Survey of Image quality and Patient Dose in Simple Radiographic Examinations in Madagascar: Initial results

Marie Jeanne Ramanandraibe
Institut National des Sciences et Techniques Nucléaires, Antananarivo, MADAGASCAR
Raoelina Andriambololona
Institut National des Sciences et Techniques Nucléaires, Antananarivo, MADAGASCAR
E.C Rakotoson
Centre de Soins et de Santé, Antananarivo, MADAGASCAR
Virginia Tsapaki
Konstantopoulio Hospital, Athens, GREECE
Hans Gfirtner
Graf Tiemo Str. 16, D-94127, Neuburg, GERMANY

Abstract - The purpose of this study is to survey image quality and patient doses in radiographic examinations and to perform comparisons with the international Diagnostic Reference Levels (DRLs). This study is part of an International Atomic energy Agency (IAEA) project (RAF/9/033) and one public hospital and two private hospitals were selected. The rate of unsatisfactory images and image qualities grade were noted, and causes for poor image quality were investigated. Doses delivered to patients were determined in terms of entrance skin dose (ESD) based on X-ray tube output measurements and X-ray exposure parameters. Corrective actions were taken mainly in terms of field size and exposure parameters adjustment and data were recollected. The image quality was improved up to 35 % in these three hospitals. Results showed that there is a large variation of patient doses for common examination in three hospitals. Patient dose reductions ranging from 2 to 82% were achieved. Comparisons of dose levels with IAEA Guidance Levels (GLs) after implementing corrective actions showed that patient doses are lower than reference levels except for chest exam in two hospitals and skull in one hospital. Actions are under way to extend measurements to a national level in order to establish national GLs.

Keywords— Radiography, patient dose, optimization, radiation protection

1. INTRODUCTION

The use of ionizing radiation in medical field contributes significantly to the source of exposure of the population. The Basic Safety Standards [1] require attention to the image quality and to consider corrective actions if patient exposures do not provide useful diagnostic information and do not yield medical benefits to patients. Images of poor quality have been reported in earlier studies to be as much as 15-40 % of all images [2-3]. Poor quality images result in unnecessary radiation exposure to patients through repeated radiographic examinations, loss of diagnostic information, and increase social costs in addition to the economic costs of health care. Experiences from various national surveys have shown that there is a large variation of patient doses for the same examination up to a factor of 20 or more in different hospitals or even in different rooms [4-5]. In 1982, the International Commission on Radiological Protection (ICRP) stated that the dose to patients from a given type of examination may vary between hospitals by a factor of 2 to 10 [6].

The International Atomic Energy Agency (I.A.E.A) initiated within the framework of a research project a study on the possibility of reducing the doses delivered to patients undergoing X-ray examinations in radiography and computed tomography [7]. Dose reduction of 20 up to 69% was noted. In 1996, the ICRP [8] recommended that this step should be implemented at national level according to the techniques and radiological facilities used. In Madagascar, patient dose assessment undergoing different X-ray procedures was planned in 2005 under the IAEA project, RAF/9/033 entitled “Strengthening Radiological Protection of Patients and Control of Medical Exposure” for 15 African countries.

A pilot study to survey image quality and patient dose in the most common radiographic examinations and to compare assessed dose to IAEA Guidance levels (GLs) was performed by the Institut National des Sciences et Techniques Nucléaires (Madagascar-INSTN) in three hospitals. The present paper describes the results of the work carried out in this study.

2. MATERIALS AND METHODS

For this study, one public hospital (hospital 1), with two X-ray rooms and two private hospitals (hospital 2 and hospital 3) with one room respectively were selected. The project was implemented in two phases. The work in phase I involved assessment of the baseline data by scoring image quality and identification of the causes for poor image quality for a 2 weeks period. Each radiographic image was graded as A, B and C. Grade A images were those clearly accepted by reporting radiologists without any remark or reservation. Grade B included all images that were accepted with some remarks or reservations. Grade C images were those that should be rejected. Along with image quality analysis, patient dose assessment for a sample of 10 adult patients per selected radiographic projection was performed. Before patient dose assessment, information on X-ray exposure parameters (kVp, mAs) and geometric parameters (X-ray tube focus-skin distance, and film size) used in radiographic examinations of the selected patients was collected. The surveyed X-ray exposure parameters were used later to estimate patient doses through a two steps protocol: X-ray tube output measurements, and entrance skin dose (ESD) calculation.

2.1. X-ray tube output measurements

X-ray tube output measurements were conducted using Ratemeter- Timer, Model 3036, with an internal ionization chamber, calibrated at the Secondary Standard Dosimetry Laboratory (SSDL) of Madagascar-INSTN. The dosimeter was positioned in central beam axis such that the X-ray tube focal spot –detector-distance (FDD) was 100 cm. The radiation field size (FS) at FDD was set just to cover the dosimeter in order to avoid the possible influence of scatter radiation to the dosimeter. The tube potential was set at 50 kVp and any mAs value (depending on convenient tube load conditions), an X-ray exposure made and the dosimeter reading recorded. This step was repeated once more at same kVp and mAs settings and the average dosimeter reading determined. The X-ray tube output was determined as the ratio of average dosimeter reading (air kerma) to the tube current-time product used. Similar X-ray tube output measurements were determined for 60, 70, 80, 90, 100 and 120 kVp settings or closest values depending on typical selectable kVp values. The values of X-ray tube output were plotted against tube potential and the resulting output-kVp curve fitted to a square function.

2.2. ESD determination

The ESD for each adult patient undergoing particular X-ray examination was determined from the product of X-ray tube output (derived from output-kVp curve corrected for the inverse square law between the patient‘s distance from the X-ray focus and distance of output measurements), the mAs used during X-ray examination and the back scatter (BSF). The BSF value of 1.35 was used in this work, as suggested in the European Guidelines [9]. The average ESD was compared with the international Guidance Levels (GLs) recommended by the IAEA for each examination [1]Before beginning phase II of this project, basic quality control (QC) tests were performed to identify equipment malfunctions and to apply corrective actions based on image quality analysis and equipment performance. Finally in Phase II, a second series of image quality analysis and patient doses assessment for the same type of examinations as in phase I was performed, after having implemented corrective actions to investigate possible patient dose optimization.

3. RESULTS

Results of the study are summarized in the following tables.

Table 1: Corrective actions taken before implementing Phase II

	Hospital identification			
Corrective actions	**H_1 (room 1)**	**H_1 (room 2)**	**H_2**	**H_3**
Field size adjustment	X	X	X	X
Change in exposure parameters	X	X	X	X
Change of focus to film distance in chest exam			X	

Table 2: Image quality improvements before and after implementing a quality control programme

Hospital identification	Image quality (%)					
	Grade before QC			Grade after QC		
	A	B	C	A	B	C
H_1 (room 1)	41	56	3	52	47	1
H_1 (room 2)	40	56	4	54	45	1
H_2	96	3	1	98	2	0
H_3	90	5	5	94	3	3

Table 3: Mean ESD (mGy) before implementing a QC programme

	Hospital identification				GLs (mGy)
Exam	**H_1 (room 1)**	**H_1 (room 2)**	**H_2**	**H_3**	
Chest	2.4	-	0.4	1.3	0.4
Lumbar spine AP	-	-	5.3	24.3	10.0
Lumbar spine LAT	-	-	9.0	70.9	30.0
Pelvis	-	22.4	5.3	23.2	10.0
Abdomen	12.0	-	5.3	22.9	10.0
Skull	9.3	15.0	4.0	20.6	5.0

Table 4: Mean ESD (mGy) after implementing a QC programme

	Hospital identification				GLs (mGy)
Exam	**H_1 (room 1)**	**H_1 (room 2)**	**H_2**	**H_3**	
Chest	0.7	-	0.3	0.5	0.4
Lumbar spine AP	-	-	4.4	7.2	10.0
Lumbar spine LAT	-	-	8.8	24.0	30.0
Pelvis	-	7.0	4.2	6.6	10.0
Abdomen	4.8	-	4.2	4.5	10.0
Skull	3.3	6.1	3.8	3.6	5.0

Table 2 presents the results of the image quality assessment before and after implementing a quality control programme. It can be seen that poor quality (grade B and C) ranged from 4% to 56 % before implementation of QC programme. The analysis of B and C grade films showed that the major causes of poor quality was due to the existence of artefacts (79%, 79 %, 75%, 100% in Hospital 1, room 1 and 2, Hospital 2 and Hospital 3 respectively), followed by field misplacement (25% in Hospital 2) and over or under exposure (17% in both rooms of hospital 1). The analysis of results indicates that the image quality has improved as grade A films increases ranged from 2% to 35%.

The results of mean ESD to adult patients undergoing radiographic examinations in the three hospitals before and after implementing a QC programme are presented in tables 3 and 4. The GLs recommended by IAEA in terms of ESD [1] are also indicated. Comparison with these GLs values showed that after implementing corrective actions, the ESD values were significantly lower than before QC and they are even lower than the international values [1], except for chest exam in room 1 of Hospital 1 and Hospital 3 and skull exam in the second room of Hospital 1. For these latter, the ESD values were slightly higher than the IAEA GLs.

Table 5: Percentage of dose reduction after implementing corrective actions

Radiographic projection	**Dose reduction (%)**			
	H_1 (room 1)	**H_1 (room 2)**	**H_2**	**H_3**
Chest PA	71	-	34	59
Lumbar spine AP	-	-	17	70
Lumbar spine LAT	-	-	1	66
Pelvis	-	69	21	72
Abdomen	60	-	21	80
Skull	65	65	6	82

For participating hospitals, the results showed (tables 3 and 4) that the ESD varied by a factor of 6 (chest posteroanterior), 5 (lumbar spine anteroposterior), 8 (lumbar spine lateral), 4 (Pelvis), 4(Abdomen), and 5(skull). The main explanations of the discrepancies, between rooms, and between the different hospitals are given by the exposure parameters used and the total tube filtration. The ESD reductions for patients undergoing the most common radiographic examinations as a result of implementing a QC programme in the three hospitals are presented in table 4. The achieved ESD reductions ranged from 2 to 82%. The maximum dose reduction was found in Hospital 3. Dose reductions were achieved by increasing tube potential, reducing mAs and field size adjustment.

4. DISCUSSION

The initial results of the study in 3 major hospitals in Madagascar show that image quality was improved and patient doses were optimized after corrective actions in these hospitals. Surveys on the status of image quality and radiation doses to patients in radiographic examinations form an important component of a QA program. Information on image quality and patient doses is better known in developed countries, where QA programs have been already set up and a number of national surveys performed. However, similar information is grossly lacking in majority of the developing countries where efforts to establish QA programs were initiated by IAEA. Therefore the information obtained in the present study in conventional radiography practice is aimed at assessing the situation, in terms of differences in practices and potentials for optimization such that it can be used to contribute to establishment of QA programs. Madagascar has regulation on radiation protection that is based on the International Basic Standards [1] and use of radiation sources in medical field is included in this regulation. According to this national regulation, QC is required before issuing authorization for possession and use of X-ray equipment, but image quality analysis and patient dose assessment are not included in this procedure. Efforts should be made to set up QA programme in each hospital to ensure that appropriate radiation exposure is delivered to the image receptor to produce an image quality that is adequate for the diagnostic task. A large variation of patient doses has been observed. In a United Kingdom survey, the variations expressed in terms of maximum to minimum ratio ranged from 53 to 283 [4]. In this study, the variations are smaller, probably because of the small number of three hospitals in this study against 371 for U. K national survey.

5. CONCLUSION

The survey of image quality and patient dose levels in 3 hospitals in Madagascar has been presented. Although the majority of ESD were lower than international values after implementing corrective actions, the existence of high entrance skin doses needs a regular patient dose assessment for optimal results. The potential for increased awareness on such optimization need is one positive impacts of this study in reducing unnecessary patient dose. By comparing local practice against IAEA GLs, it was demonstrated that guidance levels are important for the optimization of patient protection in diagnostic radiology. Establishment of national GLs in medical exposure should be given a high priority in country participating in the IAEA project RAF/9/033. This study was performed only in 3 hospitals in the capital city. Actions are under way to extend measurements into a national level in the near future in order to establish GLs in Madagascar. Initial results showed that image quality can be improved and patient doses can be reduced simply by increasing the tube potential values, reducing of both mAs and field size parameters by keeping image quality.

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