

Original Article

Quality Control Status of Radiology Centers of Hospitals Associated with Mashhad University of Medical Sciences

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Abstract

Introduction

Using ionization radiation for diagnostic and treatment fields has increased worldwide dramatically. This issue causes an increase in the absorbed and collective doses in society noticeably. With regard to two main principles in radiation protection, i.e., justification and optimization, it is necessary to have imaging process with minimum dose to patients and personnel. For achieving this, it is vital to perform quality control tests regularly. On this topic, many studies have been performed and reported worldwide which show necessities and meaningfulness of QC tests.

Materials and Methods

In this study, Unfors Mult-O-Meter model 303 is used for surveying accuracy of kVp and time, linearity of exposure with mAs, and reproducibility of exposure.

Results

According to recommendations of AAPM (2002) and ICRP 103, in this study, 27% of apparatuses in accuracy of kVp, 45% in accuracy of timer, and 30% in accuracy of reproducibility were out of accepted range.

Conclusion

In surveyed apparatuses, both ends of operating range have large errors in therefore it is recommended that these devices should not be used in the mentioned regions. Performing strict quality control on all radioactive devices is one of the radiation protection priorities that should be done periodically. With regard to the results, repair, substitution or omission of some devices are suggested.

Keywords: Mult-O-Meter, Quality Control; Radiography; Reproducibility of Results.

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1. Introduction

Increasing use of ionizing radiation to diagnose and treat medical problems has led to a dramatic rise in dose rate. In the US, the number of radiological examinations has increased tenfold from 1950 to 2006[1]. Number of radiological examinations has increased by 100% from 1980 to 2005, while the world population during this period grew by 45% [2]. According to NCRP160, about 95% of the total number of diagnostic radiology tests are medical examinations and this includes 74% of the cumulative dose of radiation in the US[3]. Moreover, the contribution of artificial sources of radiation sources has increased from 18% (BEIR IIV) to 52% [1]. Considering two important principles of radiation protection, including the justification and optimization, it is necessary to optimize the image with minimum dose to the patient and staff. Technical parameters measurements and stability control is necessary to X-ray equipments for reliable performance and long durability based on periodic program. These tests are known as quality control (QC). QC ensures us that all parts of the imaging are at optimum situation. It results in good-quality images, the minimum dose to the patient and the operator, the minimum possible frequency of tests, X-ray unit durability, and increasing longevity of tube.

Studies show that the performance parameters of radiological devices are not acceptable in Iran. In one study, it has been shown that 57% of units in terms of accuracy kVp, 42% in terms of exposure linearity with mAs, 14% in terms of irradiation time accuracy, and 7% in terms of reproducibility have not acceptable results[4]. In another study, 50% of the units in terms of mA linearity, 50% in terms of the voltage accuracy, 30% in terms of timer accuracy, and 25% in terms of the radiation output reproducibility have not been approved considering international standards[5]. In other study, results suggest that the quality control programs can reduce the average dose for chest examination by about 40%[6]. It is necessary to perform QC and fix technical

flaws periodically, reduce the cumulative effective dose and annual effective dose, and therefore reduce the harmful effects of ionizing radiation.

2. Materials and Methods

At the beginning, according to type and number radiographs, kV, mA, and exposure times, which are mostly used, have been identified and our measurements were within this range. Generally, 11 radiographic units used in radiology departments in Imam Reza Hospital, Ghaem Hospital, Shahid Hashemi Nejad, Shahid Kamyab Hospital, Omid Hospital, and Doctor Sheikh Hospital were evaluated.

To evaluate the accuracy of kV, timer accuracy, linearity between exposure and mAs, and repeatability of exposure, Mult-O-Meter (Model 303, Unfors, Sweden) was used.

To determine the accuracy of tube voltage, Mult-O-Meter was placed on the X-ray unit bed at a distance of 100 cm in the center of the field and kV and exposure time were given to the units in a way that did not increase the tube load. kVp variations should not be greater than $\pm 5\%$ [7,8,9].

To determine the accuracy of the timer, test methods such as kV checking with the difference that kVp was fixed and time was variable and applied times were selected based on technical chart at each center were implemented. Time variations of measured radiation for times greater than 10 ms is $\pm 5\%$ and for times less than 10 ms was $\pm 20\%$ [7,8,9].

To check the linearity of the exposure with mAs, Mult-O-Meter device was placed on the bed in the center of the radiation field and at a distance of 100 cm from the focal spot and kVp to 70, time to 100 ms, and mA to 50, 100, 200, and 400 were set. We recorded the readings and milli-Roentgen per mA for different mAs was computed. Using the following equation mA linearity variance was obtained:

$$\text{linearity variance} = \left(\frac{\frac{mR}{mAs_{\max}} - \frac{mR}{mAs_{\min}}}{\frac{mR}{mAs_{\text{ave}}}} \right) \div 2 \quad (1)$$

Where maximum acceptable variance is $\pm\% 5$ [7-,9].

To determine the exposure reproducibility, equipment adjustments were done such as previous method except that the following conditions selected on the radiographic units: kVp 80, mA 100, and ms 100.

With these conditions, milli-Roentgen was recorded for five separate radiations. Reproducibility variance was obtained from the following equation:

$$\text{Reproducibility variance} = \frac{(mR_{\max} - mR_{\min})}{(mR_{\max} + mR_{\min})} \quad (2)$$

where maximum acceptable variance is $\pm\% 5$ [7-9].

3. Results

The results of accuracy of kVp and time, linearity of exposure with mAs, and reproducibility of exposure are shown in Figures 1-5. Difference between the unit nominal value and the Mult-O-Meter reading was considered as error.

The results show that errors in unit No. 3 of Shahid Kamyab Hospital and unit No. 3 of Ghaem Hospital are more than the others. The minimum error was observed in unit No. 1 of Shahid Hashemi Nejad Hospital and unit No. 2 of Ghaem Hospital.

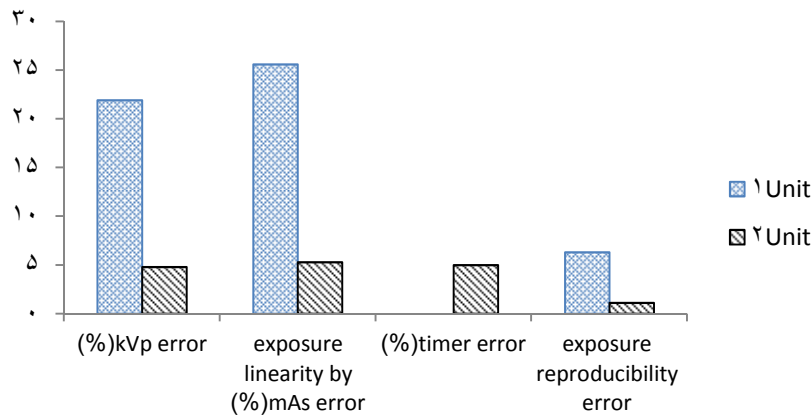


Figure 1. Results related to the accuracy of the output voltage (kVp), linearity of exposure with mAs, timer accuracy, and reproducibility of the exposure in Imam Reza Hospital.

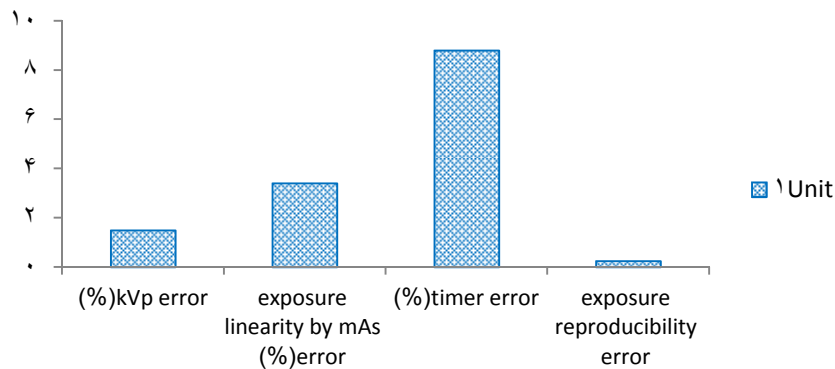


Figure 2. Results related to the accuracy of the output voltage (kVp), linearity of exposure with mAs, timer accuracy, and reproducibility of the exposure in Omid Hospital.

Quality Control in Diagnostic Radiology

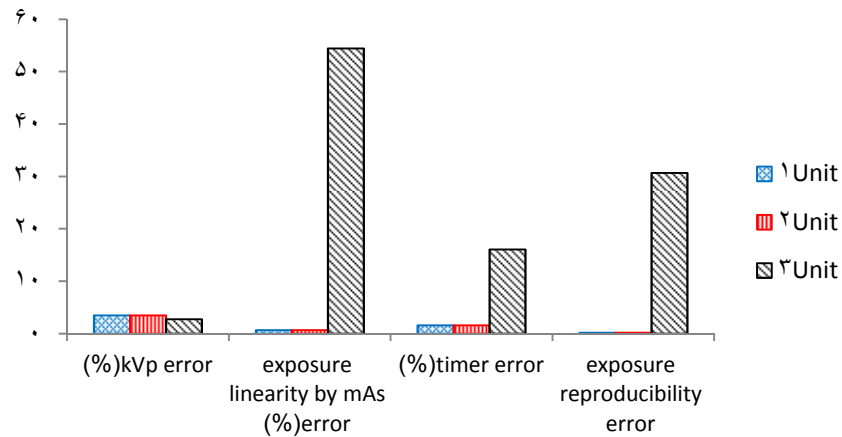


Figure 3. Results related to the accuracy of the output voltage (kVp), linearity of exposure with mAs, timer accuracy, and reproducibility of the exposure in Shahid Kamyab Hospital.



Figure 4. Results related to the accuracy of the output voltage (kVp), linearity of exposure with mAs, timer accuracy, and reproducibility of the exposure in Shahid Hashemi Nejad Hospital.

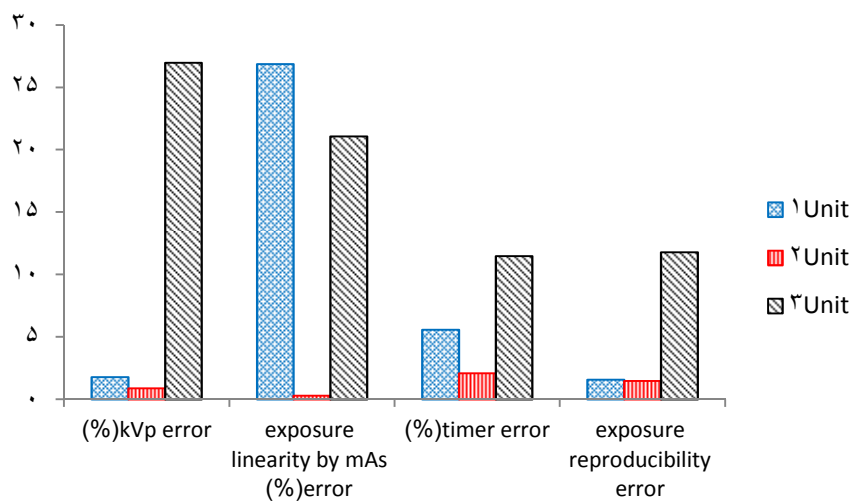


Figure 5. Results related to the accuracy of the output voltage (kVp), linearity of exposure with mAs, timer accuracy, and reproducibility of the exposure in Ghaem Hospital.

For example, one of the time measurements that is related to unit No.3 of Imam Reza Hospital, is given in Table 1. These data indicate that the selection of a small times (3 and 6 ms) can reduce the accuracy greatly.

Table 1. Time measurements of unit No. 3 of Imam Reza Hospital (kVp=70 and mA=300).

Selected time on unit (ms)	Mean of measured time (ms)	Error (%)
3	5.1	70
6	8.13	35.4
20	21	5
30	30.9	2.8

It is worth noting that some of the data that have been gathered at the beginning of X-ray unit work range are not reliable and not included in the statistical analysis.

4. Discussion

The results obtained in this study that were performed on the 11 sets, also confirmed that some of the devices are outdated.

According to the results and recommendations of the AAPM and ICRP103[7,8], 27% of the units in terms of kV accuracy, 54% of the linearity of exposure, 45% timer accuracy, and 30% in the accuracy of reproducibility were outside acceptable limits. Results of Saghatchi et al. showed that 57% of the units in terms of the kV accuracy, 42% in terms of exposure linearity, 14% in terms of accuracy in measuring time, and 7% in terms of reproducibility accuracy were outside the acceptable limits[4]. In another study by Esmaili et al, the above-mentioned items, were 55, 50, 30, and 30%, respectively[5].

References

1. Mettler FA, Jr., Bhargavan M, Faulkner K, Gilley DB, Gray JE, Ibbott GS, et al. Radiologic and nuclear medicine studies in the United States and worldwide: frequency, radiation dose, and comparison with other radiation sources--1950-2007. *Radiology*. 2009 Nov;253(2):520-31.
2. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. Medical radiation exposures, annex A. 2008 Report to the General Assembly with annexes. New York, NY:United Nations (in press).
3. The National Council on Radiation Protection and Measurements(NCRP). Ionizing radiation exposure of the population of the United States.Report No.160,2009.

Data related to time measurements of unit No. 2 in Imam Reza Hospital are given in Table 1 which show that the data for 3 and 6 ms have high errors, because they are at the beginning of X-ray unit work range and many years have passed since the maximum lifetime of the unit so it is not recommended to use it in this area anymore. According to the above, unit No. 2 of Imam Reza Hospital and unit No. 5 of Ghaem Hospital, if not possible to repair, get out of the treatment cycle.

5. Conclusion

Performing strict quality control on all radioactive devices is one of the radiation protection priorities that should be done periodically. If we do not have good accuracy and precision of X-ray units and periodic quality control programs, it is possible that patients and personnel take extra doses. In our country, many old X-ray units do not have good precision and good accuracy but are still used. For this reason, a radiographic imaging may be done several times.

It is recommended that some of the units, if not possible to repair, get out of the treatment cycle

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Quality Control in Diagnostic Radiology

4. Saghatchi F. Quality control of diagnostic X-ray units in hospitals of Zanjan University of Medical Sciences. Master Thesis of Medical Physics, Mashhad University of Medical Sciences, 1999.
5. Esmaili S. Measurement of patient skin dose of common techniques in diagnostic radiology in 15 radiology centers and quality control of those units in Mashhad. Master Thesis of Medical Physics, Mashhad University of Medical Sciences, 2006.
6. Shahbazi D. Quality control of radiological units in hospitals of Cheharmahal-o-Bakhtiari Province. Journal of Shahrekord University of Medical Sciences. 2003; the fifth year (4): 5-11.
7. The American Association of Physicists in Medicine(AAPM). Quality Control in Diagnostic Radiology.Report No.74, 2002.
8. International Commission on Radiological Protection “ICRP 103 The 2007 Recommendations of the International Commission on Radiological Protection” Ann. ICRP 37(2-4) , 2007.
9. Papp J. Quality management in the imaging sciences: Elsevier Health Sciences; 2013.