV_p at a distance 100 cm from x-ray tube with exposure time 100 ms. The dose to mA ratio, X and the linearity coefficient L, can be determined for the formula (Ranallo, 1998):

$$X = \frac{Dose}{mAS}; L = \frac{X_{max}-X_{min}}{X_{max}+X_{min}} \quad (2)$$

2.3 Linearity with output

For output linearity as a function of tube voltage, air kerma was measured at constant tube current and exposure time. During the experiment three exposures was used at 160 mA and 100 ms. For each exposure FDD was 100 cm.

2.4 Half value layer

For the HVL computation, the air kerma corresponding to different thickness of aluminum filters are measured. To avoid scattering the aluminum filters were placed as close as possible to the x-ray tube. Data was also taken without a filter to get the initial doses to compute HVL for different potential. During this measurement the dosimeter was kept at a distance of 100 cm from the x-ray tube. This was done in two hospitals with two different x-ray machines. The effective energy (keV) can also be obtained by using an established empirical formula which was obtained by the interpolation value from Hubble mass attenuation coefficients (Rahman et al., 2008);

$$E = 22.03t^{0.341} + 0.1469t^{2.01}; t = HVL\ for\ Al \quad (3)$$

3. Results

3.1 Voltage accuracy test

Table 1 shows the precision of kV for various organ's imaging in three x-beam machines. Tube voltages in different organs were performed in accordance with published international standard (Health Canada, 2008) and well suited for patients' health. For machine 1 (Shimadzu IEC60601-1-2-2001) the varieties lay from 4.67% to 2.56% for tube voltage 60-90 kV. For machine 2 (Shimadzu IEC60601-1-2-2001) it was about 0% to 3.1% for tube voltage 60-120 kV and 0.31% to 2.1% for 65-120 kV in machine 3 (Shimadzu IEC60601-1-2-2001) individually. That was, for the majority of the tube voltage the variety was impressive.

Table 1. The accuracy of kV used for different organ's x-ray examination of three machines.

Name of organ	Machine 1 (Shimadzu IEC60601-1-2-2001)			Machine 2 (Shimadzu IEC60601-1-2-2001)			Machine 3 (Shimadzu IEC60601-1-2-2001)		
	Tube voltage (kV)	**Mean kV_p**	**Deviation (%)**	**Tube voltage (kV)**	**Mean kV_p**	**Deviation (%)**	**Tube voltage (kV)**	**Mean kV_p**	**Deviation (%)**
Chest	60	62.800	4.667	60	60	0	65	65.200	0.308
Cervical	60	61.00	1.667	-	-	-	-	-	-
Thorax	74	75.100	1.486	-	-	-	-	-	-
Abdomen	80	82.700	3.375	80	80.600	0.750	80	81.300	1.625
Head	90	92.300	2.556	100	103.100	3.100	90 100	91.600 102.100	1.780 2.100
Skull	-	-	-	120	120.100	0.083	120	122.200	1.833

3.2 Time accuracy test

The accuracy of exposure time of three x-ray machines were carried out by setting the source to detector at 100 cm for different kV. The exposure time applied to the different organ imaging at two hospitals that ranged 50-125, 172-318 and 40-70 ms, and are presented in the Table 2. The time variation for machine 1 (Shimadzu IEC60601-1-2-2001) varies from 0% to 0.8%, for machine 2 (Shimadzu IEC60601-1-2-2001) it was from 0% to 1.18% and for machine 3 (Shimadzu IEC60601-1-2-2001) it was from 0.5% to 2.29%.

Table 2. The accuracy of time for different kVs of some organ's imaging test of three machines.

Organ	Machine 1 (Shimadzu IEC60601-1-2-2001)		Machine 2 (Shimadzu IEC60601-1-2-2001)		Machine 3 (Shimadzu IEC60601-1-2-2001)	
	Exposure time, measured time (ms)	**Deviation (%)**	**Exposure time, measured time (ms)**	**Deviation (%)**	**Exposure time, measured time (ms)**	**Deviation (%)**
Chest	71.000 71.300	0.420	220.000 220.600	0.270	45.000 45.500*	1.100
Cervical	100.000 100.000	0.000	-	-	-	-
Thorax	50.000 50.400	0.800	-	-	-	-
Abdomen, Pelvis	100.000 100.500	0.500	220.000 220.600	0.273	70.000 71.600	2.290
Head	125.000 125.300	0.240	-	-	40.000 40.200	0.500
Head	-	-	318.000 318.000	0	40.000 39.900	0.250
Skull	-	-	170.000 172.000	1.180	40.000 40.200	0.500

*It was taken at tube voltage of 65 kV.

3.3 Linearity of output as a function of time

All the measurements were performed at fixed exposure time and tube voltage 80 kV. The proportional variation of dose and mA for x-ray machines was checked at fixed exposure time as shown in Table 3. The coefficient of linearity for exposure time is 0.017.

Table 3. Linearity of output as a function of mA at exposure time 100 ms and tube voltage 80 kV.

Mean (kVp)	Tube current (mA)	Measured time (ms)	Air kerma (μGy)	Dose to mA ratio, X	Linearity, L
81.5	160	100.5	646.900±18.111	40.430	0.017
81.6	200	100.8	781.600±21.884	39.080	
81.6	250	100.5	988.800±27.686	39.550	
81.8	320	100.5	1274.000±35.672	39.810	

3.4 Linearity of output as a function of kV

At a constant exposure time and tube current, three exposures were performed with different tube voltages. Table 4 shows the measurement value for the linearity of output as a function of kV.

Table 4. Linearity values of output as a function of kV at fixed exposure time 100 ms and tube current 160 mA.

Tube voltage (kV)	Mean kVp	Air kerma (μGy)
60	60.2	344.7
100	101.9	1001.0
120	121.4	1385.0

3.5 Half Value Layer measurements

It was measured for two machines namely Machine 1 and 4 (Siemens part8375545g2107). The filtration of the x-ray unit for Machine 1 was measured for 40-100 kV,40 mAs and SSD 100 cm. The output dose was measured with a different thickness of Al sheet (1.5, 3, 3.5, 4 mm). Again, the x-ray filtration of Machine 4 was measured for 40-99 kV,10 mAs and source to detector distance was 100 cm. and the output dose was measured for different filter thickness of Al sheet (1.5, 3, 3.5, 4 mm). Then the dose was plotted as a function of thickness for each x-ray unit and the thickness for which the dose reduced to half gave the half value thickness. The thickness of aluminum needed to reduce the intensity of the beam to one half of its original values for Machine 1 and Machine 4 (Figure 2 and Figure 3). From the attenuation curve, HVL values were extracted which is given in Table 5 for Machine 1 and Machine 4 and Compared with the recommended value given by International Electrotechnical Commission 2008 IEC 2008 (Health Canada, 2008) of aluminum for x-ray tube voltages.

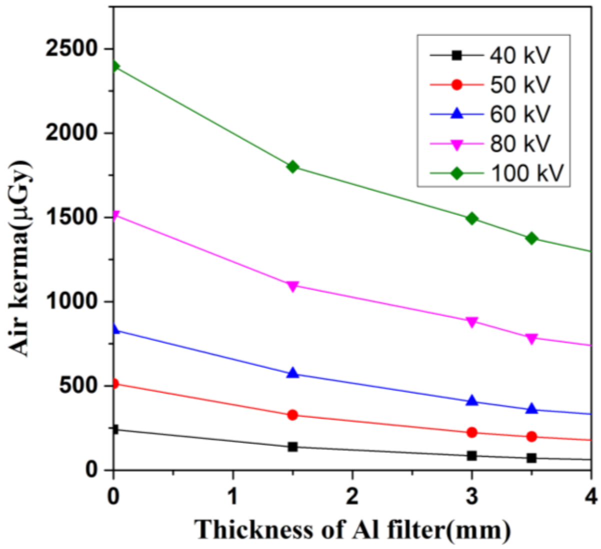

Figure 2. Graphical representation of dose as function of thickness for HVL measurements of Machine 1 (Shimadzu IEC60601-1-2-2001) for 40, 50, 60 80 and 100 kV respectively.

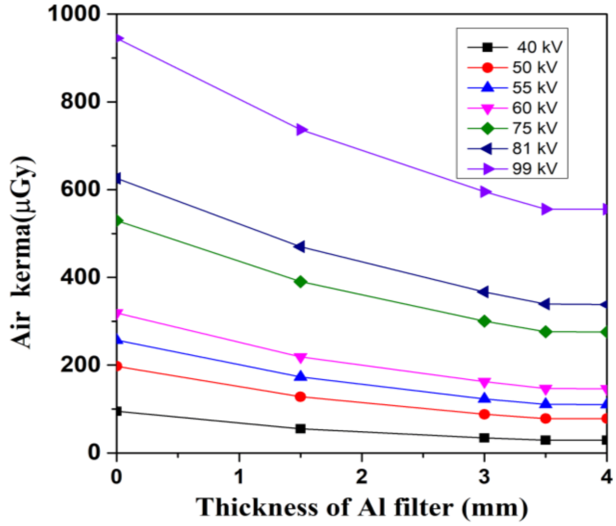

Figure 3. Graphical representation of dose as function of thickness for HVL measurements of Machine 4 (Siemens part8375545g2107) for 40, 50, 55, 60, 75, 81 and 99 kV respectively.

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Table 5. Experimental value of HVL value and comparison with IEC.

Tube potential (kV)	Inherent filtration of 1.5 mm Al filtration, M1 (Shimadzu IEC60601-1-2-2001)	Inherent filtration of 1 mm Al filtration, M4 (Siemens part8375545g2107)	IEC 2008 (Health Canada, 2008)
40	1.89	1.89	1.42
50	2.41	2.52	1.78
55	-	2.85	1.96
60	2.87	3.14	2.14
75	-	3.97	2.68
80	3.81	-	2.90
81	-	4.33	2.90
99	-	5.38	3.55
100	4.68	-	3.60

4. Discussion

During radiological assessment, it is imperative to keep the openness portion low with great picture quality thinking about patients' constitution. Idea of QC assists with diminishing the fluctuation of the same sort of assessments. In this investigation the QC test has a decent concurrence with the suggested acknowledgment levels. In any case, there is a need to take care of the chest x-beam assessment of machine 1 as it is near acknowledgment level. The accuracy of kV is very good for three machines that lie within the acceptable limit ±5% (Ranallo, 1998). Though all the results were good, the deviation was very close to the boundary of the acceptance level at tube voltage 60 kV used for chest and at tube voltage 80 kV used for abdomen in the x-ray machine 1. During time accuracy tests there is higher deviation for abdomen in machine 3 than others. The accuracy of exposure time was found good in agreement with all settings for imaging lying within the tolerance limit ±5% (Ranallo, 1998). The coefficient of linearity for exposure time is 0.017 which does not exceed the recommended value, i.e. it is within the tolerance limit ±5% (International Commission on Radiation Units and Measurements, ICRU Report -51, 1993) which indicates that there is no need to calibrate the machine urgently. From Table 5 it is seen that HVL is not less than the recommended value. For machine 1 with inherent filtration 1.5 mm, the HVL is 2.87 which is slightly close to the value 2.14. The effective energy (keV) can be evaluated by using the established empirical formula which was obtained by the interpolation value from Hubble mass attenuation coefficients (Rahman et al., 2008). The measured half value layer was used in this formula to determine the effective energy for two x-ray machines at two hospitals. Different effective energy corresponds to different HVL for different tube voltages. To evaluate an exposure dose, the effective energy of the x-ray is required for which the measurement of HVL is also needed.

5. Conclusions

The quality control test assumes a significant part to have a decent picture without reiteration of openness. Without appropriate exactness of x-beam boundaries utilized during imaging tests, there is likelihood that the patients and the radiation laborers can have additional portions. Sometimes excessive radiation can create inherent exposure to healthy cells. That is not only dangerous for patients but also for radiation workers (Doctors. Patients, nurse and Medical physicist). In this investigation, the outcomes are inside a worthy breaking point. In spite of the fact that it gives great outcomes, the utilization of new gear will assist with lessening the conveyed portion by utilizing legitimate radiological boundaries. This investigation mirrors not only the current circumstance of utilizing radiography framework in diagnostic radiology but also the safety measurement taken the Government republic of Bangladesh with the Secondary Standard Dosimetry Laboratory, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh.

Acknowledgement

This research work was performed in collaboration with Four Government Medical colleges of Bangladesh in association with Bangladesh Atomic Energy Commission and Department of Physics, University of Chittagong. We acknowledged all team workers of different sectors at Radiology departments.

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