Impact of quality control on radiation doses received by patients undergoing abdomen X-ray examination in ten hospitals

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Background: The X-ray machines used for radiodiagnosis should meet certain quality assurance (QA) programmes. These are necessary to have good quality radiographs at reasonably low exposure to patients. ***Materials and Methods:*** Dose reduction methods in abdomen X-ray examination were carried out in 10 hospitals in Tehran. This paper presents the work, which was implemented on 200 patients and evaluated using the entrance skin dose (ESD) in the Anterior-Posterior (AP) abdomen projection measured directly at the center of the X-ray field. In addition, the machine room, and dark room parameters, as well as work practices and repeat rates were studied. ***Results:*** The quality control (QC) parameters and the ESD were evaluated utilizing an anthropologic phantom to define the optimal exposure condition at all hospitals before and after QC. Results show that after using the QC parameters and optimization of the exposure conditions, the mean of mAs and ESD can be decreased by 62% and 65% respectively. ***Conclusion:*** The quality of the radiographs generally increased. The reported method is easily implemented in any clinical situation where optimization of abdomen radiography is necessary. **Iran. J. Radiat. Res., 2006; 3 (4): 177-182**

Keywords: *Quality assurance, quality control, X-ray radiography, diagnostic radiology, entrance skin dose, dose reduction.*

INTRODUCTION

One hundred years after the discovery of X-rays, the diagnosis through the use of X-ray equipments is one of most important fields in clinical medicine, thus becoming the most important cause of human exposure to artificial sources. For this reason, in the last twenty years, most of the developed countries did the utmost to establish programs which could warrant the quality of the radiographic image. Optimization in X-ray imaging in order to reduce patient doses during diagnostic X-ray examinations is a complex process given the high level of image quality required(1). Experiences from the industrialized countries show that the patient absorbed dose can be greatly decreased by regular use of the QA programmes at radiology centers, and by avoiding unnecessary testig(2).

One of the main reasons of rejected radiological plates is the lack of applying QC programmes at the radiology centers. In addition, this leads to increased expenses and unnecessary exposure to radiation, which consequently increases the risk to develop cancer in patients. Unfortunately in Iran, many medical practitioners can request X-rays without reviewed by a radiologist as well as patients dose has no justified. While physicians other than radiologists also interpret films, they "look" at films incompletely. The radiologist has nearly completely examined all parts of the X-ray (in a few seconds) while the untrained physician never looks at the outside portions of the radiography. In addition, this leads to increased expenses and unnecessary exposure to radiation, which consequently increases the risk to develop cancer in patients.

In 1991, a coordinated research programme on the assessment of radiation doses in diagnostic radiology and on the study of methods for dose reduction was started in the

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International Atomic Energy Agency (IAEA) member states in cooperation with the radiation protection research action of the Commission of the European Communities (CEC). The results show that dose reduction was achieved without deterioration of the diagnostic information of the images, by applying simple and inexpensive methods[3,4] .Connected to these efforts, a QA programme was also implemented at diagnostic radiology centers in Iran[5,6].

MATERIALS AND METHODS

The present work, conducted in 2004, evaluated the performance of 10 X-ray equipments located at 10 different hospitals (1. Shariati, 2. Farabi, 3. Mirza Koochak Khan, 4. Amir Alam, 5. Medical Center of Children, 6. Ziaeian,7. Vlieasr, 8. Cancer Institute, 9. Emam Khomeini, 10. Baharloo, respectively) in Tehran.

One of the regular tests performed at radiology centers is the AP abdomen projection. The AP abdomen projection for 10 patients at each hospital was therefore considered. Optimization in abdomen radiography requires evaluation of patient dose and image quality[7] .

In our experiments, a Multi-Function Meter (MFM, RMI 240-A), a Rad- Check Plus (RCP, Victoreen 06-526), a B/W transmission densitometer (X-rite Incorporated RMI 331), a HVL attenuator set (RMI 115A), a dual color sensitometer (X-rite Incorporated RMI 334), and an anthropologic phantom (Randoman phantom, Alderson Research Lab. Inc.) were used. The darkroom conditions were tested in each hospital, including fog level, safety lights, X-ray leakage, processor parameters (temperature, developer, and rinsing),

and cassette conditions (speed, air trapping, light leakage, and cleaning). The ESD of 200 patients was measured using the RCP instrument. The exposure rate was measured at the center of the X-ray space and as legality of ALARA (As Low As Reasonably Achievable); all measurements were made with no patient in position. Water phantom to consider backscatter factor was used.

The following procedures were implemented for the selected X-ray machines:

Step 1; Determination of every patient's exposure parameters, including: kVp, mAs, Focal Film Distance (FFD), Focal Skin Distance (FSD) and ESD before starting the QC stage, which included 10 patients for AP abdomen radiography in each hospital.

Step 2; Determination of the average values of kVp, mAs, FFD, FSD, and ESD of each group of 10 patients stated in step 1.

Step 3; According to the information obtained in steps 1 and 2, corrective measures were implemented, e.g., reduction of the mAs by reducing the optical density of the film as well as optimizing the kVp, FFD, and filtration. Thereby, an anthropologic phantom, originally designed for dose measurements during abdomen data[8], was used for defining the best exposure conditions at all hospitals.

Step 4; Step 1 and 2 were repeated after the QA in step 3 for another 100 patients.

RESULTS AND DISCUSSION

The measured values of ESD were significant in this investigation. The ESD in patients before QC was between 2.65 mGy (at hospital no. 5) and 7.38 mGy (at hospital no. 6) with an average of 4.82 mGy in 10 hospitals. After determination of the ESD, in the next stage of QC, tests were performed by varying the parameters listed below.

Assessment of the X-ray equipment operation

The physical operation of the X-ray equipment is one of the most important parameters in QC. The machine parameters were, therefore, tested as presented in table 1. It is obvious that some of the machine parameters are unacceptable from the operational view, so at this stage, considering the hospitals utilities, we tried to eliminate these problems. X-ray and light space at the different hospitals were not the same, which

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Table 1. Physical operation of the X-ray equipment at the selected hospitals.

Parameters \ Hospitals	1	2	3	4	5	6	7	8	9	10
The tube is perpendicular to the table surface	+	–	–	–	+	+	–	+	+	+
Regulating lamp of X-ray space is available	+	+	+	–	+	+	+	+	–	+
Regulating light of the bucky is available	–	–	–	+	+	+	–	–	–	+
X-ray and light space are coincident	–	–	–	–	+	–	–	–	–	+
The padlocks are operating	+	–	+	–	+	+	–	+	+	+
The axis of the X-rays is perpendicular to the film surface	–	+	+	+	+	–	+	+	–	+
The grid grooves and the X-rays are in same direction	+	+	–	–	–	–	–	+	–	+
HVL (at 80 kVp)	–	+	+	–	–	+	+	+	+	+
Presence of visual light leakage in the dark room	–	–	–	–	–	–	–	+	–	+
X-ray leakage in the dark room	–	+	+	+	+	+	+	+	+	+

Acceptable: +
Unacceptable: –

leads to the need of repeated exposure and consequently increased patient absorbed dose. The leakage of visual light in the dark room causes increased fog background on the developed radiographs, which decreases the radiograph quality.

Assessment of the exposure parameters

The exposure parameters have always been one of the most important issues in QC. In this investigation, the kVp parameters (including accuracy, reproducibility, and consistency), the exposure time (including reproducibility and accuracy), and the output of the machines (including linearity coefficient and output reproducibility) were measured with the MFM and the RCP for all X-ray machines. The results are presented in table 2.

The kVp accuracy should not exceed ±5 kVp, and the reproducibility and consistency should not exceed ± 10%. As shown in table 2, at three hospitals (number 3, 4 and 5) the kVp accuracy of the machines was not up to

Table 2. Assessment of the exposure parameters for the X-ray machines used at the selected hospitals

Parameters \ Hospitals		1	2	3	4	5	6	7	8	9	10
kVp	Accuracy (kVp)	4.5	-3	7	-6	-8	2	-2	3.5	-4	5
	Reproducibility (%)	3	-2	5	-4	3	-3	3	1	-2	4
	Consistency (%)	4	-4	3	-2	-4	1	4	5	-1	2
Exposure time	Accuracy (%)	3	-4	2	-3	6	4	-2	4	2	-1
	Reproducibility	0.96	0.98	0.95	1	0.97	1.02	1.11	0.99	1.04	0.98
Output	Linearity Coefficient	4	-11	12	-11	7	12	-13	11	13	-11
	Reproducibility	0.03	0.07	0.06	0.1	0.02	0.08	0.11	0.12	0.09	0.09

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the standard, while at the other hospitals the measured kVp parameters compelled with the standards and needed no repair. The error in the exposure timer should not exceed ±10 %, and the reproducibility should be within the 0.95 to 1.05 ms range. It can be seen from table 2 that the accuracy and reproducibility of the exposure time at all hospitals was up to the standard, except the reproducibility at hospital number 7. The coefficient of output linearity should not exceed ±10 and the reproducibility should be less than 0.05(9-15).

From table 2 it is obvious that the measured values of these two parameters were up to the standard just in hospital number 1 and 5. In all the other cases, proper adjustments were done in accordance with the rate of deviation of every machine.

Finally, the whole procedure was repeated in the same way as before QC, and another 100 patients at the 10 hospitals were subjected to AP abdomen radiography (10 patients/ hospital). In this stage we tried to increase the kVp and decrease the mAs in order to decrease the absorbed dose in patients.

For each radiographic measurement/ exposure, the optical density rate depends on the FFD. Before QC in AP abdomen projection, the FFD at most of the hospitals was not regarded or measured at a distance of less than 130 cm. Hence, in the next stage the FFD was measured at 130 cm distance at all hospitals. Figure 1 shows clearly how the FFD increases after QC. Figure 2 presents the average kVp after QC, ranging from 80 kVp (at hospital no. 5) to 98 kVp (at hospital no. 9).

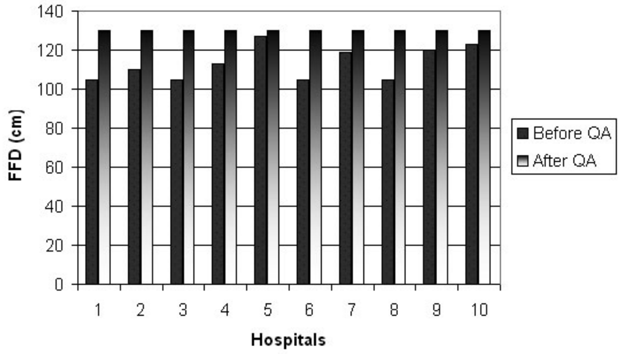

Figure 1. Average FFD measured in abdomen radiography at the selected hospitals.

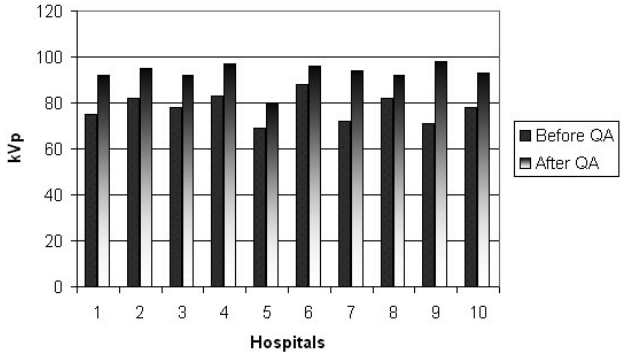

Figure 2. Average kVp measured in abdomen radiography at the selected hospitals.

Considering the increase in kVp to compensate for the optical density decrease of the plate, mAs should be decreased at the same ratio. However, changing several factors at the same time (kVp, mAs, FFD) may deteriorate the quality of the radiographs. Therefore, mAs for all hospitals were kept constant at 12 mAs. According to figure 3, we obtained stable mAs after QC by decreasing the exposure time.

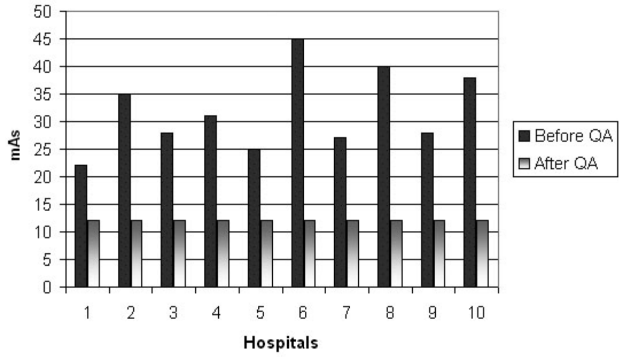

Figure 3. Average mAs measured in abdomen radiography at the selected hospitals.

Regarding the statistics of rejected radiographic plates before QC, it shows that out of 100 plates 21% were rejected for repetition. The main reason for repetition, included patients' movement (3%), underexposure (5%), overexposure (6%), exposure to external light (2%), developing conditions (3%), and positioning (2%). Repeated exposure increases the ESD in patients.

After QC, great care was devoted to eliminate these factors, and also to the

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problems with faint (colored) plates. However, during Q.C in this work, we were so careful to have no repeat rates and we helped patients and technologists and instruct some techniques to them for this case. For example by using stabilizations we avoided the patient motions. Assuring optimal conditions for X-ray exposure of patients, not only there were no more rejected plates, but also the quality of the radiographs increased generally. As we showed all patients's radiographs to radiologists for image quality evaluation. They avouched that the quality of radiographs was much better than before Q.C and also dose reduction was justified.

The ESD in patients after QC was between 1.18 mGy (at hospital no. 5) and 2.42 mGy (at hospital no.9), with an average of 1.67 mGy, which means a decrease of 65% compared to the value before QC. Figure 4 shows a comparison between the average ESD of patients before and after QC.

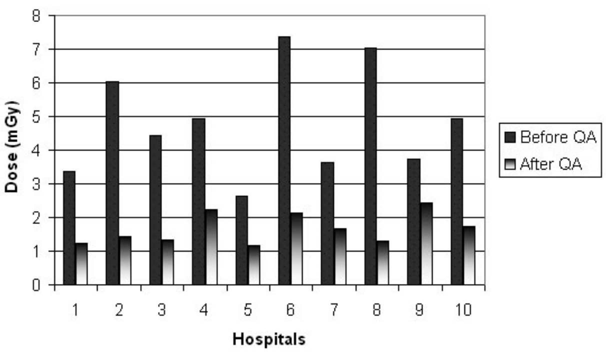

Figure 4. Average ESD measured in abdomen radiography at the selected hospitals

In table 3 we summarized the change in average due to the change of exposure parameters and ESD. Table 4 shows the percentage of change of each exposure

Table 3. The average of the exposure conditions in chest examination before and after QC at all hospitals.

QC Parameters	Average values	
	Before QC	After QC
kVp	78	94
mAs	32	12
FFD (cm)	113	130
ESD (mGy)	4.82	1.67

Table 4. The percentage of change of the average exposure parameters, and the rate of decrease in ESD at all hospitals.

QC parameters	Alteration (%)
kVp increase	21
mAs decrease	62
FFD increase	15
ESD decrease	65

parameter and the rate of decrease in ESD. The results show that by applying these simple and inexpensive methods a considerable dose reduction was achieved without deterioration of the diagnostic information in the images.

CONCLUSION

The study revealed that the average ESD of patients before QC were higher than the other studies and after QC the average ESD of patients were lower. The doses measured by this study were not alarming but significant.

According to the obtained results, the difference between the average ESD before and after QC in AP abdomen radiography is 3.15 mGy. Although individual doses are usually small, in total exposure, diagnostic x-rays account for the major portion of man-made radiation exposure to the general population. Based on the available data[(6)], the total number of AP abdomen radiographs in 1994 in Iran was 1.6 million, and the estimated number in 2005 has increased to more than 2 million. So, the reduction of 65% for patients' exposure in abdomen AP projection can be lead to a significant reduction of collective dose in Iran. According to this figures, and if we consider our evaluated difference due to QC as a general result for Iran, the reduction of the patients' exposure in abdomen AP can be estimated to about (2000000 × 3.15) 6300000 man-mGy. Hence, the total dose can be decreased with 6300 man-Sv as a result of the proposed method. It is obvious that with the QA/QC program, the exposure of the patients to

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other kind of radiological tests can also be decreased. Consequently, the risk of inducing cancer in patients will be effectively limited.

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