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Study the Factors Affecting the Quality Assurance of Superficial RadiotherapyX-RayMachine

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Abstract: ***The aim of this study was to analyze factors influencing the quality assurance of superficial radiotherapy X-raymachine such as dose output reproducibility, linearity, kV accuracy, time accuracy. Moreover the entrance skin dose for hand, face and nose using Perspex phantom was measured. We measured these factors and entrance skin doses using Unidose master connected with 0.2 cc soft X-Ray Chamber type 23342, which was placed above a Perspex phantom inside the chosen field size of used applicator on the couch.The reproducibility of dose output was 0.17%, the kilo voltage accuracy percentage and time accuracy percentage were ranged from .38 to 0.87 % and -0.96 to 3.4 % respectively. Linearity of radiotherapy X-ray machine was 0.02which lower than the tolerance limit of the American Association of physicist in Medicine reference value, the limit specified in the academic literature and international publications. The relative error for entrance skin dose equals 3%. The entrance skin doses for face, nose and hand were 56.68 ± 0.307, 241.2 ± 2.15 and 60.52 ± 0.104 mGy respectively. The tests for the quality assurance of superficial radiotherapy X-ray machine was compared and assessed with the international tolerance.***

Keywords: Quality Assurance, Unidose, 0.2 cc Soft X-Ray Chamber

1. Introduction

Superficial kilovoltage X-rays have a lot of applications in radiotherapy , such as treatment of basal or squamous cell carcinomas of the skin and the palliative irradiations of bone metastases (Evans, 2001). Perfet quantity of dose delivered during superficial X-ray radiotherapy is recquired for patient dose evaluation (Ismail, 2011).The main objective of the assurance of quality of superficial X-ray machine is to get timely and accurate assessment. A supplementary objective is the maximization of the exposure of radiation and getting high radiation quality. The assessment can be made through the performance of the X-ray machine by using optimum operating parameters. These include dose output reproducibility, linearity,entrance dose measurements according to code safe practices for using X-ray in medical diagnosis (NRL, 1994).

Many associations reported their efforts related to quality assurance of superficial X-ray machine such as(AAPM, 2008) and (AAPM, 1995)that describes the protocol for the assurance of quality for superficial radiotherapy X-ray equipment at the level of therapeutic technologist.AAPM(AAPM, 2001) has introduced a new protocol. The protocol was introduced by Task Group 61 of the Radiation Therapy Committee. It was presented for reference dosimetry of medium and low energy X-rays for radiobiology and radiotherapy (for tube potential between 40 kV and 300 kV). The protocol is found on ionization chambers that were regulated in air with respect to air kerma(AAPM, 2001) and (Austerlitz *et al.*, 2008) mentioned that differences presented through the beam outputs had a range between -13% to +25%. (Mehran *et al.*, 2010) mentioned that the assessed output exhibited an increase that was up to 7.3% in comparison to the neutral position. The neutral position is given as 0° cross-plane and 0°in-plane. The probable range of angles are given for in-plane rotation for the value of 75 kVp (HVL (half-value layer) = 1.84 mm Al)(Mehran *et al.*, 2010).

There is a wide use of Kilovoltage X-ray therapy in superficial cancers. The treatment results are highly affected by equipment calibration and radiation prescription. It is recommended to use a quality control protocol. It results in the proper performance of the machine during operation. There are several key control parameters in this respect. These parameters are used in superficial X-ray units and orthovoltage. The parameters include output constancy, beam symmetry, beam quality, integrity and identification of filters, linearity and timer accuracy, and filter interlocks. For monitoring the stability of machine output, a constancy check is performed for assistance. The check ensures the accurate delivery of intended prescribed dose. In addition to checking the accuracy of dose, the check assists in monitoring the performance of the machine by physicists. Through this monitoring, corrective measures are taken for addressing the deviations from the predefined action levels. Currently, there are no specific recommendations for ensuring the constancy of the output. The output should have constancy in different positions of the X-ray tube. The positions include tube head rotation that is termed as rotation. Another position is head title that is termed as in-plane. These positions are provided by the common dosimetry protocols. The protocols provide standards for superficial X-rays and orthovoltage. The treatment of the patients is made in such a way that the orientation of the X-ray unit is aimed towards patient comfort. The unit is aimed to keeping normal incidence and eliminating unneeded stand-off between the cone and the patient. The dependency of the output on tube head rotation and tube head tilt is a crucial issue. There is a lack of academic literature on the issue of the output dependency of the kilovoltage radiotherapy unit in relation to tube head rotation(Mehran *et al.*, 2010).

Modern research shows that there is a successful and continued use of kilovoltage X-ray units. They are being used for superficial therapy. The units have varied designs in comparison to linear accelerators. It shows the need for particular advice for such equipment. Other scholars who have provided guidelines for quality control of kilo-voltage units include (Klevenhagen *et al.*, 1996)mentioned that the system interlocks, applicator, and dose monitor performance that are used in checking of Gulmay D3300 kilovoltage X-ray therapy unit met the requirements. The leakage of the tube was less than the UK recommended standard of maximum. The standard mentions air kerma rate at 5 cm from the tube head to be 300 mGy/h. The quality assurance of therapeutic X-ray is founded on the standard of safety known as in safety series (ICRP,SS-115, 1994). It is also based on the standards of International Commission of Radiological Protection. These standards mention that there is no limit for the medical-related exposure but they emphasize on ensuring that medical-related exposure has to be decided in consultation between professional bodies and medical authorities.

This paper aims to analyze factors influencing the quality assurance of superficial radiotherapy X-ray such as dose output reproducibility, linearity,Kv accuracy, time accuracy and measurements of entrance skin dose for hand, face and nose.

2. Material and Method

The Xstrahl superficial X-ray machine was investigated for some factors of quality assurance such as reproducibility and linearity. Reproducibility is one component of the precision of a test and reported as a standard deviation. Reproducibility of dose output of Xstrahl machine was measured with unidose dosemeter connected with 0.2 soft X-ray chamber , which was placed inside the chosen field on the couch and contacted with an applicator to avoid any air gap inside a field size and five exposures were made. The measurements were carried out using same operating condition such as 50kV, 90mAs, 5mA and 6 sec. The reproducibility P_z was calculated based on New Zealand Radiation Laboratory, NRL protocol (Plotti, 1995) and (FDA,1999).

$$\boldsymbol{P_z = \frac{SD}{Z_{av}} \times 100\%}$$

Where: *SD* defines standard deviation of a range of measurements dose denoted by [mGy], Z_{av} is the average value of the assessed dose [dose is denoted by mGy]. Extensive measurements were carried out for the assessment of changes in mAs on linearity and reproducibility of the output of radiation. It developed over a series of clinical settings. Calibrated ionization chamber is utilized for the measurement of output denoted by µGy per mAs, without backscatter, at a distance set in advance.

Linearity

The linearity of superficial X-ray machine was studied using farmer dose master that connected with 0.2 cc soft X-ray chamber above Perspex phantom.The linearity was checked using the next equation that was stated by New Zealand Radiation Laboratory, NRL protocol (Plotti, 1995) and (FDA,1999).

$$\frac{|X_1 - X_2|}{X_1 + X_2} < 0.1$$

Where X_1 and X_2 are two successive readings.

ApplicationsofSuperficial X-rayMachine

Xstrahl 150 X-ray system low energy X-ray for treatment a wide range of superficial dermatological condition including: Squamous cell carcinoma, basal cell carcinoma, and dermatological conditions. Dermatological conditions also include psoriasis. Orthovoltage unitsare still in use today for the treatment of superficial lesions. The truth of the matter is that these were on ground the only machines for the treatment of skin lesions before electron therapy was introduced in recent years. The X-ray tube of the Xstrahl machine was located in middle of the room surrounded by one meter from each side. The focus to skin distance, FSD for each applicator under use was adjusted for surface radiotherapytreatment such as hand, face and nose of tissue equivalent phantom. The Ionization chamber was adjusted for operating conditions of the X-ray machine as filter 1, 50 kV, 5 mA, 0.2 min, and 0.2 mm Al for different applicators.

Surface radiotherapy dose for PMMAhandsequivalent was measured using applicator for hand treatment for 5 cm diameter and focus to skin distance, FSD and PMMA phantom.Surface radiotherapy dose for face and nose of skull phantom were conducted using suitable applicator for each case. Theapplicator for face treatment was 3 cm diameter and 15 FSD andthe applicator for nose treatment was 1.5 cm diameter, 15 FSD.

3. Results and Discussions

Reproducibility

Dose reproducibility for repeated doses of Entrance Skin Dose (ESD) was measured using unidose meter connected with 0.2 Soft X-Ray Chambers ionization chamber on the surface of Perspex phantom as shown in table (1).The operating condition of superficial radiotherapy machine where using 50 kV, 60 mAs, 5 mA, 0.20 min, 12 sectreatment time at focus to skin distance, (FSD), 50 cm .In the present work the maximum value was 60.60 mGy, the minimum value was 60.4 mGy and mean doses and standard deviation of the measurements was 60.52 ± 0.104. The machine reproducibility was found to be 0.17% which is lower than the tolerance limit of 5% as mentioned in New Zealand Radiation Laboratory, NRL protocol (Plotti, 1995).

Table 1: The Dose reproducibility for superficial radiotherapy machine.

Run No.	*Dose (mGy)* *0.2 Soft X-Ray Chambers*
1	60.60
2	60.40
4	60.45
5	60.50
6	60.65
Mean ± Standard Deviation	60.52 ± 0.104

Linearity ofX-ray Machine

Linearity of X-ray X-Strahl machine in physics department -umm alqura university was measured using unidose meter connected with 0.2 Soft X-Ray Chambers ionization chamber on the surface of Perspex phantom as shown in table (2). It studied at X-ray operating conditions of 81 kV, source to image detector 50 cm and exposure time ranged from 12 to 30 sec and coefficient of variation presented as shown in tables 2. The mille-amper second was changed from 30-120 mAs and the corresponding dose in mGy was measured using soft X ray chamber connected with unidose.

The dose output was measured as a function in milliampere second. These measurements were recorded at 50 cm source to detect distance using special applicator of diameter 25 × 25 cm^2as shown in Table(2). The linearity of the superficial X-ray machine was given a result of 0.02 which lower than0.1 that means it is lower than the tolerance level of the American Association of physics inMedicine (AAPM, 1995)and New ZealandRadiation Laboratory, NRL protocol (Plotti, 1995). Linearity was accepted that means the X-ray tube of a machine is calibrated. In addition within the range of research work published by (Ismail, 2011).

Table 2: Linearity of Superficial X-ray Machine

Setting	Time (sec)	mAs	Dose (mGy)	Dose output mGy/mAs
50 kV,5mA, 0.2 mmAl	6	30	28.76	0.95
	12	60	58.1	0.96
	18	90	88.5	0.98
	24	120	119.6	0.99

Kilo Voltage Accuracy

kV accuracy of X-Strahl superficial X-ray machine in physics department of umm alqura university was calculated from assigned and backup kilovoltage as shown in table 3 and the percentage errors were presented as shown in table (3).

Table 3: kVp Accuracy for X-Strahl X-ray machine in UQU.

Machine setting			
SID= 100 cm		60 mAs	
kVp Accuracy			
kVp Set	KVpavg	kVp % Error	P/F
50	50.05	0.10	P
60	60.23	0.38	P
70	70.61	0.87	P
80	80.78	0.98	P
90	90.4	0.44	P

P/F: Pass/Fail

Kilo-voltage Accuracy of X-Strahlsuperficial X-ray machine in UQU was range from 0.38to 0.87 % . It was lower than 5% kV accuracy acceptance tolerance limit of the American Association of Physicist in Medicine recommendation (AAPM,1990) and (J.L.1995). kVp accuracy was good at all kVp stations. The obtained results were close to the data set published by (Taha.M.T, 2015) and (H.A.Ismail, 2015). In addition within the range of research work published by (Ismail, 2011).

Time Accuracy

Time accuracy of X-Strahl superficial X-ray machine in physics department of umm Alqura University was studied for wide exposure time as shown in tables (4).

Table 4: Time Accuracy for X-Strahl superficial X-ray machine UQU

Machine setting			
SID=50 cm	1.0 mAs	50 kVP	
Time Accuracy			
Time, min.	time avg. min,	min. % Error	P/F
0.2	0.18	3.4	Pass
0.3	0.29	2.6	Pass
0.4	0.39	2.5	Pass
0.5	0.48	-0.96	Pass

Time Accuracy for*X-strahl*superficial X-ray nachunein UQU was ranged from -0.96 to 3.4 % . It was within the time accuracy percentage of 5% presented by (AAPM.1990 and J.L.1995). Time accuracy was good at all-time stations.The obtained results were close to the data set published by (Taha.M.T, 2015) and (H.A.Ismail, 2015).In addition within the range of research work published by (Ismail, 2011).

Measurement the Surface Radiotherapy Dose for Hands, Face and Nose

The Surface dose for skin, nose and hand were recorded as shown in table (5). The maximum dose is found on the surface of phantom.Hence, skin acts as a structure of dose-limiting when patients are treated bysuperficial x-ray doses at depth about 7 cm at which the dose is 50% of the maximum. Therefore the physician can calculate the treatment dose for superficial X-ray therapy for each case by control a time point of view of radiation protection concept.

Table 5: Entrance SkinDose (ESD) measurements for face, nose and hand.

Applicator dimensions	Examination	ESD (mGy)
3 cm diameter, 15 FSD	Face	56.68± 0.307
1.5 cm diameter, 15 FSD	Nose	241.2 ± 2.15
5 cm diameter, 15 FSD	Hand	60.52 ± 0.104

4. Discussion

The output of the system was evaluated using a fixed and reproducible geometry (AAPM-1990).Coefficient of variation for dose output was 0.17. All the calculated dose coefficients were lower than the tolerance levels of AAPM, (AAPM, 1990, 1981). The kilovotage and time accuracy on superficial X-ray equipment are important because they directly affect dose out put measurement (AAPM-1990). The X-ray tube kVp is most critical. A small error of this variable will have a greater effect on the final dose out put . Kilovoltage accuracy was 0.38 to 0.87 % and within kV accuracy as mentioned in American Association of Physics where the measured kVp within ±5 kVp of the set value from 50 kVp to 95 kVp, which are used in (AAPM-1990)and close to values published by(Ismail, 2015).Time Accuracy was studied for superficial X-ray machine in umm Alqura Universityand it was ranged from 0.96 to 3.4 % and was within the time tolearance limit as mentioned by (AAPM.1990) and In addition within the range of research work published by (Ismail, 2011). Time accuracy was good at all-timestation. Linearity of superficial X-ray machine was studied and coefficient of linearity was lower than 0.1.The entrance skin doses for face, nose and hand were 56.68 ± 0.307, 241.2 ± 2.15 and 60.52 ± 0.104 mGy respectively.

5. Conclusion

The present investigations demonstrate the quality control evaluations of superficial X-ray machine.It conculudedthat the reproducibility of dose output of superficial radiotherapy X-ray machine was found to be 0.17%, Linearity of that X-ray machine was lower than 0.1, kilovoltage accuracy was ranged from 0.38 to 0.87 % and within kV accuracy and time Accuracy for X-strahl*superficial* X-ray nachune in UQU was ranged from -0.96 to 3.4 % . The tests for the quality assurance of superficial radiotherapy X-ray machine was compared and assessed with the international publications. The quality control tests of X-Strahl superficial X-ray machine indicated that the physical operationgparametrs of that machine well qualified. The maximum dose was found on the surface of Perspex phantom. The treatment time for hand, face, and nose cancer calculated via the entrance skin dose measurements.

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