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Quality Control measurements for general X-Ray machine through X-ray meter

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ABSTRACT

The aim of a quality assurance (QA) program is to assist a radio-diagnostic machine to obtaining adequate radiological quality information with a minimum of dose to the subject. An integrated part of a quality assurance program is Quality Control (QC) ascertaining quality by measurements and other procedures. QC in diagnostic radiography begins with production of predictable exposures. In this study the four tests (reproducibility, accuracy of kV, half value layer (HVL) and mAs linearity) were determined by Piranha X ray meter and were carried out for General X-Ray machine at Olaya Medical Complex. The QC tests have been carried out according to the intentional standard reports (AAPM No. 74) and National recommendations of King Abdullah City for Atomic & Renewable Energy. Various safety measures are taken by considering work personnel's safety. Thus, some QC tests were determined using the X-ray meter. For the accomplishment of this study, the tests of tube voltage accuracy and reproducibility, HVL and effective energy, air Kerma and air Kerma rate were performed, with their associated errors calculated. The obtained results were in the acceptable limits. The survey revealed that the QC program was conducted to this X-ray machine at regular intervals. Thus the calibration accuracy results Confirm that, the X-Ray E Machine Result is Pass.

Keywords: Quality Assurance, Quality Control, X-Ray Machine, X-ray meter

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INTRODUCTION

It is well known that medical exposure procedures such as diagnostic radiology, nuclear medicine and radiotherapy remains the largest source of man-made exposure to ionizing radiation and continues to grow substantially. This makes the role of quality assurance (QA), an important tool in medical exposure procedures. Quality Control (QC) tests and procedures for X-ray equipment are designed to verify the mechanical stability of the device and the completeness of the safety mechanisms. QC is part of the QA programmed and quality control techniques used in testing and maintenance of the technical components of an X-ray system. A program of QC is designed to ensure provide optimal image produced through good equipment performance and resulting in minimal patient radiation dose. QC program starts with proper selection of equipment. Then acceptance test for x ray producing and image processing before clinical use. Many factors affect image quality should be evaluated and measured such as milliamperage, scan time, kilovoltages (kVp), field of view (FOV) slice thickness which also play role in quantity of radiation dose [1-3]. The testes must be performed on regular intervals. The results from all tests must be recorded using a consistent format. The tested parameter documented and should indicated within specified guidelines. Responsibility for QA programs are shared between technologists and medical physicists. The radiology QC program for digital radiography equipment, include all parameter shown in Table 1. The objective of such tests, when carried out routinely, allows prompt corrective action to maintain X-ray image quality and minimum dose to patient. This report will demonstrate using piranha X-ray meter as part of tests with some of the X-ray tube QC tests such as kV accuracy, reproducibility, mAs linearity and half value layer (HVL) which were done by the accuracy calibration for maintenance establishment's team [4-7].

Table 1: List of QC test for general X-ray machine that have been carried out in this study.

1	Congruence of radiation and light field	2	Focal spot size
3	Beam alignment	4	Tube voltage accuracy
5	Field size	6	Exposure time accuracy
7	Minimum focus to skin distance	8	Constancy of output µGy/mAs
9	Light Beam Illumination	10	Constancy of kVp
10	Satisfactory operation of the fine density control	11	Constancy of exposure time
12	Tube output Variation of µ**Gy**/mas with kv2	13	Check for image quality
14	Tube output Variation of µ**Gy**/mas with ma	15	Measurements of scatter radiation
16	Tube output Variation of µ**Gy**/mas with time	17	Constancy of film density with kv
18	Measured Leakage Radiation	19	Constancy of film density for various patient thicknesses
20	Total filtration of x ray tube	21	Detector matching
22	Calibration Distance and scale	23	Constancy of film density for all chambers in one AEC

MATERIALS AND METHOD

The measurements were carried out with X-ray model in Table 2. High voltage generator to accelerate electrons from cathode to anode, focal spot size and collimation used to define size and shape of x ray beam are most important parameters for image quality. All in need to determine the quality control tests to tube voltage reproducibility, tube voltage accuracy, mAs linearity and half value layer by specialized tool to obtain measurements [5-7]. All the measurements were carried out using the X-ray QA meter shown in Fig. 1. It is a black piranha system used for quality control X-ray equipment. it can measure mammography, fluoroscopy, computed tomography, and dental X-ray. It is multi-functional QA meter used for most of X-ray QC measurements shown in Fig. 1. The black Piranha is solid state detector and has several properties to measure kV, mAs, calculate and detect wide range of total filtration directly from one exposure. Also, can be used with ion chambers to measure the dose. All tests of machine were done by using black Piranha with distance 100 cm source detector distance.

Table 2: This a list of X-ray machine information

Department /Room	Radiology Department X Ray Room E	Model No.	4803404X1953
Manufacture	Siemens March 2002 Made in Germany	Serial No.	02410
Max/Focus	140kV/ 0.6 mm Al 1 mm Al	Add. Filtration	1 mm Al/70 kV 1.5Al /80
Part No.	Opti 150/30/50 HC-100	Generator	SHIMASDZU

Figure: 1. A photo of the Black Piranha X-ray QA meter. It is a self-contained, multi-functional meter for all X-ray based QA applications, providing easy and fast X-ray quality control. The Piranha along with its range of accessories makes X-ray QA easy and fast because the connection is automatic.

RESULTS AND DISCUSSION

The main Objective of QA for an X-Ray machine is to ensure that minimum possible radiation dose to the patient(s) and optimum image quality of radiological procedures is achieved. It also means systematic actions necessary to provide adequate confidence to the end-user(s) that a medical diagnostic X-ray equipment will perform satisfactorily in compliance with safety standards specified by the Saudi Authority. QA for an X-Ray machine as per the Nuclear and Radiological Regulatory Authority (NRRA) program is mainly carried-out at the acceptance testing after the installation of X-ray equipment at user's institution(s) to ensure its conformity with the specifications i.e. operating license. This part is responsibility of the user. The QA tests should be carried out thereafter at regular intervals (periodicity-once every year) and also after repairs of the equipment or when equipment malfunctions is suspected. This is to ensure that the equipment continues to function as per prescribed standards. It includes many tests. The kVp meter and exposure timer measures the peak x-ray accelerating voltage from tungsten X-ray generators. For measuring peak kV we simply places the instrument in the beam and takes an X-ray. In addition to measuring kVp, the unit also measures the exposure time and displays the x-ray waveform type. Kilovolt Peak (kVp) is the component that controls the quality of the x-ray beam produced. It is also what controls the contrast or gray scale in the produced X-ray film or detector. The higher the kVp, the lower the contrast.

mAs linearity

Milliamperage is the measure of electrical current flowing through circuit. The x ray beam intensity is directly controlled by mA. The Intensity of beam means quantity. mAs is the product ma and exposure time in second and the mA and time are inversely proportional. Measurements should not exceed 0.1.

Coefficient of linearity determined by:

$$\text{Coefficient of linearity} = (\times_{max} - \times_{min} / \times_{mas} + \times_{min})$$

Tube Voltage Accuracy and Reproducibility:

Kilo voltage affects the quantity and quality of x ray reaching the image receptor and the kV Influence the contrast and density of the image. Any variation effect on the image quality.

$$\textbf{Percentage KVp error \%} = (V0 - Vs)/Vs \times 100$$

The reproducibility of kVp output of an X-Ray machine at a given setting should be reproducible when all the other parameters are fixed. Measurements of tube voltage accuracy and reproducibility should be between ±5% kVp.

Half value layer:

The determination of the half value layer of the x-ray beam is the good method for specified quality of the X-Ray beam. Measurement of the HVL gives information on the total filtration in the x-ray beam. Small filtrations give patient unwanted radiation.

Equipment must be appropriate and able to deliver the quality necessary for a particular imaging task at a cost to both patient and hospital. Performance comparisons should be made routinely to assure constancy in the performance of each device as well as consistency between devices. The frequancy with these tests are annually and when machine goes to repair. QC tests have been done according to the intentional standard reports (AAPM No. 74) and National recommendations of King Abdullah City for Atomic & Renewable Energy.

Table 3 : The mAs linearity teat that was performed to determine if the X-ray unit produces the same radiation output linearity for the same kVp and mAs regardless of the mA station used. Thus the kV were set to 81 kV and four exposure where made as shown below.

#	Set mAs (mAs)	Focal spot	Exposure (mGy)	Exposure/mAs (mGy/mAs)
1	10.00	small	0.5091	0.05091
2	20.00	small	1.012	0.05061
3	40.00	Large	2.020	0.05049
4	80.00	Large	4.034	0.05043

mAs linearity

Linearity in radiography is the production of a constant amount of radiation for different combinations of milliamperage and exposure time". In the clinical setting, it is essential that all general x-ray units produce a proportional change in exposure as milliamperage (mA) varies. The assumption is that an increase in mAs, should produce proportional increases in radiation exposure. If the x-ray unit is not properly functioning, the unit must be serviced as retested before used again for diagnostic procedures. Linearity tests are performed to monitor patient dose and image quality. Variation in output intensity during diagnostic exposures can result in unnecessary dose to the patient due to repeats from poor quality images. Measurements were collected by keeping kV and time constant and radiation output with different mA shown in table 3 the set kV was 81 kV. the linearity of mA with exposure represented in Fig. 2 and the Coefficient of linearity are 0.05091 and0.05061 for small focus and 0.05049 and0.05043 for large focus. variation between set mAs and the measured were within limits ±10%.

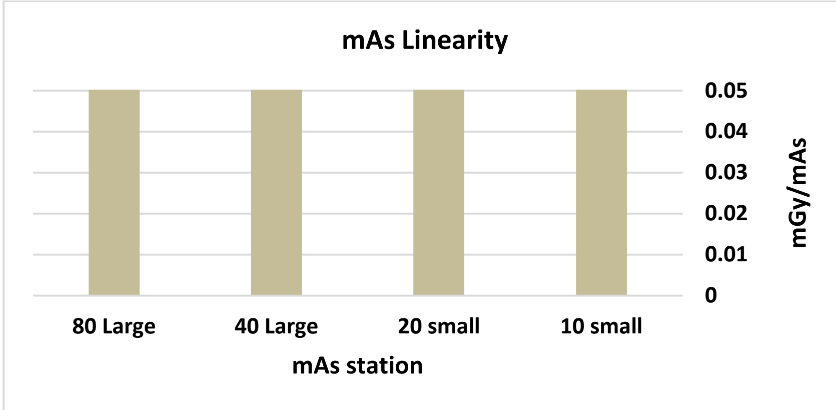

Figure 2: The graph of mAs linearity

Tube voltage accuracy

Kilovolt peak (kVp) is a technical factor set by the technologist when performing X-rays. Its purpose is to set the penetrating power of the X-rays or the quality of the beam. The number set is the highest amount of energy that an X-ray photon could have leaving the tube. The most direct way of measuring kVp is by using a high voltage divider. This invasive test device is connected between the generator and the X-ray tube and provides isolated low level analog voltage signals proportional to the kilovoltage applied across the tube [8]. Such invasive test is not very common. On the other hand electronic, non-invasive kVp devices provide a measurement based on the change in X-ray transmission through varying thicknesses of filtration. These devices are accurate (if properly used) and widely employed for routine quality control due to their ease of use. Accurately calibrated and consistent kVp’s are important in diagnostic imaging to control both optical density and contrast of the X-ray image as well as radiation dose to the patient [9]. Poor kV calibration can increase dose if kV’s too low and can cause poor mA linearity, leading to possible repeats.

Table 4: the non-invasive kVp measurments. Note that most instruments used for such test do not measure true peak voltage, but rather a value that is integrated over exposure time and the ratio of the signals. This value is called effective kV (kVeff) and is lower than the actual kVp

#	Set kV	Tube voltage(kV)	kVp diff%	Exposure (mGy)	Exposure time (ms)
1	50	50.66	1.3	0.1851	16.05
2	60	59.95	-0.1	0.2794	15.55
3	70	69.76	-0.3	0.3839	18.09
4	81	80.36	-0.8	0.5098	21.07
5	90	89.91	-0.3	0.6231	23.60
6	100	98.97	-1.0	0.7515	26.11
7	109	108.03	-0.9	0.8818	28.60

Test was performed 50 kV up to 109 kV tube voltage, at the highest available tube current 20mAs. The voltage, time and the output were noted down to find the accuracy of tube output time and kV. From the values shown in table 4 represent maximum tube voltage inaccuracy is approximatly 1.3% at 50 kV . recommended Variation between set kvp and the measured should be with in ± 5%. the analyses of the values from the differences are shown in Figure 3.

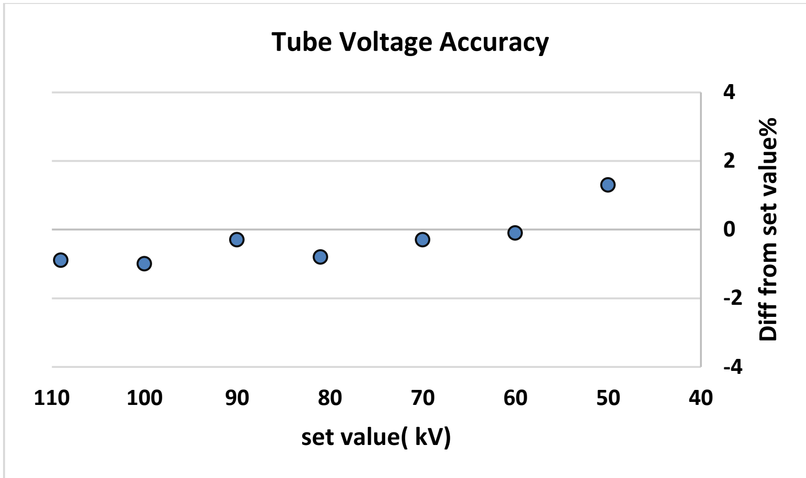

Figure 3: The graph of Set values (kV) vs difference from set values %.

Tube Voltage Reproducibility:

Exposures made at the same kVp and mA stations of the same phantom thickness should produce the same optical density on the resulting image. This is referred to as reproducibility [1, 6].

Table 5: Measurments of kv reproducibility. In this QC test we use a kV of 81 and mAs of 10, and we perform the test three times and in each time we registerd the reading of tube voltage, Exposure and the exposure time.

#	Tube voltage (kV)	Exposure (mGy)	Exposure time (ms)
1	80.60	1.014	42.17
2	80.58	1.015	42.15
3	80.57	1.014	41.67

The machine was set up to 10 mAs. the x ray meter at distance 100cm from source . the kV was set to 81 and noted down the readings of kV. The same procedure was repeated for the voltage of 81 to find the reproducibility of kV. Cofficient of variation is 0.0%. The mean value of is 80.85 the and standerd deviation approximatly 0.02 kV the maximum deviation from mean value is 0.0% . Reproducibility of kV of the machine was 0.0% which is in the limit ± 5%.

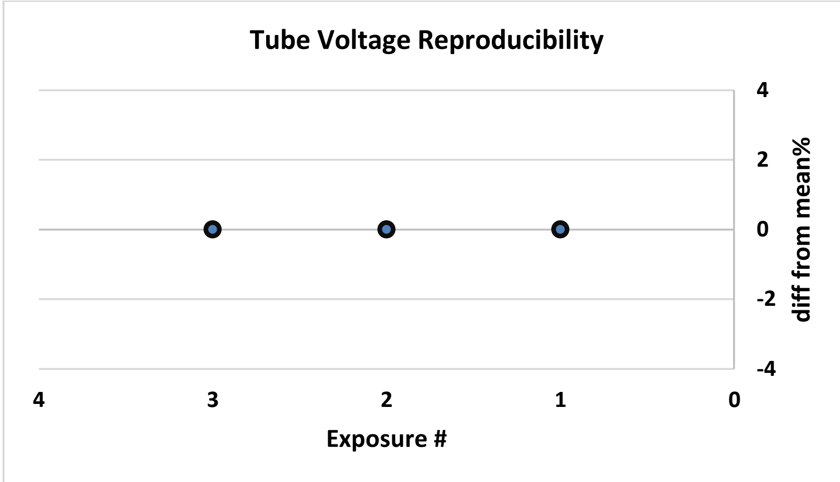

Figure 4: The graph of exposure number vs differance from mean value%

Half Value Layer

Half-value layer (HVL) is the width of a material required to reduce the air Kerma of an X-ray ray to half its original value. This applies to narrow beam geometry only. With broad-beam geometry, a greater amount of scatter will reach the detector, falsely overestimating the degree of attenuation. HVL is commonly used for radiation protection to determine what thickness of a given material is necessary to reduce the exposure rate from a source to some level. At some point in the material, there is a level at which the radiation intensity becomes one half that at the surface of the material. Therefore, determination of the HVL is often used to describe the X-ray beam quality. The HVL of a beam is the thickness of material required to reduce the intensity of an X-ray or gamma-ray beam to one-half of its initial value (2, 3). HVL is an important index of the image quality or radiation risk for example in mammography. Radiation risk of the breast tissue is evaluated with the average glandular dose. The HVL index is indispensable for the average glandular dose computations.

There are different methods for calculating the HVL for instance by determining the attenuation coefficient of a material. This can be found in a table of attenuation coefficient or from the manufacturer of the material. Divide 0.693 by the attenuation coefficient to determine the HVL. In this study the machine was set up to 80.34 kVp and 42.09 mS and the detector was positioned at source detector distance of 100 cm. The reading was taken to find out HVL from one exposure. The Measured HVL is 3.24 mm Al. HVL can be accepted with the given value 2.5 - 3.5 mm Al as shown in table 6. A summary of all the results carried out in this study is shown in table 7.

Table 6: Half value layer measurement

C	Tube voltage (kV)	Exposure time (mS)	Exposure (mGy)	Exposure (mGy/s)	HVL (mm Al)	Total filter (mm Al)
1	80.34	42.09	0.5093	24.14	3.27	3.4

Table 7: Show tests measured in this work. All tests are within limits

Test	Limit	Pass/Fail
mAs linearity	mGy/mAs should be ≤ ±10%	Pass
Kilovoltage Accuracy	Max. Inaccuracy ≤ ±5%	Pass
Kilovoltage Reproducibility	Should be ≤ ±5%	Pass
HVL	Within the limits	Pass

CONCLUSION

Regular implementation of QC program in diagnostic X-ray facilities may affect both image quality and patient radiation dose due to the changes in exposure parameters. The goal of QA in diagnostic radiology is to obtain optimum image quality and minimum patient dose. QC tests should be within limits before clinical use in acceptance test or after repair major components. kV and HVL are important to ensure the beam energy is enough to produce good image quality with small amount of soft tissue dosage. Solid state black piranha can measure several important parameters, Tube voltage kV reproducibility, Tube Voltage kV Accuracy, mAs linearity and half value layer. All these QC tests fulfill and done with requirements.

REFERENCES

1. AL-Jasim, A. K., Hulugalle, S. N. C. W. M. P. S. K., & Al-Hamadani, H. K. (2017). A quality control test for general X-ray machine. World Scientific News, 90, 11-30.
2. Gray L, Dowling A, Gallagher A. et al. Acceptance testing and routine quality control in general radiography: mobile units and film/screen fixed systems. Rad Protec Dosimetry, 2008, 129(1/3): 276–78
3. Huda W, Nickoloff EL, Boone JM. Overview of patients dosimetry in diagnostic radiology in the USA for the past 50years. Med Phys. 2008, 35(12), 5713–28
4. K. A. Jessen, P. C. Shrimpton, J. Geleijns, W. Panzer, and G. Tosi, Dosimetry for optimization of patient protection in computed tomography, Applied Radiation and Isotopes, vol. 50, no. 1, pp. 165–172, 1999
5. Sonawane, A. U., Singh, M., Kumar, J. S., Kulkarni, A., Shirva, V. K., & Pradhan, A. S. (2010). Radiological safety status and quality assurance audit of medical X-ray diagnostic installations in India. Journal of Medical Physics/Association of Medical Physicists of India, 35(4), 229.
6. Tompe, A., & Sargar, K. (2020). X-Ray Image Quality Assurance. StatPearls [Internet].
7. Wilbroad E. Muhogora, Nada A. Ahmed, Aziz Almosabihi, Jamila S. Alsuwaidi, Adnan Beganovic, Ciraj-Bjelac Olivera, et al. Patient doses in radiographic examinations in 12

countries in Asia, Africa, and Eastern Europe: initial results from IAEA projects. AJR American Journal of Roentgenology, 190 (6) (2008), pp. 1453-1461.

8. IEC 60601-1-3 “Medical electrical equipment –Part 1-3: General requirements for basic safety and essential performance –Collateral Standard: Radiation protection in diagnostic X-ray equipment” 2013-04.
9. IEC 61676 “Medical electrical equipment – Dosimetric instruments used for non-invasive measurement of X-ray tube voltage in diagnostic radiology” 2009. Annexe B.