Quality control of radiology devices in Health Centers Affiliated with Hormozgan University of Medical Sciences

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Original Article

Abstract

Introduction: Regular quality control of radiology devices and fixing their defects can play a crucial role in reducing absorbed dose of patients, increasing their longevity, and improving the quality of radiographic images. This study was aimed at performing quality control according to the standards and features of radiology machines in the teaching hospitals of Hormozgan Province.

Methods: Several parameters were examined in this study, including voltage accuracy, voltage reproducibility, exposure time reproducibility, output linearity with mA, and adaptation of optical field with radiation field.

Results: Evaluation of voltage accuracy showed that the radiology devices of No. 3 in Shahid Mohammadi Hospital of Bandar Abbas, No. 1 in Hazrat Abolfazl Hospital of Minab, and No. 1 in Hazrat Fatemeh Zahra Hospital of Qeshm exceeded the normal ranges in all voltages, and the radiology devices of Shariati Hospital in Bandar Abbas in 78 kV and 85 kV.

Conclusion: Quality control of radiology devices in health centers reduces patients' absorbed dose during various radiographies, increases their efficiency and longevity, and improves the quality of radiographic images and the disease diagnosis by physician.

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Introduction:

The radiographic examination plays an important role in the diagnosis and treatment of diseases. Given the widespread use of such tests, a lot of people which are exposed to X-rays, therefore X-rays are now considered the most important source of artificial exposure of population to ionizing radiations (1). Currently, it is estimated that a third to a half of serious and definite medical decisions are made based on X-ray examinations and diagnoses, although early detection of certain diseases is completely dependent on experiments performed by X-ray (2). Regular quality control of radiology devices and fixing their defects can play a crucial role in reducing absorbed dose of patients, increase their longevity, and improve the quality of radiographic images (3). Quality assurance (QA) is a comprehensive management plan to ensure ultimate optimization of the health system through which data are regularly collected and evaluated. The primary purpose of a quality assurance program is to improve patient care and promote the quality of services provided to them; quality control is a part of quality assurance which discuss about factors affecting image quality and patient and staff care in radiology departments. Assessment of the quality of equipment used in the center is an important part of a quality control program.

The topic of quality control was first introduced by Frederick Winslow Taylor in 1900 and was entered in radiology units in the early 1930s (4,5). In general, there are three types of quality control tests including acceptance, routine, and correction tests. The acceptance test verifies the manufacturer's claims regarding the characteristics of a new system; the routine tests include specific periodic testing for example in a daily, weekly, monthly, or annually manner; and the corrective tests evaluate the performance of the system after repair (4-6). Critical tests are another type of tests which should be done by the device installation unit and include a review of diagnostic radiology devices in terms of safety and performance of warning equipment. Through these tests, the radiation indicators are evaluated in terms of the necessary and adequate protection for staff, patients, and clients (4).

Given the importance of quality control of radiology devices, several researches have been performed in this field. In a study by Kaykhah et al. in 2011 for quality control of radiology devices in the hospitals of Sistan and Baluchestan Province, the results showed that the quality control programs reduced patient absorbed dose and increased image quality (7). In another study by Shahbazi to control the quality of radiology devices in hospitals of Chaharmahal and Bakhtiari Province, the results showed that the quality control programs decreased patients absorbed dose during chest X-ray by approximately 40% (8). In a study by Godechal et al. entitled a quality assurance program for X-ray machines, systematic measurements were performed to evaluate the efficacy profile of X-ray machines and insufficient filtration of devices was found to be the fundamental weakness (9). In another study by Servoma et al. named quality control and patient dose in X-ray tests carried out in some hospitals in Estonia, the measurements included technical performance, image quality, patient dose, and film processing (10).

This study aimed at performing quality control tests according to standards and features of radiology devicess in the teaching hospitals of Hormozgan Province.

Methods:

Each QC program in diagnostic radiology included objectives such as investigating the compliance of a series of experiments of X-ray devices with standards, considering the parameters of radiation protection, checking all devices and the required tests, as well as additional information that may be needed by legal unit. With regard to facilities and devices, the study was divided into four stages:

1. Collection of basic information and selection of diagnostic (educational) radiology center in the province.
2. Designing data entry forms.
3. Measurement of parameters.
4. Data analysis.

Given the limited number of study population, the research was carried out through the census method, and all diagnostic radiology devices of hospitals affiliated to the Hormozgan University of Medical Sciences were examined, including 13 devices in the following medical centers:

1. Shahid Mohammadi Hospital of Bandar Abbas (device No. 1 of emergency)
2. Shahid Mohammadi Hospital of Bandar Abbas (device No. 2 of emergency)
3. Shahid Mohammadi Hospital of Bandar Abbas (device No.3 of radiology department)
4. Shariati Hospital of Bandar Abbas
5. Children's Hospital of Bandar Abbas
6. Hazrat Abolfazl Hospital of Minab (device No. 1)

7. Hazrat Abolfazl Hospital of Minab (device No. 2)
8. Hazrat Fatemeh Zahra Hospital of Qeshm (device No. 1)
9. Hazrat Fatemeh Zahra Hospital of Qeshm (device No. 1)
10. Ali-ebn Abi-Taleb Hospital of Rudan
11. Abdul Bagher Niapoor Hospital of Bandar Khamir
12. Shahid Beheshti Hospital of Bandar Lengeh
13. Health Development Center of Hormuz

Several parameters were examined in this study, including voltage accuracy, voltage reproducibility, exposure time reproducibility, output linearity with mA, and adaptation of optical field with radiation field. The comprehensive quality control kit of Barracuda (RTI Electronics, Sweden) was used in this study, which is the most advanced quality control kit for X-ray devices and is able to measure mAs, KVP, Time, Dose, Dose rate, HVL, KV, and mA (Figure 1).

Figure 1. A view of Barracuda kit

To perform the voltage accuracy test for each X-ray machine, the difference between the voltage set on the X-ray machine and the measured voltage was obtained in three different voltages in constant mA and ms conditions. Reproducibility evaluation means that in a fixed kV peak set on the X-ray machine, with changes in radiation conditions in terms of mA and exposure time, the measured voltage is equal to the value set on the device (constant kV peak) and the value remains unchanged following changes in radiation conditions.

Evaluation of reproducibility of the exposure time means that in a constant exposure time set on the X-ray machine, following changes in radiation conditions in terms of mA and kV peak, the measured exposure time is equal to the value set on the X-ray machine (constant exposure time) and after changing the radiation conditions, the value remains unchanged. Evaluation of reproducibility of the X-ray output tube means that a similar amount of radiation is produced in an X-ray machine in constant radiation conditions. Other quality control tests were performed with regard to the quality control guidelines of fixed radiology machines established by Atomic Energy Organization of Iran (AEOI) entitled Diagnostic Radiology Devices Quality Control presented in 2008. All variables in this study were quantitative. The data were entered into the computer and analyzed by Excel 2007. Appropriate charts were used to describe the data.

Results:

The desired parameters of X-ray devices were measured in the mentioned hospitals using the equations (1) to (4) provided by the Atomic Energy Organization;

Calculation of kilo voltage accuracy and exposure time (error rate):

$$ER = \frac{\sum|X_t - X_i|}{X_t}$$

Calculation of kilo voltage accuracy and exposure time (error percent):

$$\%\mathrm{ER} = \frac{\sum|\mathrm{X_t} - \mathrm{X_i}|}{\mathrm{X_t}} * 100$$

Calculation of reproducibility of kilo voltage, time, and output:

$$CV = \frac{1}{\bar{X}} \sqrt[2]{\frac{\sum(X_i - \bar{X})^2}{n-1}}$$

$$L = \frac{X_2 - X_1}{X_2 + X_1}$$ Calculation of output linearity with mA and time

Where xt is the adjusted value, xi the read value, n the number of measurements, and x1 and x2 the output per unit of mA seconds.

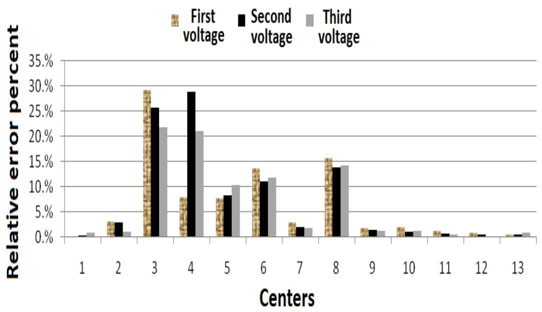

Diagram 1. Results of Voltage Accuracy in Health Centers

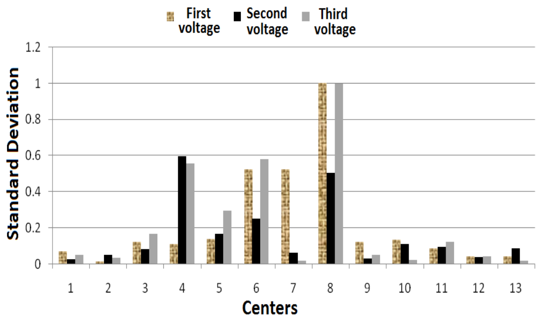

Diagram 2. Results of Voltage Accuracy Reproducibility in Health Centers

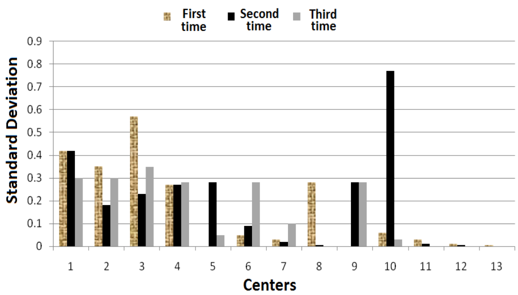

Diagram 3. Results of Time Reproducibility in Health Centers

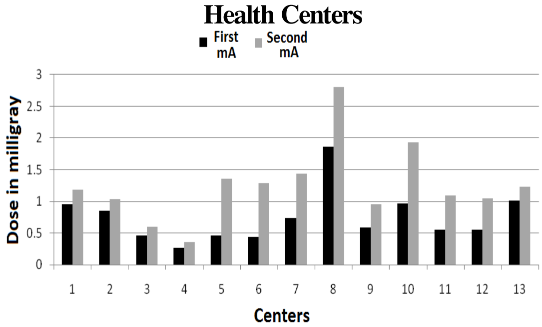

Diagram 4. Results of Output Linearity in mA in Health Centers

Adaptation of optical field with radiation field: this test was conducted through the eight coins method for each machine; the results are as follows:

Evaluation of voltage accuracy indicated that the X-ray machines of No. 3 in Shahid Mohammadi Hospital of Bandar Abbas, No. 1 in Hazrat Abolfazl Hospital of Minab, and No. 1 in Hazrat Fatemeh Zahra Hospital of Qeshm exceeded the normal ranges at all voltages, the radiology device of Shariati Hospital in Bandar Abbas at 78 kV and 85 kV, and the radiology device of Children's Hospital of Bandar Abbas at 90 kV (Diagram 1). Evaluation of voltage and time reproducibility showed that the coefficient of variation of all radiology devices was in the standard range (Diagram 2). Evaluation of linearity of output with mA indicated that only the device No. 1 in Hazrat Abolfazl Hospital of Minab was not at the standard range and other X-ray devices were at the specified standard range (Diagram 4).

For assessment of adaptation of optic field with radiation field, one centimeter deviation in radiation field and optic field is acceptable according to the Atomic Energy Organization guidelines. Optical system of X-ray machines No. 1 and 2 in Shahid Mohammadi Hospital of Bandar Abbas, Ali-ebn Abi-Taleb Hospital of Rudan, No. 1 in Hazrat Abolfazl Hospital of Minab, No. 1 in Hazrat Fatemeh Zahra Hospital of Qeshm, and Children's Hospital of Bandar Abbas needs to be modified (Table 1).

Table 1. Adaptation of Optical Field to Radiation Field

Direction	Deviation of optical field from X-ray field (cm)												
	Device 1	Device 2	Device 3	Device 4	Device 5	Device 6	Device 7	Device 8	Device 9	Device 10	Device 11	Device 12	Device 13
Up	۰/۸	۰/۷	۱/۵	۱	۰/۴	۱/۲	۰/۶	۱/۹	۰	۲/۳	۰/۸	۰/۲	۰
Right	۰/۵	۱/۵	۰/۷	۰/۴	۱	۱	۰/۵	۰/۵	۰	۰/۵	۰/۵	۰/۲	۰/۵
Left	۰/۷	۱/۵	۰/۷	۱	۰/۴	۰	۰/۸	۱	۰	۰/۲	۰/۵	۰/۴	۰
Down	۳	۱	۱/۱	۰	۱/۵	۰/۷	۰/۴	۱/۴	۰/۴	۱/۳	۰/۴	۰/۲	۰

Conclusion:

Diagnostic X-ray is the main source of exposure of people to radiation, which can be reduced through avoiding unnecessary testing or replications as well as improving the performance of the devices. On the other hand, both patients and radiology staff should be protected against radiation (11). Decrease in dose absorbed by patients and paying more attention to the risks created by X-rays is of important concern given the increasing use of ionizing radiation (this issue is also due to population increment and rise in trust to radiology accuracy in detection and diagnosis of diseases) (8).

Substandard performance of X-ray machines can increase the absorbed dose of patients and staff and may lead to biological effects and diseases resulting from exposure in them. Studies by Hollins and Jankwoski et al. showed that implementation of quality control programs on radiology devices can reduce patients absorbed dose by 30-50% (11,12). The standard quality control forms for fixed radiology machines have been provided by AEOI in 2008 entitled Diagnostic Radiology Devices Quality Control. The standard values for quality control tests were as follows:

Voltage accuracy test: a difference of ≤10% between the voltage values set on the device and the measured values is acceptable.

Exposure time accuracy test: a difference of ≤10% between the exposure time set on the device and the measured values is acceptable.

Evaluation of voltage reproducibility, exposure time reproducibility, and X-ray tube output reproducibility: a coefficient of variation of ≤5% of the measured values is acceptable. An adaptation of optical field with radiation field of ≤1 cm is acceptable.

X-ray machine No. 3 in Shahid Mohammadi Hospital of Bandar Abbas located in the radiography department had a substandard performance in the voltage accuracy quality control test and the highest error. A main reason can be the long life of the X-ray machine tube in this department. The device is in need of special attention.

In a quality control study of X-ray machines in hospitals of Chaharmahal and Bakhtiari Province, it was shown that non-standard performance of some devices was from long life of their tubes (8). Since the maximum errors in voltage accuracy test in the present study was occurred over 70 kV peak, the devices' voltage must be calibrated especially in kVs over peak 70. The results of Bahraini Toosi et al. about the accuracy potential of tubes showed that in 320 or 300 mA, about 44% of the devices had a difference of more than 5% between the set potential of tubes and the measured values (13). While in this study, the radiology devices of No. 3 in Shahid Mohammadi Hospital of Bandar Abbas, No. 1 in Hazrat Abolfazl Hospital of Minab, and No. 1 in Hazrat Fatemeh Zahra Hospital of Qeshm had exceeded errors at 300 and 200 mA and all kV ranges, that of Shariati Hospital of Bandar Abbas at 600 mA and 78 and 85 kVs, and the radiology device of Children's Hospital of Bandar Abbas at 200 mA and 90 kV.

It was shown in all quality control tests performed in this study that the radiology devices of No. 2 in Hazrat Abolfazl Hospital of Minab, No. 2 in Hazrat Fatemeh Zahra Hospital of Qeshm, and those of Abdul Bagher Niapoor Hospital of Bandar Khamir, Shahid Beheshti Hospital of Bandar Lengeh, and Health Development Center of Hormuz Island had the necessary standards. The radiology devices of No. 1 and No. 2 in Shahid Mohammadi Hospital of Bandar Abbas and Ali-ebn Abi-Taleb Hospital of Rudan were at standard ranges in all tests except for adaptation of optical field with radiation field; this can arise from low workload in these wards resulting in more sound tube. Proper implementation of quality control programs will have valuable results such as reducing exposure of patients to radiation. In a study by Kaykhah et al. in 2011 for quality control of radiology devices in Sistan and Baluchestan Province hospitals, the results showed that the quality control programs reduced patient absorbed dose and increased image quality (7). The present research can serve as preliminary action for initiating proper implementation of quality control programs in radiology departments of all parts of Hormozgan Province not only to reduce the X-ray absorbed dose of patients during various radiographies, but also to increase the efficiency and life of devices as well as the quality of radiographic images. Finally, the major problem encountered during implementation of this research was the lack of quality control systems which are able to perform other factors of quality control; we hope that the University can purchase them, if God wills.

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