ORIGINAL ARTICLE

Evaluation of Radiation Protection Status of Diagnostic Radiology Departments of Hamadan University of Medical Sciences Hospitals

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Abstract

Purpose: The concept of Quality Control (QC) is considered a regular method to control, stabilize, and inspect the function of the diagnostic imaging system. The objective of implementing the QC program is to produce high-quality images by applying a minimum dose of radiation based on the As Low As Reasonably Achievable (ALARA) principle. Therefore, this study aimed to evaluate the status of radiation protection in diagnostic radiology wards of educational hospitals affiliated with Hamadan University of Medical Sciences.

Materials and Methods: In order to implement the QC programs, standard QC tests were performed for 11 devices at educational hospitals affiliated with Hamadan University of Medical Sciences. A Sweden QC kit called Pirranha was used to carry out the QC tests of X-ray devices, and the dosimetry of controlled areas. Also, the measurement of ambient dose in different places was performed by Graetz dosimeter made in Germany.

Results: Voltage Reproducibility, Exposure time reproducibility, tube outlet Linearity, and tube outlet reproducibility tests in all radiology departments which were in accordance with standard criteria were accepted; however, about 10% of the total filtration resulted in different centers needed to be corrected. In terms of radiation protection, 5% of the centers had problems related to warning signs, dimensions of radiology rooms were not standard at 7% of wards and also required protection was not sufficient at 9 percent. Moreover, there were problems with 12% of radiology centers in terms of dosimetry results and the efficiency of different parts of the radiology device.

Conclusion: QC programs performed by authorized companies are costly. But if these programs are done by qualified physicists in addition to reducing costs, we will see a significant increase in the accuracy and precision of the obtained results.

Keywords: Radiation Protection; Quality Control; Dosimetry; Radiology.

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1. Introduction

The most important feature of X-rays is the power of penetration and ionization in the environment. This beam can pass through solid and liquid environments and therefore has many benefits for patients from medical imaging. The number of imaging tests for patients is increasing every year. Some studies have shown that more than 10 million radiographic tests and 100,000 nuclear medicine tests are daily performed worldwide [1-3]. Irradiation of such a large population, even at the low dose levels used in diagnostic radiology has led to public concern [4]. Despite its benefits for diagnosing and treating diseases, ionizing radiation is a source of potential hazards from a radiation protection perspective [5]. Contact with the excess amount of standard radiation can affect the various parts of the body, such as the hematopoietic system, the reproductive system, and the central nervous system, which are considered as the most important side effects of low-intensity ionizing radiation. The doses less than 10 mSv can increase the risk of cancer to 1 in 2,000. Radiation from diagnostic imaging devices can also cause abnormal effects on radiology technicians and the patients, especially when safety issues and Quality Control (QC) are not observed for the devices. Ignoring safety issues in radiology centers can lead to diseases, such as cancer, cataract, cell death, hair loss, and reduction of blood platelets and the failure of the immune system, genetic abnormalities, cardiovascular problems and skin burns in personnel working in these wards [6-8]. Complications of ionizing radiation include the deterministic and stochastic effects; deterministic effects depend on the radiation doses delivered to organs or areas of the body and are observed in radiation above the threshold dose, and with higher doses more severe effects become apparent. The stochastic effects may appear either as cancer in patients or as genetic disorders in their next generation. The probability of stochastic effects increases with increasing absorbed radiation [9-10].

Applying radiation protection, deterministic effects can be prevented and also stochastic effects can be reduced [9]. The stochastic effects can be seen for any amount of delivered dose, so there is no dose level that can be called absolutely harmless. This fact indicates the importance of radiation protection in medical imaging departments [11-12].

In diagnostic radiology, we have three kinds of radiance, there are primary, scattered, and the beam leaked of X-ray tube and each of them has a set of protective principles. In the case of the scattered beam, if the protection principles of buildings regarding the initial beam are considered correctly, due to lower energy of scattered beam, it will no longer be a serious hazard. In the case of the leaking beam, the dose should be 0.1 rem per hour at a distance of one meter from the device when the device is operating continuously at the highest conditions [10].

The observance of the principles of radiation protection in the buildings in which there is a source of ionizing radiation inside them can greatly reduce the effects and risks of these rays [13]. The main objective of radiology departments is to perform the necessary actions to identify safety errors and reduce or eliminate them in the shortest possible time [14]. Continuous monitoring and the measurement of the scattered radiation dose and its amount at workplace is one of the most significant actions to reduce the complications of ionizing radiation which is to be kept always under the rated risk level [15]. However, these actions should be taken to minimize the exposure of patients and radiographers during the diagnostic tests. The maximum conclusion which is the diagnosis of disease should be concluded by using the minimum dose [16]. One of the main reasons for the unnecessary radiation exposure is the lack of QC programs or quality assurance at the level of radiology centers [17-18].

The concept of QC is considered as a regular method to control, stabilize, and inspect the function of the diagnostic imaging system. The objective of implementing the QC program is to produce the high-quality images by applying a minimum dose of radiation based on the As Low As Reasonably Achievable (ALARA) principle. Regular QC programs can also reduce the maintenance costs of devices and prevent unnecessary charges at radiology centers [19]. QC program by detecting the rickety weak parts prevents the complete failure of the device and thus it is very useful to increase the X-ray devices lifetime [20-21]. Generally, the goals of QC programs are to increase the quality of images, to reduce the received dose of radiation by patients, to decrease the repetition of diagnostic imaging tests, to increase the lifetime of radiographic devices, and to reduce the dose of radiation received by personnel [22-24].

In the field of radiation protection, studies have been conducted all over the world, including in the United States, Poland, Australia, Sweden, and Iran in the cities of Kurdistan, Tehran, and Mashhad [13, 25-32]. Considering the mentioned necessities and the fact that no study has been done in Hamadan in the field of radiation protection and in order to validate companies performing the radiation protection; therefore, this study aimed to evaluate the protection against ionizing radiation in the diagnostic radiology wards of educational hospitals affiliated with Hamadan University of Medical Sciences.

2. Materials and Methods

There were 11 active radiology rooms in five educational hospitals of Hamadan city (Shahid Beheshti, Fatemiyeh, Sina, Besat, heart hospital of Farshchiyan). The first dimensions of the rooms were measured and then dosimetry (dosimetry of areas in which the existence of the beam can be possible there) and QC of devices were performed. This study included leakage of the X-ray tube, amount of peripheral scattered radiation, condition of lead-lined walls, floors and ceiling, leaded glass window and door of X-ray room situation, QC of devices, the existence of personal protection shields, and the use of individual dosimeter by personnel.

The dosimetry of controlled areas and measurement of ambient radiation dose in different places were performed by Graetz dosimeter (X5C Plus, Germany). The measurement of this dosimeter ranged from 0 nSv to 10 Sv, used to detect X-ray and gamma rays. First, the ambient dose outside the radiology ward was measured with a dosimeter (Background radiation dose). Afterward, the average dose of irradiated areas (Control room, patient waiting room, corridor, and personnel restroom) was measured. It should be noted that the correct measurement is performed when the device is on and works with the maximum working load. In order to implement the QC programs, standard QC tests were performed for 11 devices in the educational hospitals of Hamadan city.

A Sweden QC kit called Pirranha was used to carry out the QC tests of X-ray devices. After collecting and recording the data, the obtained data were statistically evaluated and the error percentage of each parameter was compared with the existing standards and classified into three groups of acceptance, correction, and suspension. Quantitative criteria for acceptance, correction, and suspension have been developed by the Atomic Energy Organization. Accordingly, if the error obtained from measurements is in the approved range of the Atomic Energy Organization, it will be acceptable. If the error is in the correction range, the intended defect should be repaired and if the error percentage is higher than this value, the device must be suspended.

Table 1 defines the quantitative criteria for accepting, modifying, and suspending the standard parameters for the QC tests.

3. Results

The technical specifications of the devices are shown in Table 2. Among the studied devices, five devices have been made by Shimadzu Company (Japan), two devices by Toshiba Company (Japan), one device by Varian Company (USA), one device by Siemens Company (Germany), one device by Hologic Company (Netherlands) and one device by MehranTeb Company (Iran). 5 out of 11 devices had the Automatic Exposure Control (AEC) system, which is not currently used to determine the amount of radiation exposure in all centers.

The test results and the related criteria are shown in Table 3. Voltage reproducibility, exposure time reproducibility, tube outlet linearity, and tube outlet reproducibility tests in all radiology wards which were in accordance with standard criteria were accepted. However, about 10% of the total filtration resulted in different centers needed to be corrected.

The measurement of ambient radiation dose in different places (Control room, patient waiting room, corridor, and personnel restroom) was performed by Graetz dosimeter. The results of these measurements are given in the table. These results show that the dose values obtained are lower than the standard values developed by the Atomic Energy Organization. The evaluation results of radiology devices of different hospitals showed that 98% of the set's performance was optimal. The results also demonstrated that compared to the required standards the radiology control room's condition was 93% favorable. The results of dosimetry and protection of radiology wards were only 90.8% favorable, compared to the defined standards.

These results showed that the leakage rate of 12% of the surveyed sections was 0 to 15% more than the allowed radiation criteria. Regarding the presence of warning signs, it was observed that 95% were in a good condition in terms of radiation danger lights, warning posters for pregnant women, and radiation hazard posters.

Table 1. Definition of important Quality Control (QC) parameters for evaluation in radiology departments

Parameter	Definition	Acceptance	Correction	Suspension
Voltage accuracy	$\frac{KV(Measured) - KV(Nominal)}{KV(Nominal)}$ **KV:** Kilo-Voltage	≤10%	%10 - %20	20%<
Voltage Reproducibility	$SD=\sqrt{\frac{\sum(x_i-\overline{x})^2}{n-1}}$, $CV = \frac{SD}{\overline{X}}$ **SD:** Standard Devotion **CV:** Coefficient of Variation **n:** The size of the population **x_i:** Each value from the population **$\overline{x}$:** The population mean	CV≤%5	%5<CV≤%20	CV≥%20
Exposure time accuracy		≤10%	%10 - %20	20%<
Exposure time Reproducibility	At the constant exposure time and clinical tube loadings, at least three exposures were performed. Then, SD and CV were calculated for the measured exposure time. $X=\frac{Dose}{mAs}$ $SD=\sqrt{\frac{\sum(x_i-\overline{x})^2}{n-1}}$ $CV = \frac{SD}{\overline{X}}$ **mAs:** Milliampere-seconds	CV≤%5	%5<CV≤%20	CV≥%20
Tube outlet Linearity {D=f(s)}	At constant tube voltage and current, two exposures were performed at different time intervals. $X=\frac{Dose}{mAs}$ $L = \frac{X_1-X_2}{X_1+X_2}$ **L:** Linearity	L ≤ 0.1	0.1< L ≤0.2	L>0.2
Tube outlet Linearity{D=f(ma)}	At a constant tube voltage and time, two exposures were performed with different tube currents. $X=\frac{Dose}{mAs}$ $L = \frac{X_1-X_2}{X_1+X_2}$	L ≤ 0.1	0.1< L ≤0.2	L>0.2
Filtration (HVL)	The thickness of the aluminum filter which is necessary to reduce the intensity of X-rays by half	≤%20	%20 - %50	%50<
Tube outlet Reproducibility	$SD=\sqrt{\frac{\sum(x_i-\overline{x})^2}{n-1}}$ $CV = \frac{SD}{\overline{X}}$	CV≤%5	%5<CV≤%20	CV≥%20
Tube and collimator Leakage	Amount of Leakage radiation from X-ray tube and collimator	≤1mGy/h	1-5mGy/h	5mGy/h<
Adaptation of optical field and radiation field	Deviation of the light field from the beam field at a distance of one meter	≤1cm	1cm<	
Perpendicularity of Beam and Film	Perpendicularity of output beam from X Ray tube to the surface of radiology film	≤ 3	3-5	>5
Light intensity of the collimator	Measuring the intensity of the light beam generated by the device's collimator	100 lux ≤	< 100 lux	

Table 2. The technical specifications of the devices

Device	Manufacturer	Maximum KV (kv)	AEC System	Total filtration thickness (mm Al)
H01	TOSHIBA	150	Yes (not used)	2.4
H01-P	SHIMADZU	125	No	0.7
H02-1	MehranTeb	150	Yes (not used)	2.1
H02-2	SHIMADZU	150	No	2.5
H02-P	SHIMADZU	125	Yes (not used)	0.7
H03	TOSHIBA	150	Yes (not used)	2.4
H04-1	Varian	150	No	2.7
H04-2	SHIMADZU	150	Yes (not used)	1.0
H04-3	HOLOGIC	150	No	-
H04-4	SHIMADZU	150	No	4.0
H04-5	SIEMENS	150	No	1.0

4. Discussion

Devices that have been in use for more than 10 years had problems with the Half-Value Layer (HVL) test, which may be due to repeated repairs and the replacement of filters. All devices with a patient load of more than 36,000 per year did not perform well at least in two tests. In other words, QC programs should be implemented more orderly for high-load devices and old units [25-32]. In other words, for such devices that have higher imaging rate, QC tests should be performed with more precision and order. The QC programs of radiology devices depend on parameters such as test performer, device age, device workload, QC dosimeter, etc.

Accordingly, we believe that the results of QC evaluations in different periods cannot be very reliable. For example, the QC report performed for all parameters mentioned in this study (12 cases) was accepted by companies performing the QC process; whereas differences were observed between the results obtained from these companies and those obtained by this study (Table 3). The biggest difference was in the total filtration test, in which about 10% of the centers required the correction. Devices equipped with an automatic exposure control system can automatically control the irradiation time based on the density of the target tissue, and reduce the patient's absorbed dose and increase the image quality. Unfortunately, despite the fact that 5 out of the 11 devices evaluated in this study had an AEC system, but this ability was not used to reduce the patient dose. Another purpose of this study was to evaluate the status of radiation protection in radiology wards of educational hospitals affiliated with Hamadan University of Medical Sciences. The results of this study showed that most radiology wards had a good radiation protection status. The major limitation of this study was the small sample size due to financial limitations. In order to perform a comprehensive study, it is therefore recommended that future studies be examined more devices, including CT scan units and dynamic imaging techniques such as fluoroscopy and angiography.

5. Conclusion

QC programs performed by authorized companies are costly. But if these programs are done by qualified physicists, in addition to reducing costs, we will see a significant increase accuracy and precision of the obtained results. The accuracy and precision of results of different devices play an important role in increasing the image quality, reducing the received dose of radiation by patients, decreasing the repetition of diagnostic imaging tests, increasing the lifespan of radiographic devices, and reducing the dose of radiation received by personnel. The use of an automatic exposure control system can greatly reduce the repetition of radiographic procedures and the additional dose to the patients. About 45% of the centers evaluated in this study had an AEC system, which, unfortunately, due to the lack of proper training for radiographers, this possibility is currently unused. Therefore, it is recommended that in order to reduce the patient dose and provide the optimal images in radiology centers, appropriate training courses are held for radiographers to persuade them to use this system (AEC) properly.

Table 3. Test results and related criteria

Experiment	Criterion		
	Acceptance	Correction	Suspension
Voltage accuracy	97.1%	2.9%	0
Voltage Reproducibility	100%	0	0
Exposure time accuracy	96.3%	3.7%	0
Exposure time Reproducibility	100%	0	0
Tube outlet Linearity {D=f(s)}	100%	0	0
Tube outlet Linearity{D=f(ma)}	98.2%	1.8%	0
Filtration (HVL)	90.4%	9.6%	0
Tube outlet Reproducibility	100%	0	0
Tube and collimator Leakage	98.9%	1.1%	0
Adaptation of optical field and radiation field	99.1%	0.9%	0
Perpendicularity of Beam and Film	98.8%	1.2%	0
Light intensity of the collimator	99.3%	0.7%	0

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