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Survey Effect of the Corrective Actions and Quality Control in Image Quality and Patient Dose in Radiography Examinations

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ABSTRACT

Objectives: X-ray exposure in medicine is considered to be the major part in man-made radiation. The purpose of this study was to survey the effect of optimization in image quality and entrance skin dose for patients in radiographic examinations.

Methods: In this survey, seven radiographic examinations were studied. First, patient dose of radiation was measured and the quality of the radiography images was considered. Also, the number and causes of rejected films were checked. Then, corrective action of the European Commission (EC) was implemented and quality control of radiology equipment was performed. Once more, patient radiation dose, quality of radiographic images and number and cause of rejected films were analysed.

Results: The image quality was not convenient before corrective actions. With implementation of the corrective actions, the quality of radiographic images was increased so that it was statically significant. Total rejections in all types of radiographies were 18.33% and 11.17%, respectively, before and after improvements. Entrance Skin Dose for patients was 1.59 mGy before improvements and 1.21 mGy after improvements.

Conclusion: The result of this survey demonstrated that it's possible to implement a program for coordination of protection optimization in general radiology. After implementing the corrective actions for optimization of protection, the radiation dose decreased with clinically acceptable images as well as with the number of rejected films. This decreased dose can reduce cumulative dose, which reduces probability of cancer risk and genetic effects in society.

Keywords: Radiological examination, Entrance skin dose, Image quality, Rejected film, P-value

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Introduction

Nowadays, imaging techniques are so improved and without applying these techniques correct diagnosis is impossible in many injuries and diseases. On the other hand, the biologically harmful effects of radiation are obvious [1]. All national and international organizations always persist in minimizing the use of this radiation. The International Commission on Radiological Protection (ICRP) emphasizes three principles: justification; optimization protection and dose limit [2]. Justification is the first step in radiological protection. It is accepted that diagnostic exposure is justifiable only when there is a valid clinical indication, no matter how good the imaging performance may be. Each examination must result in net benefit to the patient. Once a diagnostic examination has been clinically justified, the subsequent imaging process must be optimized to obtain the required diagnostic information for a patient dose that is as low as can be reasonably achieved. Because the diagnostic medical procedures are usually for the direct benefit of the patient, somewhat less attention has been given to the optimization of protection in medical exposure than other applications using radiation sources [3] and this is a danger due to increasing the patient dose in society. In the optimization area of diagnostic radiology, there is considerable scope to reduce doses without the loss of diagnostic information, but the extent to which the measures available are used varies widely. The protection optimization in diagnostic radiology does not necessarily mean the reduction in patient dose; it is paramount that the obtained image contains the intended diagnostic information [4]. In this study, we try to decrease the patient dose or keep it at a permissible qualitative level. For this aim, the radiation dose was measured in patients and the image quality and the number of rejected films was checked. Then, the corrective action was implemented and again the whole process was analysed. Also, we demonstrated in practice that quality assurance programs and quality control protocols are the essential parts of the optimization process. Therefore, to cover physical and technical parameters, such programs are associated with the types of X-ray examinations and are carried out to be investigated in any medical X-ray facility. This research aimed to study the optimal effect of the corrective actions and quality control in image quality as well as in the patient dose in radiographic examinations.

Material and Methods

This study aimed to survey the corrective actions of affection and quality control on patient dose and image quality in radiography. The survey was performed in four radiography rooms in one of the hospitals of Ilam. This hospital had the maximum number of patients in all of Ilam's hospitals. Seven radiography examinations were evaluated such as: Chest PA (Posterior-Anterior), Chest Lat (Lateral), Skull AP, Skull Lat, Pelvis, Lumber Spine AP and Lumber Spine Lat. First, we measured patient dose in each examination. In general radiology, Entrance Skin Dose (ESD) and Entrance Surface Air Kerma (ESAK) in mGy expressed the dose amount. Four record exposure factors and other effective factors in ESAK were provided on the forms completed by all personal. These forms consisted of some information such as: the number of radiography rooms, equipment types and models, year of utilization of X-ray equipment, kVp (kiloelectron-Volt peak), mAs (miliampere-second), FSD (Film-Screen Distance), FOV (Field of View) and type of patients (fat adult upper than 80 kg, moderate adult between 60 and 80 kg and thin adult less than 60 kg – child – infant). Simultaneously, with radiation factor registration by personal, X-ray equipment output was measured by one of the modern solid state dosimeters. In this case, we performed an exposure and gained output. This action has been done for different kVp (constant mAs, constant FSD and FOV). Actually, it gained tube output for different kVp with the Barracuda dosimeter that is produced by RTI electronic company. This device can measure mAs, kVp, dose, dose rate and Half Value Layer in one expose. Then, with this data, the ESAK was estimated. The ESAK formula calculation is as follows:

$$\mathrm{ESAK} = \frac{\mathrm{H} \times \mathrm{mAs}}{\mathrm{d}^2} \qquad \mathrm{Eq.1}$$

where H is tube output, mAs is tube current and d is film for source distance.

ESAK does not include backscatter factor (BSF) and cannot be the correct patient estimate dose. For this, with multiplication BSF (BSF represented by ICRP and other international organizations [5] in ESAK, the ESD resulted. ESD is a correct estimate from patient dose.

$$\mathrm{ESD} = \frac{\mathrm{H} \times \mathrm{mAs}}{\mathrm{d}^2} \times \mathrm{BSF} \qquad \mathrm{Eq.2}$$

Then image quality was evaluated by anatomists and expert radiology technologists. To optimize, dose monitoring is often conducted with image quality assessment. This is a common practice in many parts of the world [6-11]. The patient exposures need minimum necessity to observe the needed diagnosis and to accept the image quality in the clinical purpose. This necessity has been established by the professional organization. In this study, the European Commission (EC) instruction was used for the criteria of evaluation in radiography image quality [12]. In each radiography examination, the image quality survey was done by presenting the EC check lists. Then, the numbers and causes of the rejected films were evaluated. In each radiography examination, about 180–200 images were considered. To probe, the image quality was evaluated in about 60–85 rejected films. In the next step, implementing six quality control examinations of X-ray equipment consisted of: kVp accuracy; time accuracy; radiation output linearity; radiation output linearity than mA; radiation output linearity than time and evaluating Half Value Layer (HVL) and available faults were resolved in necessity. Corrective action was also performed according to recommendation of the EC for each radiography examination (expressed in Appendix). After these actions, again radiography image quality and numbers and causes of rejected films were evaluated. Finally, ESD was calculated. All data were processed in computer and analysed by SPSS software version 21.

Results

Following data collection and analysis, the results are illustrated in the following tables and diagrams. The results show that the image quality was not acceptable before the corrective actions and with implementing-

Table 1. Comparing ESD of patients before and after corrective actions and that *p*-value

Type of examination	Patent type	ESD (mGy)				
		Before optimization		Radiation dose after optimization (mGy)	comparing	
		Mean radiation dose (mGy)	Standard deviation		Mean difference	P-value
Chest PA	Fat adult	0.48	0.34	0.96	-0.47**	<0.001
	Moderate adult	0.31	0.24	0.69	-0.38**	<0.001
	Thin adult	0.23	0.15	0.12	0.105**	0.005
	children	0.14	0.08	0.12	0.017	0.31
	infant	0.06	0.03	0.05	0.007	0.25
Chest LAT	Fat adult	0.95	0.49	1.33	-0.38**	0.003
	Moderate adult	0.63	0.32	0.88	-0.25**	0.002
	Thin adult	0.47	0.23	0.44	0.03	0.56
	children	0.27	0.14	0.31	-0.04	0.22
	infant	---	---	----	----	----
Lumbo sacral AP	Fat adult	4.86	3.52	3.1	1.76*	0.032
	Moderate adult	2.9	1.79	2.12	0.82*	0.049
	Thin adult	1.92	0.9	1.36	0.56**	0.009
	children	0.62	0.43	0.39	0.23*	0.02
	infant	0.22	0.21	0.07	0.15**	0.003
Lumbo sacral LAT	Fat adult	7.41	3.54	4.45	2.95**	0.001
	Moderate adult	5.29	2.47	3.42	1.87**	0.002
	Thin adult	4.25	2.67	2.13	2.12**	0.002
	children	1.12	0.86	0.53	0.58**	0.005
	infant	0.32	0.21	0.07	0.25**	<0.001
Pelvic	Fat adult	4.05	3.15	2.7	1.35	0.06
	Moderate adult	2.85	2.44	2.25	0.59	0.28
	Thin adult	2.02	1.33	1.32	0.7*	0.02
	children	0.47	0.48	0.26	0.21	0.05
	infant	0.22	0.2	0.07	-0.48**	<0.001
Skull PA	Fat adult	2.14	0.99	2.11	0.02	0.9
	Moderate adult	1.72	1.03	1.7	0.02	0.9
	Thin adult	1.5	0.9	1.25	0.26	0.19
	children	0.77	0.51	0.67	0.09	0.38
	infant	0.44	0.28	0.11	-0.33**	<0.001
Skull LAT	Fat adult	1.84	0.87	1.7	0.14	0.46
	Moderate adult	1.53	0.84	1.36	0.17	0.36
	Thin adult	1.25	0.69	1	0.25	0.11
	children	0.63	0.42	0.51	0.12	0.22
	Infant	0.34	0.37	0.07	0.27**	0.003

*Significant at P < 0.05
**Significant at P < 0.001

corrective actions the increase was statistically significant. The images qualities were evaluated in Figures. 1–5. For instance, in merely one of them, in the case of Chest PA, maximum mark is 10, while minimum mark is 1 (chart No. 1).

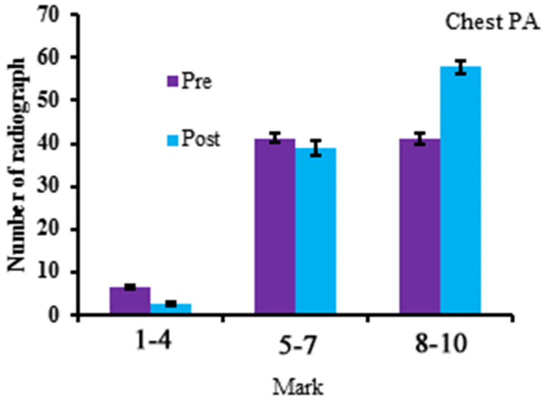

Figure1. The radiographic marks in Chest PA before and after corrective actions

For generalization and easy understanding, it was assumed that marks 1 to 4 are low, 5 to 7 are fair and 8 to 10 are acceptable quality. In Chest LAT the maximum mark for quality was 9; 1–3 was considered low, 4–6 fair, 7–9 acceptable quality. In the Lumbar AP examination, the maximum mark was 6; 1–2 was considered low, 3–4 fair and 5–6 acceptable quality.

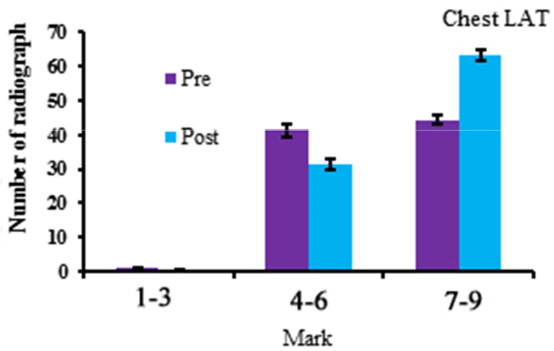

Figure 2. The radiographic marks in Chest LAT before and after corrective actions

In Lumbar LAT, maximum mark was 5; 1–2 was low, 3 was fair and 4–5 was acceptable quality. In Pelvic AP, the maximum was 6; then 1–2 low, 3–4 fair, 5–6 acceptable quality. In Skull, maximum mark was 6; then 1–2 low, 3–4 fair, 5–6 acceptable quality. In Skull LAT; maximum mark is 11; 1–5 low, 6–8 fair, with 9–11 being acceptable quality. In this study, the main reasons for rejections of films was their poor quality which was investigated. Figure 6 shows all these reasons in detail, before and after corrective actions. To observe the advantages of quality assurance programs and improvements in reducing number of rejections and having better quality, their percentiles are showed graphically in Figure. 7. Also, total rejections in all radiographies types are 18.33% and 11.17%, respectively, before and after improvements. In Table 1, the result of the measurement of patient dose was compared before and after corrective actions. For this, the comparison used one sample *t*-test and we calculated *P*-value.

Discussion and Conclusion

When a diagnostic examination is justified in the clinical aspect, the imaging process should be optimized until the necessary diagnostic information is obtained and also, the patient dose is performed in the lowest logical level achievable to optimize the imaging process based on EC recommendation implementing corrective actions and quality control in radiology equipment. Muhogora et al. (2008) examined 12 countries in Asia, Africa and Eastern Europe and showed that the fraction of images rated as poor was as high as 53% (13). Following from this, the image quality increased to 16% points in Africa, 13% in

Asia and 22% in Eastern Europe after quality control (QC) program installation and in this study, the image quality increased to 17%.

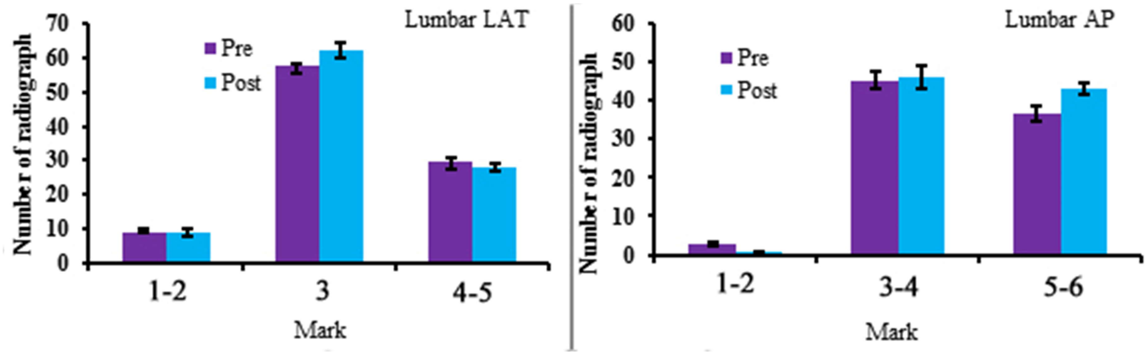

Figure 3. The radiographic marks in Lumbar AP and LAT before and after corrective actions

Also, they suggested that the patient dose reductions ranging from 1.4% to 85% were achieved, which was about 70% in this study. In another study, Farzaneh et al. (2011) showed that the quality of radiographic images increased between 0% and 10% after launching the quality control program.

to 17% and patient dose reduced to 70%. Saure et al. (1995) showed a reduction in patient dose from an average 9.2 µGy to 5.4 µGy. Also, they suggested dose reduction to 25% or less without loss of information [15]. Also, this study showed that patient dose reduction from 1.59 mGy to 1.21 mGy was achieved with improvement in image quality. In another study, Ahmad et al. (2009) evaluated patient dose and image-

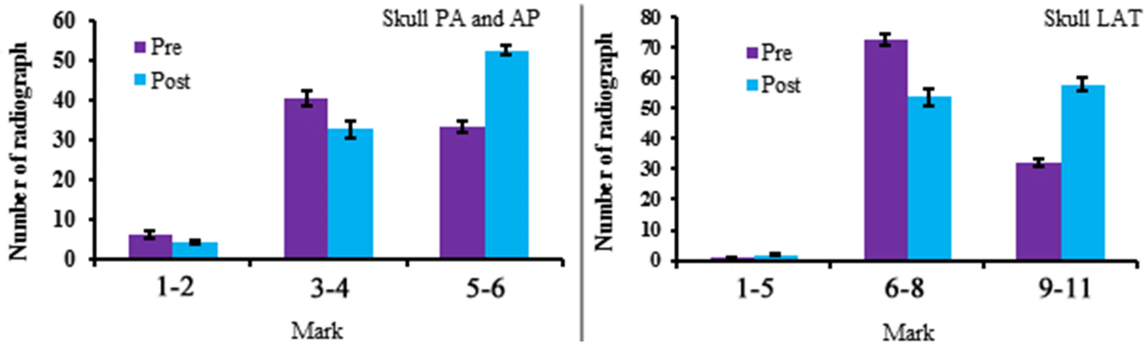

Figure 4. The radiographic marks in Skull PA or AP and LAT before and after corrective actions

Their results showed that quality of a quality control program is essential to reduce patient dose and increase radiographic image as well as to ensure all radiological examinations are performed under the terms of lower received dose for the patients and the best qualitative images [14]. Results obtained in this study were similar to their study in such a way image quality increased

quality in radiography [16]. The reject analysis showed a repeated range of 4.5%–24.27% at the radiographs level and after corrective actions showed a reduction per cent of repeated range of 2.6%–19.3%. However, in this study the total rejections were 18.33% and 11.17%, respectively. Also, they showed that the patient dose reduced after corrective action was similar to the result of this study. Implementation of an optimization program increased radiography image quality in all examinations studied (Figures 1–5).

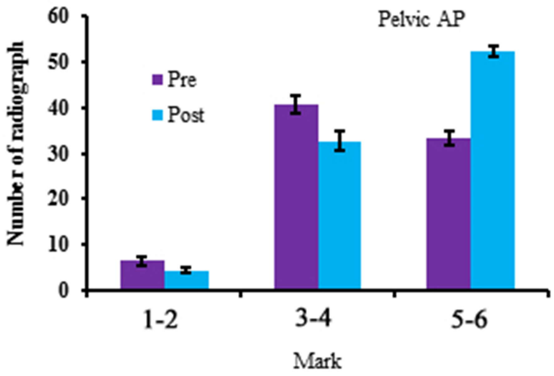

Figure 5. The radiographic marks in Pelvic AP before and after corrective actions

This increased image quality is very important because the disease diagnostic improved it as the final aim of the imaging process and also prevented repetition of the radiography examination.

patient dose. And it increased the rejected films percentages caused by patient movement and position/collimation error not being the direct effect on the patient dose (Fig. 6).

This can decrease the patients' doses of radiation. In this study, the optimization program, cause in decrease patient dose generally being obvious in Figure. 8. The effect of the optimization program on the patient dose in each radiography examination is illustrated in Table 1. Regarding this point, we found that increased patient dose was observed after optimization program in the Chest PA and LAT in fat and moderate adult patients. The cause of this increase is low image quality in the two examinations before optimization program and the image quality is acceptable with implementing the optimization program (Figs. 1–2).

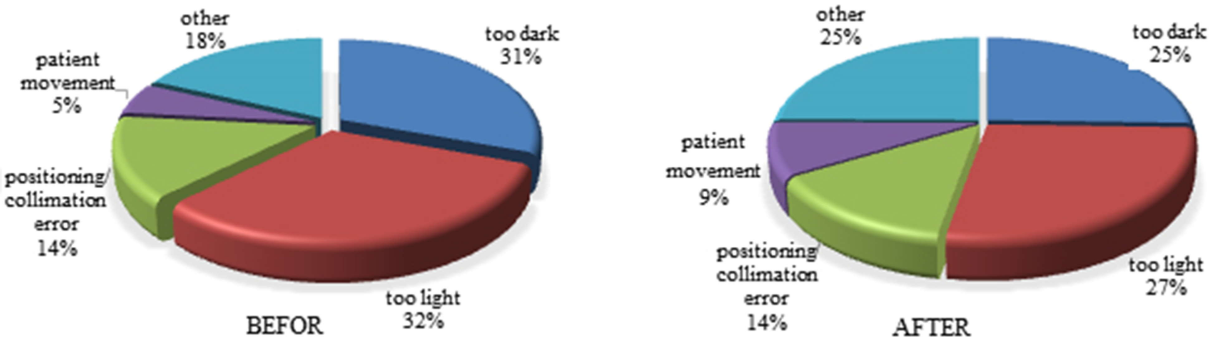

Figure 6. Percentage of rejected films with the reasons before and after corrective actions

Figure 7 shows that following the optimization program, reduced the number of rejected films and saved the allocated time, as well as cost and decreased the radiation doses of patients. After implementing the optimization program, the per cent of too light and too dark rejected films was reduced as the direct effect of

In this study the radiated dose to the patients is still lower than international levels and other studies. Patient dose after optimization program in Chest LAT in children was observed. Its P-value was more than 0.05 and was not statistically significant. Except in the above cases, dose in other selective radiography examinations was reduced as well as for all types of patients. In some cases, as changes show in Table 1, this radiation dose is not statistically significant, however, it is very important in radiobiology as well as in the radiation protection aspect because any small reduction in radiation dose can reduce the probability of radiation damage.

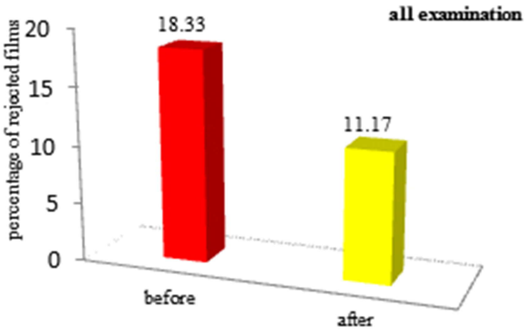

Figure 6. Percentage of rejected films with the reasons before and after corrective actions

The results of this study show that, in general, applying the protection optimization is available in diagnostic radiology. After implementation, corrective actions in protection optimization led to decrease in the radiation dose with clinically acceptable images as well as decrease in the number of rejected films. This radiation dose reduction both decreases the collective social dose and the risk of human cancer types as well as genetic effects. Because cancer and genetic effects are the stochastic and non-threshold effects, they are independent of dose rate. Therefore, any slight radiation dose reduction can decrease the probabilities of danger. It is worth noting that ESD reduction in children and infants happened after implementing the corrective actions in this study due to Genetically Significant Dose (GSD) decreases. Radiation test is more sensitive in infants and children than in adults. Therefore, ESD reduction in infants and children is followed by the optimization program being more important than in adults, because these patients are more sensitive than the others. Finally, a ‘culture’ of regular patient dose measurements, film rejects analysis and image quality assessment needs to become part of diagnostic radiology.

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Appendix

List of corrective actions for radiographic diagnosis:
CHEST PA and LAT:
1. Radiographic device: vertical stand with stationary or moving grid
2. Nominal focal spot value: ≤1.3
3. Total filtration: ≥3.0 mm Al equivalent
4. Anti-scatter grid: r = 10; 40/cm
5. Screen film system: nominal speed class 400
6. FFD: 180 (140–200) cm
7. Radiographic voltage: 125 kV
8. Automatic exposure control: chamber selected - right lateral
9. Exposure time: PA: <20 ms, LAT: <40 ms
10. Protective shielding: standard protection

Skull PA and LAT:
1. Radiographic device: grid table, special skull unit or vertical stand with stationary or moving grid
2. Nominal focal spot value: 0.6
3. Total filtration: ≥2.5 mm Al equivalent
4. Anti-scatter grid: r = 10; 40/cm
5. Screen film system: nominal speed class 400
6. FFD: 115 (100–150) cm
7. Radiographic voltage: 70–85 kV
8. Automatic exposure control: chamber selected - central
9. Exposure time: <100 ms
10. Protective shielding: standard protection

Lumbosacral AP and LAT:
1. Radiographic device: grid table or vertical stand with stationary or moving grid
2. Nominal focal spot value: ≤1.3
3. Total filtration: ≥3.0 mm Al equivalent
4. Anti-scatter grid: r = 10; 40/cm
5. Screen film system: nominal speed class 400
6. FFD: 115 (100–150) cm
7. Radiographic voltage: PA: 75–90 kV LAT: 80–95 kV
8. Automatic exposure control: chamber selected—central
9. Exposure time: PA: <400 ms LAT: <1000 ms
10. Protective shielding: where appropriate, gonad shields should be employed for male patients and for female patients if possible.

Pelvic:
1. Radiographic device: grid table
2. Nominal focal spot value: ≤1.3
3. Total filtration: ≥3.0 mm Al equivalent
4. Anti-scatter grid: r = 10; 40/cm
5. Screen film system: nominal speed class 400
6. FFD: 115 (100–150) cm
7. Radiographic voltage: 75–90 kV
8. Automatic exposure control: chamber selected - central or lateral
9. Exposure time: <400 ms
10. Protective shielding: where appropriate, gonad shields should be employed for male patients and for female patients if possible.