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Full Length Research Paper

Study the quality assurance of conventional x-ray machines at medical city in Baghdad

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Abstract

The primary goal of a radiology quality assurance (QA) program is to ensure adequate clinical diagnostic information and low dose (ALARA principle). This can be achieved by optimum operating parameters such as kVp (peak voltage the highest kilo voltage used in producing a radiograph), Entrance skin dose ESD, linearity of tube current and exposure time and beam quality assess of x-ray machine. Six conventional X-ray instruments in medical city at Baghdad from different origins and different manufacturing time. Protocol for QA was perform to measure different parameter such as patient entrance surface dose air kerma ESD, reproducibility of peak tube voltage, linearity of tube current, linearity of exposure time, and the filtration. The mean (ESD) were measured for different organ using (Dosimax), (Unfors) ionization chamber and thermoluminance dosimeter (TLD). (TLD) reading was higher than average value of ionization chamber because the scattering of radiation inpatient body, the scattering coefficient were range between (1.1 – 1.05). The voltage stability for the machine were tested for three machines (A, B, and C) and found the percentage of voltage ripple to machine (B and C) is (3.79) and (4.856) respectively and for machines A was 11.4. The Linearity of current and exposure time exposure were assess, and found that this relationship is linear for the machines (B and C) but not for the machine (A). Half Value Layer (HVL) test for the three machines was measured.

Keywords: QA, diagnostic x-ray, kVp, current linearity

INTRODUCTION

X-ray diagnostic examinations are one of the main exposure to public from man-made ionizing radiation is the medical application specially X-ray diagnostic examinations. UNSCEAR (2000) was reported that the contribution of the radiation dose due to all diagnostic procedure is 80-90% of the total dose due to manmade radiation sources.

Implementation (QA) programs are important factors for justification and optimization of medical exposures radiation safety.

Donabedian (1988) define the quality of care in medicine as" that kind of care which expected to maximize an inclusive measure of patient welfare, after one has taken account of the balance of expected gains and losses that attend the process of care in all parts".

X-ray images must meet a certain level of quality, to minimize errors of interpretation and allowing an accurate diagnosis with low radiation dose. Bad quality image causes the repetition of imaging, duplication of radiation dose to the patient, and additional costs. Procedures and QA based on the IAEA Basic Safety Standards (BSS)

(1996). Many workers investigate important parameters in diagnostic x-ray such as linearity of exposure time and tube current, reproducibility of peak tube potential, and beam quality.

Gaetano Compagnone et al., (2005) measure (ESD) for assessing the dose received by a patient in a single radiographic exposure by direct measurement on six phantoms using an ionization chamber or calculations based on a mathematical model. The mathematical model can be satisfactorily in ESD evaluations because it optimizes available resources, it is based on direct measurements, and it is an easy dynamic tool.

J.Bosnjaket.al (2008) has been systematically performed quality control surveys for diagnostics x-ray in Republic of Srpskafor 92 radiology depart-ments. The results showed the improvements in the implementation of the QC programme within the period 2001-2005.

Muhogora et al., (2008) assess Image quality and patient radiation doses in 12 countries in Africa, Asia, and Eastern Europe, covering 45 hospitals. There were high rate of unsatisfactory images and image quality grade, which causes poor image quality. The image quality improved up to 16 percentage points in Africa, 13 in Asia, and 22 in Eastern Europe after implementation of a quality control (QC) program. The ESD for adult patients were determined and compared with diagnostic reference levels. The majority of doses were below diagnostic reference levels.

Maria Lucia Nana I Ebisawa et al., (2009) analyses (QA) of x-ray equipment at Brazil, over a seven-year period. A significant improvement was found in the percentage of acceptance of the overall parameters described in the QA technical reports over this period.

Sonawane et al., (2010) conducted (QA) measurements of 118 medical X-ray diagnostic machines in India hospitals. The measurements conduct to check accuracy of kVp, tube current linearity. The measurements showed that the accuracy of kVp calibration was (23%), nonlinearity of mA station (16%) and timer (9%). The study contributes significantly to the improvement of radiological safety.

MATERIAL AND METHOD

Six conventional X-ray instruments in the medical city of Baghdad from different origins and different manufacturing time. A group of patients are selected for each examination. The aim was to investigate some factors affecting quality assurance of conventional X-ray such as ESD, reproducibility of peak tube voltage, linearity of mAs and the filtration.

The patient entrance surface dose air kerma is the quantity currently recommended for patient dose assessment and for comparing patient dose levels with diagnostic reference levels in general radiography were measured for most common radiographic projections, chest PA and LAT, lumbar spine AP and LAT; abdomen, AP, skull LAT and head AP. ESD were measured by three methods**:**

1- (Dosimax) ionization chamber Germany made.
2- (Unfors) ionization chamber Sweden made.

Both of ionization chamber was connected to an electrometer and placed on phantom of tissue equivalent, and put on a low scattering material (polystyrene) on a patient support setup in the vertical position.

3- TLD. Which is small, easy to fix on the patient's skin without any interfere with diagnostic information.

Ionization chambers and TLD was positioned in the central beam axis of x-ray, the tube focal spot-detector distance of 100 cm. A radiographic exposure was made and the dosimeter reading recorded, this step was repeated three times at the same settings and the average dosimeter reading determined.

The main goals to measure ESD are to assess the radiation risk from a particular examination, and ensure that the patient doses agree with ICRP standards.

RMI multifunction meter model 240 that use four balanced ionization chamber to assess effective peak voltage (kVp), exposure time (s), and the current (mA) or exposure (mAs).To measure these parameters RMI was placed on the patient couch at 100 cm of x-ray target.

Linearity of mA and s are assessed by plotting mA and s as function of ESD.

Half value layers (HVL) which is the thickness that is able to prevent the hazard of soft x-ray, by reducing the surface doses during x-ray imaging were measured. ESD as function of Aluminum thickness added were plotted for three x-ray instruments

RESULTS

Dose measurements

Entrance surface dose for six x-ray machines and for some patients were presented in Table 1.The value measured by thermoluminescence dosimeter (TLD) greater than average value measured by the ionization chambers because the radiation scattering by patient's body. The ESD doses were compared with reference level values recommended by IAEA (1996).

Peak tube voltage (kVp) constancy

Reproducibility of tube voltage setting was examined for each tube. The kVp measured by multifunction meter detector (RMI-240) as the average value for three exposures and this value compare to nominal value. The voltages ripple (R) which is defined as the amount of

Table 1. Patients ESD from six x-ray machine for different organ

Tube	Company	Exam	Projection	Patents No	Entrance Surface Air Kerma (mGy) TLD	Entrance Surface Air Kerma (mGy) Average of Unf + Dosmax	Scatter coefficients	IAEA ESD
A	Siemens 1980	abdomen	AP	8	18.1± 1.2	16.9 ± 1.6	1.07	10
		Lumbar spine	LAT	5	49.9± 1.3	45.4± 2	1.1	30
		Head	AP	5	8.2 ± 0.6	7.8± 0.4	1.05	5
		skull	LAT	10	3.39 ± 0.2	3.2 ± 0.17	1.06	3
B	Sedecal 2004	Chest	PA	10	0.51 ± 0.2	0.47 ± 0.3	1.08	0.4
		Head	AP	5	5.14 ± 0.5	4.8 ± 0.7	1.07	5
		Lumbar spine	LAT	5	34.8± 1.2	32.2 ± 2.1	1.08	30
		abdomen	AP	5	11.8± 1	11.1± 1.2	1.06	10
C	Toshiba 1995	Chest	PA	10	0.53± 0.2	0.5± 0.3	1.07	0.4
		Head	AP	10	4.03 ± 0.6	3.8 ± 0. 5	1.06	3
		Lumbar spine	LAT	10	35.6± 1.2	33 ± 1.2	1.08	30
		abdomen	AP	10	12.4 ± 0.6	11.5 ± 0.6	1.08	10
D	Phillips 1989	Chest	LAT	10	1.73 ± 0.5	1.6 ± 0.15	1.05	1.5
			PA	10	0.64± 0.1	0.6± 0.01	1.06	0.4
E	Siemens 1985	Lumbar spine	AP	10	13.7 ± 1	12.7 ± 1.1	1.08	10
			LAT	10	36.4± 1.3	34 ± 1.2	1.07	30
F	Siemens 1995	Lumbar spine	LAT	8	35.97 ± 2	33± 3.5	1.09	30
			AP	8	13.3± 0.8	12.2± 1.5	1.09	10

AP = anteroposterior; LAT = lateral; PA = posteroanterior

Table 2. Percentage of voltages ripple (R) for three x-ray tube

mA= 100 exposure time= 0.1s Focus to Detector Distance=100cm							
Tube A			Tube B		Tube c		
Nominal kVp(X_{mi}	Measure kVp (X_{max})	Voltage ripple %	Measured kVp	Voltage ripple %	Nominak Vp (X_{mi})	Measured kVp (X_{max})	Voltage ripple%
40	43± 0.06	6.98	43± 0.008	6.9	50	54± 0.01	7.4
50	55± 0.07	9.1	53± 0.01	5.6	60	62± 0.02	3.2
60	66± 0.07	9.0	62± 0.02	3.2	70	73± 0.03	4.1
70	74± 0.08	5.4	72± 0.03	2.7	80	82± 0.04	3.0
80	87± 0.08	8.1	83± 0.04	3.6	90	94± 0.04	4.2
90	96± 0.09	6.2	93± 0.04	3.3	100	103± 0.05	2.9
mA= 200 exposure time= 0.1s Focus to Detector Distance=100cm							
Tube A			**Tube B**		**Tube C**		
Nominal kVp(X_{mi}	Measure kVp (X_{max})	Voltage ripple %	Measured kVp(X_{max})	Voltage ripple %	Nominak Vp(X_{mi})	MeasurekV p(X_{max})	Voltage ripple %
40	45± 0.06	11	41± 0.007	3.6	50	55± 0.01	9.0
50	61± 0.07	18	52± 0.01	3.8	60	62± 0.02	3.2
60	76± 0.07	21	62± 0.02	3.2	70	75± 0.03	6.6
70	84 ± 0.08	16	73± 0.03	2.7	80	83± 0.04	3.6
80	92± 0.08	13	83± 0.04	3.6	90	96 ± 0.04	6.2
90	100± 0.09	10	93± 0.04	3.3	100	103 ± 0.05	4.8
	Average	=11.4	Average	=3.79		Average =4.85	

Table 3. The coefficient of linearity for tube current

Tube	kVp	Average D_{max}	$(mAs)_{max}$	$(D/mAs)_{max}$	Average D_{min}	$(mAs)_{min}$	$(D/mAs)_{max}$	CL
A	70	19.067	50	0.381	1.746	5	0.349	0.128
	90	18.407	50	0.368	2.397	5	0.479	0.165
B	70	14.43	50	0.289	2.63	10	0.263	0.047
	90	13.7	50	0.274	2.323	10	0.232	0.083
C	70	8.703	20	0.435	1.9	5	038	0.067
	90	7.89	20	0.349	1.643	5	0.329	0.029

Table 4. The coefficient of linearity for exposure time

kVp=70	mA = 30		distance = 100		
Tube	**Time(s)**	**mAs**	**D**	**D/mAs**	**CL**
A	0.1	3	0.735	0.245	0.360
	0.5	15	7.82	0.521	
B	0.1	3	1.356	0.452	0.0087
	0.5	15	6.9	0.460	
C	0.1	3	1.065	0.355	0.05
	0.5	15	5.88	0.392	

Table 5. QA test for the three machines under investigation

Test	Machine A	Machine B	Machine C	Recommended values
kVp% reproducibility	11.4	3.79	4.85	10%
Coefficient of current linearity	0.14	0.065	0.048	0.1
Coefficient of time linearity	0.36	0.0087	0.05	0.1
HVL	0.36	2.6	2.8	≤2.3

variation in the applied of X-ray machine voltage waveform relative to peak voltage during X-ray production is expressed by the equation:

$$R = \frac{Xmax - Xnin}{Xmax} x100\%$$

Where: Xmax is the measured value of voltage (kVp), and Xmin is the nominal value of voltage (kVp). The voltage ripple (R) for voltages for 3–phase-12-puls to X-ray machine in this study are presented in Table 2 which were its average values range between 3.79% -11.4 %.

Linearity of tube current (mA) and time (s) as function of (ESD)

The important factor in QA measurements was linearity of mA, and time as function of ESD since these factors effects the patient dose and image contrast. The average ratio of ESD (in mGy) to mAs at any two consecutive tube current settings must not differ by more than 0.10 times their sum. The linearity of exposure time as function of ESD can be assess by choosing fixed value of x-ray tube peak voltage and fixed tube current. The coefficient of linearity is given by:

$$|(D/X)_1 - (D/X)_2| \leq 0.\ 1(D/X)_1 + (D/X)_2$$

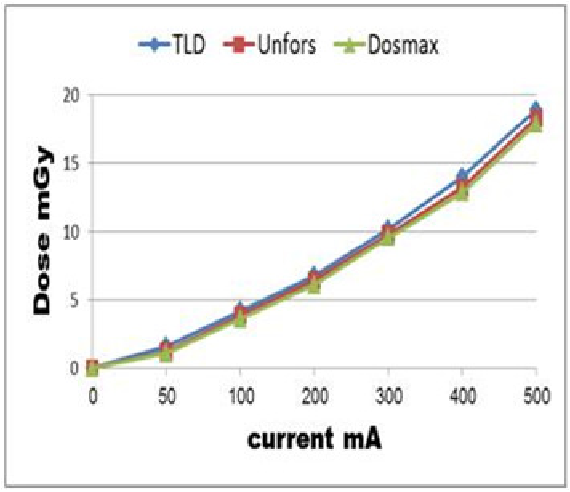
$$\text{Cofficient of linearity(CL)} = \frac{(D/X)\text{max} - (D/X)\text{min}}{(D/X)\text{max} + (D/X)\text{min}} < 0.1$$

Where:

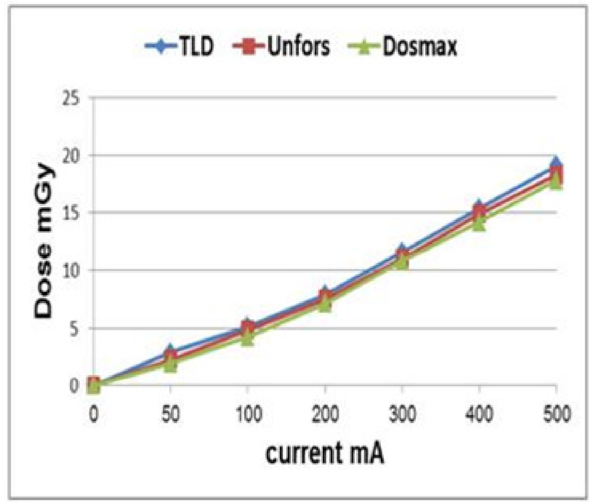
D: Entrance Surface Air Kerma (ESD) values based on 10 exposures at each of two consecutive x-ray tube current settings.

X: exposure (mAs) .

Extensive measurements were made to assess of changes in mA, s, and mAs as function of (ESD) on linearity of radiation output. (ESD) were measured for selected x-ray machine using two calibrated ionization chamber Unfors and Dosimax and (TLD), at different values of peak voltage (KVp).All measurements were performed at fixed distance from x-ray tube target (100cm) , fixed mA (100 mA) and fixed exposure time. The linearity was checked by calculating the coefficient of linearity (CL) using the above equation, the results showed in Table 3 for mA linearity and Table 4. Another way to assess the linearity is to plot mAs on x-axis as

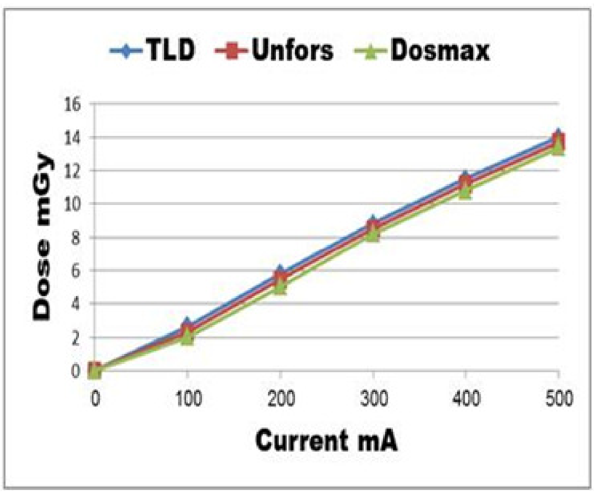


Tube A kVp=90



Tube A kVp=70

Figure 1. Current linearity mA as function of Dose at time =0.1s



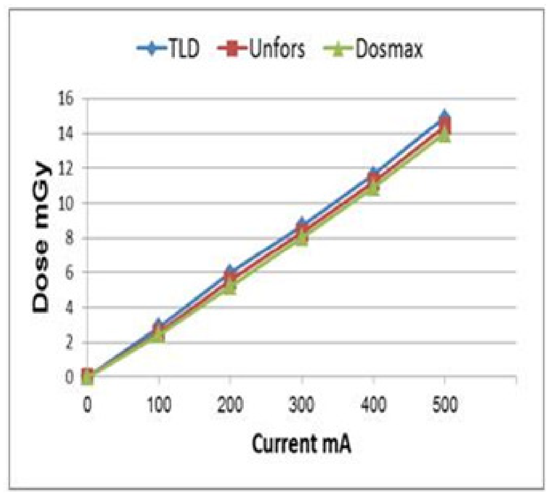
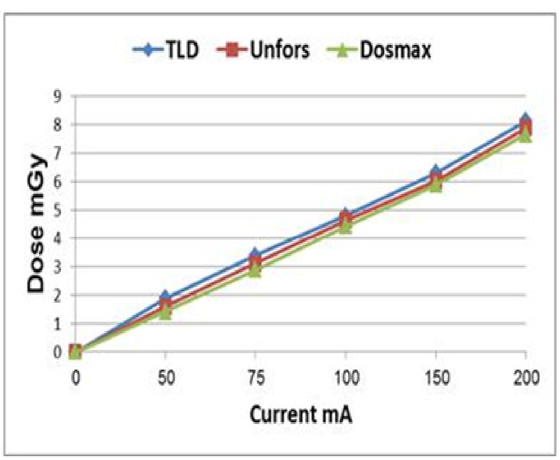
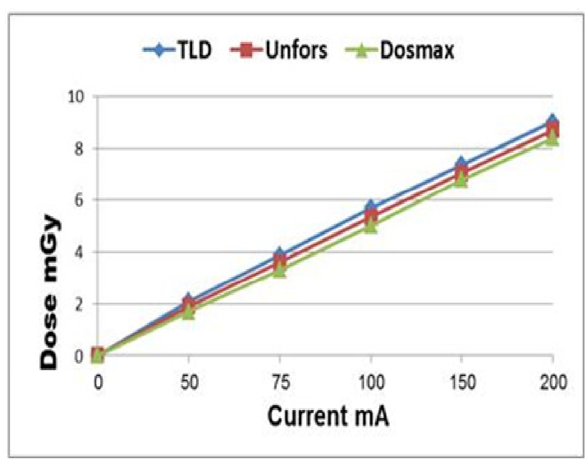


Figure 2. Exposure time linearity **Tube B kVp= 90 Tube BkVp=70**





Tube CkVp= 90Tube CkVp= 70

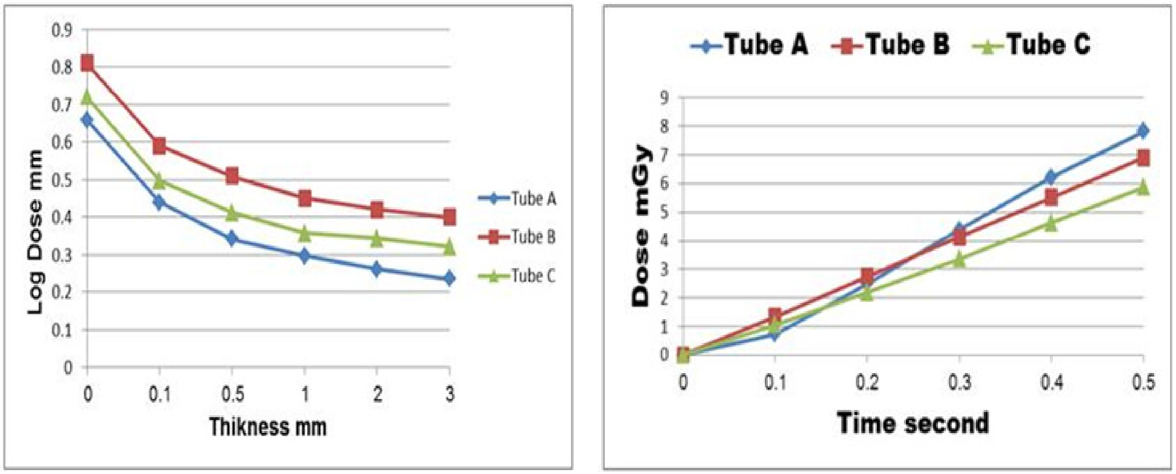


Figure 3. Log dose as function of thickness for HVL measurements

function of ESD on y-axis to get visual assessment of linearity Fig (1) for mA linearity and Fig (2) for exposure time(s) linearity.

Half-Value Layer (HVL) measurements

Half-value layer is defined as the thickness of the absorption material required to reduce the exposure value to half of its original value and determines the mean beam energy value (beam quality). Filtration of x-ray machine was measured at 70 KVp, 30 mAs, and source to detector distance 100 cm. The dose output was measured using Unfors ionization chamber. The output dose was measured with different thickness of Al sheet (0, 0.1, 0.5, 1, 2, 3,).

The patient dose (log scale) was plotted as function of thickness (linear scale) for each x-ray machine, and the thickness which gave half doses is considered as the half value thickness .The thickness of aluminum required to reduce the intensity of a beam to one half its original values HVL were (0.5, 2.6, and 2.8) for tube A, B, and C respectively.

DISCUSSION

1- The scattering coefficient which is the ratio between TLD reading and the average of dose are measured by the two ionization chamber were calculated and found to be range between (1.1 – 1.05) and this value is very close to international values which equal to (1.09) .

2- The ESD doses were compared with reference level values recommended by IAEA, It is found that the measured values were greater than recommended values for most x-ray machine, because the QA program in diagnostic radiology were not conducted in Iraqi medical hospital since 2003 due to many reasons, the most important one was the American invention which destroy the infrastructure of health on other hand most educated staff doctors and skill staff either killed or leave Iraq ,most of the adequate measuring equipment either destroyed or stolen, absence of obligatory legal acts, poor financial situation in health care system and many others. Thus the author and his post graduate students try to implemented QA program at the beginning of 2006 in diagnostic radiology departments at medical city in Baghdad in order to harmonize the good practice with other countries in the region.

3- The average voltage ripple (R) of kVp voltages for 3 –phase-12-puls in this study were 3.79% and 4.85 for to X-ray machine B and C respectively which is within typical voltage ripple values (3-10%), but for machine A its value 11.4% which is greater than the recommended upper limit.

4-The average coefficient of linearity for tube current for the machine B and C were 0.065 and 0.048 respectively which is not exceed the recommended value 0.1, but for machine A average coefficient of linearity value 0.147% which is greater than the recommended value (0.1).The plot of tube current as function of dose was linear.

The coefficient of linearity for exposer time for the machine B, and C were 0.0087 and 0.05respectively which is not exceed the recommended value 0.1, but for machine A coefficient exposer time of linearity value 0.36% which is greater than the recommended value (0.1).The plot of tube current or exposure time as function of dose was linear.

6- The thickness of aluminum required to reduce the intensity of a beam to one half its original values HVL were (2.6, 2.8) for tube A, B, and C respectively. HVL is exceeding the minimum value, passed above 2.3 mm Al at 70 KeV. This is within the accepted value of IAEA, but

HVL for machine A was 0.5 which less than the recommended value.

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