ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Assessment of Radiation Protection Practices amongst Radiographers and Quality Control of Diagnostic Radiology Devices in the Selected Hospitals of Urmia City in Iran.

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ABSTRACT

Quality assurance program is a regulatory necessity in diagnostic imaging. An unsuccessful quality assurance program can prompt low quality radiograms that can damage diagnosis, increase operating costs and give to unnecessary radiation exposure to both patients and staff. The aim of the study was to perform of the important features of QA tests and radiation safety factors in major medical X-ray installations in urmia, iran. The quality assurance tests and radiation safety factors of X-ray diagnostic examination are measured and compared with the international tolerance. The analysis of the rejected films showed an overall reject rate of 8.4% during the period of the study. KV accuracy is good at all KVp stations for five machine except one of the examined machines gave accuracy of 6.04 % which is higher than the tolerance limit. Time accuracy is lower than the tolerance limit. Reproducibility of radiation output was ranged from 0.1 to 2.5%, of time was ranged from 0.01 to 3% and of high voltage was ranged from 0.1 to 2.70% which is lower than the tolerance limit. The quality assurance program should generalize for all hospitals to ensure the quality of the x-ray machines under services.

Keywords: Radiation, Quality assurance, protection, Diagnostic imaging, Accuracy, Reproducibility.

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INTRODUCTION

Medical images should provide adequate information to allow clinicians to make medical decisions with a reasonable degree of certainty. Diagnostic radiology contributes more than 90% to the collective dose of the population resulting from all manmade radiation sources. [1, 2]The patient who endures a diagnostic X-ray examination should have a adequate net benefit against the damage that the exposure might cause [3]. This can be achieved by keeping the patient doses as low as reasonably achievable while optimising the image quality and taking advantage of all the information that could be gained.

The X-ray image is the final product of a series of procedures, where different parts and types of radiodiagnostic equipment are complicated and which should co-operate to a suitable standard.

Therefore, well established quality control tests of radiodiagnostic installations are essential not only to assure the patient radiation protection but also to assure the optimisation of the information gained.

The performance of the QA is obviously critical to the assessment and control of patient doses delivered by the equipment. Sub-standard equipment performance during diagnostic X-ray procedures can give to unnecessary patient radiation exposure [4]. The main objective of the present work was to carry out of the important features of QA tests in major medical X-ray installations. Quality control tests require the use of expensive tools but we offered in this paper the easiest and most economical method to perform quality control tests.

The projects based on the department of radiology at imam Khomeini and motahhari hospitals, urmia – iran in april 2012 for 2 years.

EXPERIMENTAL

To start with the work, the list of X – ray installations located in imam Khomeini and motahhari hospitals in urmia was obtained. With prior intimation visits were arranged to the X – ray installation for carrying radiation protection survey and QA tests. The manual of QA procedure [5] was followed while performing QA tests. The relevant data collected and observations were noted in specially prepared charts and analysed.

Evaluation of examination frequencies data were collected for each of the selected X-ray rooms for a period of two weeks.

For each X-ray projection performed in the room the following parameters were recorded:

Patient name or file number, Age, sex, weight of the patient, kVp, mA, exposure time, FFD, (focus to skin distance), film size.

These data were to provide information on the relative frequency of examinations performed in the selected X-ray room, and on the technical protocols used in that room the latter providing base line information for the future quality control program in that hospital.

Quality control tests

- Quality control tests were performed on the radiographic X-ray equipment:
- Radiation protection survey
- Film reject analysis
- Accuracy and reproducibility of set kVp
- Accuracy and reproducibility of timer
- Radiation output reproducibility test
- Constancy of radiation output at different mA settings test
- Central ray centered to the middle of the bucky test
- Light field/x-Ray field alignment

- Shutter efficiency test

Radiation protection survey

This evaluative cross-sectional study was carried out april 2012 for 2 years. Convenience sampling method was used to select two hospitals with the largest concentration of radiographers sixty-five radiographers (*n* = 65) who gave consents to join in the study were recruited. Semi-structured, self administered questionnaires were used in collecting data. An list was taken of all radiation protection equipments such as lead rubber aprons, gonad shields etc and personnel radiation monitors such as film badge dosimeters in all the centers before data collection began. All X-ray machines were visually inspected and test exposures carried out on them by one the authors to ascertain their functional statuses. Knowledge was assessed based on radiographers' understanding of risks associated with diagnostic use of ionising radiation as well as measures to adequately protect themselves, patients and the public from such risks. Radiation protection practices were assessed by observing the availability and use of protective equipments such as gonad shields, immobilizers, ray field limiting devices such as light beam diaphragm (LBD), display of x-ray warning. Knowledge shall be assumed to be poor if respondents'average score on seven questions used to assess knowledge is <50%. Their radiation protection practices shall be assumed to be poor if basic radiation protection equipments such as lead rubber aprons, gonad shields, personnel radiation monitors such as film badges etc are lacking in all the centres. Furthermore, if these essential equipments are available but are not effectively utilized, practices shall also be assumed to be poor.

Film rejects analysis

The study was conducted at the Radiology Department of the imam Khomeini and motahhari hospitals over a period of nine weeks (7/5/2014-7/7/2014). During that period, all rejected films were collected from each individual X-ray room. For each rejected film the radiographic technologists had to fill in a standarized information sheet, especially prepared for the needs of the study. the 'reject rate' was defined as the number of rejected films expressed as a percentage of the overall number of films used [6, 7]. The percentage of radiographs, retaken due to an error, represented the'repeat' or 'retake' rate . The causes for rejection of films were analyzed according to the following criteria: too dark, too light, positioning, collimation errors, patient movement, other.

Films can be rejected at both the radiographer (or technologist) level and radiologist level. Comments were sought on the respective rejection rates.

Accuracy and reproducibility of kVp and timer

We measured kVp from about 60- 120 kVp (60, 70, 80, 100, and 120) and calculated error between selected and measured value. The difference between selected and measure kVp should be within $\pm$ 5%. For Accuracy and reproducibility of timer, the cassette placed on the X-ray table face up. The spinning top Placed in one quarter of the cassette. The other three quarters of the cassette coverd with lead rubber. An exposure Set of 70 kV, 100 mA and a time of 0.1 sec. The process repeaed on each of the remaining quarters of the film. The reproducibility P_z was calculated using the formula.

$$P_z = SD / Z_{av} . 100\%$$

Where : SD is the estimator of standard deviation of a series of time [s] and voltage [KV], Z_{av} is the means value of the parameters measured, time[s] or voltage [KV].

Accuracy of time and voltage [KV] setting were examined for each machine. Four exposures were recorded for time accuracy.

The accuracy Rx was calculated using the formula.

$$Rx=X_m-X_n/X_n \ \%$$

Where: X_m is the measured value of time [s] and voltage [KV], and X_n is the nominal value of time [s] or voltage [KV].

Radiation output reproducibility test

To check that the radiation output is consistent when identical exposures and conditions are used. The cassette placed face up on the X-ray table. Three quarters of the cassette covered with lead rubber, crosswise, leaving an end section uncovered. The beam Collimated to cover the uncovered section. The step wedge placed over the area to be irradiated. This procedure repeated for each of the remaining three sections. The densities compared. The conditions for all four exposures were identical; therefore all densities should be the same.

Constancy of radiation output at different mA settings test

A test to check the reliability of the mA and time settings. The photographic effect for a given mAs value should remain constant even though the mA and time factors may be varied. All other factors being constant. Three exposures used with the same kV and mAs values, but differing combinations of mA and time.

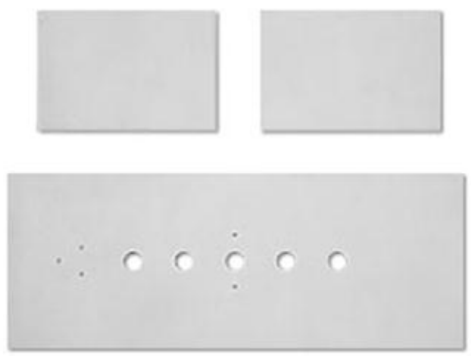
- Exposure 1: 80 kV 10 mAs (50 mA 0.2 sec)
- Exposure 2: 80 kV 10 mAs (100 mA 0.1 sec)
- Exposure 3: 80 kV 10 mAs (200 mA 0.05 sec)

Despite the fact that the mA and time vary, the mAs value remains the same, as does the kV, therefore all film densities should be the same. If the densities are not the same, then it must be assumed that one or more of the exposure factors are inaccurate or inconsistent. [8]

Central ray centered to the middle of the bucky test

The cassette placed crosswise in the bucky tray. The tube Centered to the center of the bucky. The test tool placed crosswise on the tabletop so that the central hole (the one with the two small holes either side of it) is directly over the center of the bucky and tape it down (Figure1). The central ray is therefore centered to the middle of the middle hole of the test tool. X ray Collimated to cover only the center holes. All other holes covered with the lead rubber. The tube centered over the next hole so that only this hole is uncovered. The procedure Repeated for all five holes and the identification holes, six exposures in all. [8]

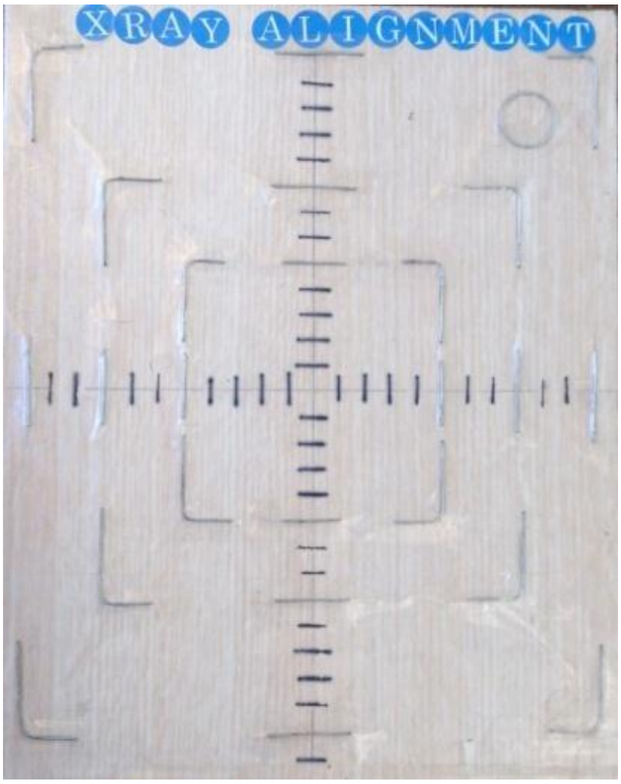
Figure 1: Grid alignment test tool



Light Field/X-Ray Field Alignment test

Loaded cassette placed on table at 100 cm focus-film distance (FFD) and collimated to three sizes of field. Light field/x-Ray field alignment test tool placed on the cassette. An exposure made of ~5 mAs at 70 kVp. [8]

Figure 2: Light field/x-Ray field alignment test tool



Shutter efficiency test

Closing the shutters in the collimator fully should prevent any radiation from reaching the film. The cassette placed on the tabletop face up. One set of shutters opened fully, leaving the other closed. An exposure made of ~40 mAs at 80 kVp. Fully the open shutters closed and fully the closed ones opened. Another exposure made. [8]

Data analysis

Data were analysed in line with specific objectives of the study. Computer programme-Excel software version 2010 was used for data analysis. The QC tests that were used are internationally accepted standards developed by the WHO and have no copyright restrictions to ensure reliability.

RESULTS

Radiation protection survey

Most modern radiation protection instruments were lacking in all the centers studied. Application of shielding devices such as gonad shield for protection was ignored mostly in hospitals. Most x-ray machines were quite old and evidence of quality assurance tests performed on such machines were lacking. Radiographers showed an excellent knowledge of radiation protection within the study period. Adherence to radiation protection practices among radiographers during the period studied was, however, poor. Radiographers should embrace current trends in radiation protection and make more concerted efforts to apply their knowledge in protecting themselves and patients from harmful effects of ionising radiation.

Film reject analysis

The analysis of the rejected films showed an overall reject rate of 8.4% during the period of the study. From the 31500 films used in the department 2646 were rejected by radiographic technologists participating in the survey. In 73 cases (2.7%), the information form was not tilled in properly, so that the confidence level of the study can be assumed to be 97.3%. By analysing the rejects we calculated the retake rate, which was estimated to a level of 3.6% (the radiologic procedure was repeated for 1148 rejected films).

Accuracy of kVp and timer

KV accuracy for different settings of five x-ray machines voltage was examined by setting the source to detector distance at 100 cm of exposure, time at 0.1 sec for different KV intervals from 60-120 KV and average of KV accuracy was presented as shown in table 1 which were its average values range between 3.25% -6.04% in imam Khomeini hospital and 2.50% -4.58% in motahhari hospital. KV accuracy is good at all KVp stations for five machine except one of the examined machines gave accuracy of 6.04% which is higher than the tolerance limit.(± 5%).

In addition time accuracy for x-ray machines was checked as shown in table 2. Time accuracy is good at all time settings stations for all examined machine which is lower than the tolerance limit. (± 10%).

Table 1: KV accuracy for different settings of five x-ray machines

mA= 200 exposure time= 0.1s Focus to Detector Distance=100cm
imam Khomeini hospital

	Tube A(M1)		Tube B (M2)		Tube c(M3)	
Nominal kVp(X_{min})	Measure kVp (X_{max})	Mean kVp Accuracy	Measured kVp	Mean kVp Accuracy	Measured kVp (X_{max})	Mean kVp Accuracy
60	63± 0.06	5.00	63± 0.008	5.00	64± 0.01	6.66
70	75± 0.07	7.14	73± 0.01	4.28	72± 0.02	2.85
80	87± 0.07	8.75	82± 0.02	2.50	83± 0.03	3.75
100	106± 0.08	6.00	102± 0.03	2.00	102± 0.04	2.00
120	124± 0.08	3.33	123± 0.04	2.50	124± 0.04	3.33
Average		6.04		3.25		3.66

mA= 200 exposure time= 0.1s Focus to Detector Distance=100cm
motahhari hospital

	Tube A(M4)		Tube B(M5)	
Nominal kVp(X_{mi}	Measure kVp (X_{max})	Mean kVp Accuracy	Measured kVp(X_{max})	Mean kVp Accuracy
60	65± 0.06	8.33	61± 0.007	1.66
70	71± 0.07	1.42	72± 0.01	2.85
80	86± 0.07	7.50	82± 0.02	2.50
100	104 ± 0.08	4.00	103± 0.03	3.00
120	122± 0.08	1.66	123± 0.04	2.50
Average		4.58		2.50

Table 2: Time accuracy for different settings of five x-ray machines

Machine No.	Mean time Accuracy % Error
M1	6.07
M2	4.25
M3	4.10
M4	3.55
M5	4.20

Reproducibility of kVp, timer and radiation output

Reproducibility for high voltage, time and radiation output for five x-ray machines were carried out for machines numbered from M1-M5 and presented as shown in table 3. Reproducibility of radiation output was ranged from 0.1 to 2.5% (tolerance limit :±10%), of time was ranged from 0.01 to 3% and of high voltage was ranged from 0.1 to 2.70% which is lower than the tolerance limit.

Table 3: Reproducibility of time and high voltage.

Machine No.	FFD [cm]	Reproducibility [%]		
		Time	High Voltage	Radiation output
M1	100	2.20	2.70	0.10
M2	100	0.40	0.30	0.20
M3	100	0.01	0.10	0.40
M4	100	0.30	0.60	0.10
M5	100	3.00	1.60	2.50

Constancy of radiation output at different mA settings test

In 4 tubes there was consistency in producing the same density using the same mAs but different combinations of mA and seconds for three exposures made at each hospital. In the other 1 tube (M1) there was differences in density for the three exposures in the resultant films. Figures 3A and 3B below show examples of test films, one with differences in density and another with equal densities from two of the hospitals.

Figure 3A: A test film showing differences in density, Fig3B.Test film showing equal densities.

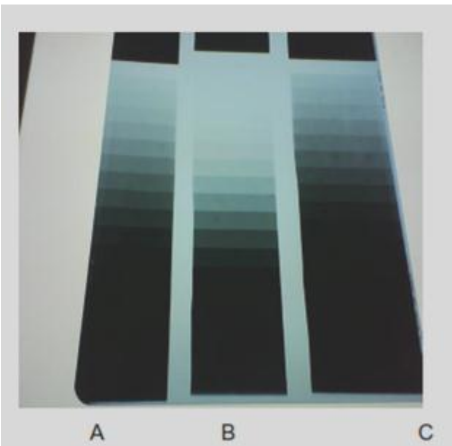


Figure 3A.

ISSN: 0975-8585

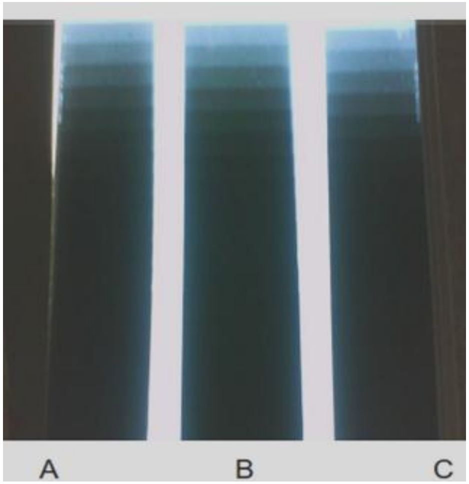
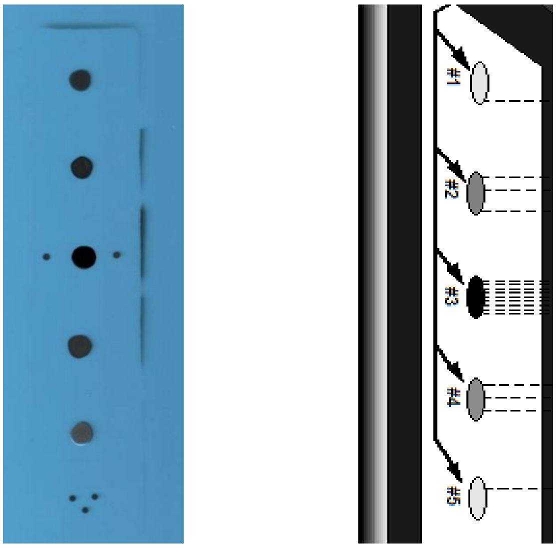


Figure 3B.

Central ray centered to the middle of the bucky test

Figure4 demonstrates the grid alignment test tool being used to test a focused grid that is in perfect alignment with the center lock position of all x-ray tubes at each hospital. When the center lock position of the x-ray tube and the center of the focused grid coincide, exposure number 3 will create the greatest density dot on the x-ray film. As the central ray is moved over the other holes of the grid alignment test tool, the optical density of the corresponding dot on the film will decrease symmetrically away from the central dot.

Figure 4. Test film showing perfect grid alignment



Light Field/X-Ray Field Alignment

According to results, in checking the light field/x-ray field alignment, in 3 (60%) tubes(M1, M4, M5) the beam alignment was misaligned.

Shutter efficiency test

The results of shutter efficiency test are presented as shown in table 4.

Table 4. Shutter efficiency

Machine No.	Lengthwise	Widthwise
M1	Fail	Fail
M2	Pass	Pass
M3	Fail	Fail
M4	Pass	Fail
M5	Pass	Fail

DISCUSSION

In the present study we have surveyed 5 X – ray installations for QA tests. In view of the poor quality of the equipments and bad practice, the rate of film rejection necessitating retakes leads to over exposure to patients in addition to overloading of machine. For mammography, the ACR recommends that the repeat rate be less than 5% [9]. This is consistent with the overall national repeat rate for radiographic films, including mammography [10-13].The analysis of the rejected films showed an overall reject rate of 8.4% during the period of the study which is higher than the tolerance limit.

Rejected films are not billable; patients receive additional radiation and may even come to hospital in another day for the repeat. Radiographer's work is increased as well as that of the support staff. The waiting room may be congested and waiting time increased. The cost of processing chemical and films are increased, thus if work is quantified in monetary terms, the cost of repeats is high.

On the test of constancy of radiation output at different mA and time settings, the results showed that out of 5 X-ray tubes that could be tested only in 1 tube were differences in density noted and in 4 tubes there were no differences. The results mean that most of the X-ray equipment produce constant radiation output according to the set mAs. Lloyd P [8] emphasized that mAs settings should be reliable to avoid producing images of lower or higher density than required, which leads to unnecessary repeats.

Actual Beam alignment and collimation QC test results, in 3 (60%) tubes the beam alignment was misaligned. The Code of Federal Regulations [14] currently requires that the individual x-ray field and light field borders agree to within ±2% of the SID. Central ray centered to the middle of the bucky in 100% of X-ray departments. Much more has to be done to monitor the equipment for beam alignment and collimation and appropriate action taken to correct the situation as beam limiting devices help to control radiation exposure to patients and improve image quality. [15] To improve the status the radiographers and radiologists must be educated for importance of QA and good work practice. Unless the X-ray tube is correctly centred to the mid-point the images produced become distorted as emphasized by Carroll. [15]

The performance of the QC test for radiation output, kVp and time measurements are obviously critical to the future assessment and control of patient doses delivered by the equipment. Reproducibility of radiation output was ranged from 0.1 to 2.5%, of time was ranged from 0.01 to 3% and of high voltage was ranged from 0.1 to 2.70% which is lower than the tolerance limit.[16]

KV accuracy is good at all KVp stations for five machine except one of the examined machines gave accuracy of 6.04% which is higher than the tolerance limit.(± 5%). [16]

Time accuracy is good at all time settings stations for all examined machine which is lower than the tolerance limit. (± 10%).[16] The x-ray tube voltage (Kilo volt [peak]), time and radiation output have a significant effect in the image contrast, the optical density and the patient dose.

The results on whether the X-ray equipment in the hospitals was being serviced or not, showed that in 2 hospitals , the equipment was not serviced. Radiographers in-Charge said the service was only done when a fault occurred. Sungita [17] stated that preventive maintenance measures of equipment are important as they ensure optimisation of quality performance. Equipment breakdowns occur due to lack of such maintenance which in turn incurs repair expenses. This lack of service and preventative measures leads tofrequent breakdown of equipment with serious financial and service delivery consequences .[18]

Lack of QA committees and QA programmes in hospitals may have resulted in having no strategies on how to ensure there are enough funds for quality improvement. There are different types of quality costs that need to be considered for quality services to be provided and to be successful. High costs may result in fixing broken equipment if the situation is not corrected by introducing QA programmes in the hospitals. Goetsch and Davis [19] stated that quality improvement reduces the cost of running a service and leads to satisfaction of customers, in this instance, the patients. Based on findings and data analysed from the study the researcher offers the following recommendations to relevant authorities related to X-ray department services and maintenance of medical equipment in hospitals in urmia. Radiographers in X-ray departments have the responsibility for ensuring the condition of quality service to patients. An undiagnostic radiograph can lead to misdiagnosis of the patient's condition and this could result in detrimental effects for the patient. Radiographers have to monitor performance of X-ray equipment from time to time as stipulated by WHO standards. QC tests are supposed to be conducted regularly to make sure the equipment is well maintained. Lack of regular testing results in frequent breakdown of equipment, which requires more funds from the government to fix or replace the equipment.

Based on our results and on reviewed literature, it is recommended that:

- All centres working with ionising radiation should ensure a strict adherence to radiation safety practices to protect radiographers, patients and the public from harmful effects of ionising radiation.
- Periodic quality assurance tests should become obligatory in all diagnostic x-ray facilities in the country.

CONCLUSIONS

In conclusion, according to results from the study there are no QA programmes and QA committees in hospitals and none in any X-ray departments. In most X-ray departments QC tests are not conducted and for those that indicated they do, there were no examples of test films to confirm that the tests are indeed conducted except in one case. A hospital needs to have a QA committee to ensure proper implementation and monitoring of the QA programme in all departments of the hospital. The lack of QA programmes for the X-ray equipment in urmia has led to frequent breakdown of machines and poor quality of radiographs resulting in greater risks of ionizing radiation. Radiographers in-Charge also have to take responsibility to ensure that the condition of X-ray equipment is well monitored and faulty parts replaced to avoid frequent breakdowns.

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