THE IMAGE QUALITY AND PATIENT DOSES IN SIMPLE RADIOGRAPHIC EXAMINATIONS: ESTABLISHING GUIDANCE LEVELS AND COMPARISON WITH INTERNATIONAL STANDARDS.

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ABSTRACT

The International Atomic Energy Agency (IAEA) mentioned in the International Basic Safety Series Number 115 that the optimization of medical exposure should be considered in the terms of the image quality and the radiation dose the patient received. The guidance levels (GL) for medical exposure should be established as the intention to be an indication of doses for averaged size patients. It should be applied with flexibility to allow higher exposures with clinical judgments and should be revised as technology and technique improve. This study is part of IAEA Research which the data were collected at two sites with high load on simple radiographic examinations. The reject analysis was as high as seven percents and the patient skin dose was also higher than the IAEA GL for the chest examination at one site. After reviewing of the data, the education and training for the technologists were immediately scheduled. The quality control was regularly performed and the patient dose was reduced as the high kVp technique was implemented. The maximum skin dose was within the guidance level. It is recommended that the image quality, the retake analysis and the patient skin dose should be obtained and reviewed regularly. The National GL should be established by the professional societies and the National Atomic Energy Authority for the benefit of the patients.

INTRODUCTION

The International Basic Safety Standards[1] (BSS) requires attention to image quality of radiography which corrective action is considered. Poor image quality results in unnecessary radiation exposure to patients and the unjustified exposure which wastes the resource. The diagnostic requirements presented as image criteria[2] for a particular type of radiograph are those deemed necessary to produce an image of standard quality. The criteria for radiation dose to the patient are expressed in terms of a reference dose value for each type of radiograph which is based on the third quartile (75 percentile) value seen in national patient dose surveys. Its purpose, if it is exceeded, as to initiate an immediate investigation into the reasons for using relatively high dose techniques and to trigger appropriate corrective action. The reference dose value can be taken as a ceiling from which progress should be pursued to lower dose levels in line with the ALARA (as low as reasonably achievable) principle. Compliance with the image and patient dose criteria was possible when the recommended techniques were used. To encourage widespread use, the image criteria have been expressed in a manner requiring personal visual assessment rather than objective physical measurements which need sophisticated equipment unavailable to most departments. However, the assessment of compliance with the criteria for

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radiation dose to the patient for a specific radiograph unavoidably involves some form of dose measurement. This requires representative sampling of the patient population. BSS also requires the establishment of Guidance Level (GL) for the country. These can be obtained if the national quality control program is implemented. The retake analysis is the good indicator for the image quality which should be considered closely to the patient dose.

MATERIALS

Two X-ray systems were studied at King Chulalongkorn Memorial Hospital (KCMH) in Bangkok as detail in table 1.

TABLE 1 2 X-ray systems of details of manufacture and model used in the study.

Hospital	Manufacturer	Model	Year of Installation
King Chulalongkorn Memorial Hospital	Hitachi	DR-155HM	1989
	Toshiba	KXO 80G/DST 101 A/DG 80G	2005

METHODS

The study consists of two phases. The first phase involves the image quality and the second phase involves the patient dose and guidance level. The details are as following:

Phase I The study of film retake rate and the image quality

1. Identify the radiographic site for the detail of the x-ray equipment.
2. Collect for film retake rate at the radiographer level, image quality grading in A, B and C by radiologists (A-Clearly accepted without any remark or reservation, B - accepted with some remarks or reservations, C - rejected.)
   - 2.1 Collect data within 2 weeks
   - 2.2 Daily record of film used, retake rate as in B and C.
   - 2.3 Analyze the causes of retake such as
     - 2.3.1 Over & under exposure
     - 2.3.2 Artifacts
     - 2.3.3 Field size misplacement
     - 2.3.4 Processing problem
   - 2.4 Educate radiographers in order to improve the retake rate.
   - 2.5 Redo 2.2-2.3
   - 2.6 Report the changes in retake rate and image quality.

Phase II Patient dose determination and Guidance Level (GL)

1. Perform quality control of x-ray equipment, record air kerma for patient dose calculation.
2. Record exposure parameters of kVp, mAs, for chest PA, abdomen AP, lumbar spine AP and lateral, skull and pelvis approximately 10 cases for each projection.
3. Perform patient dosimetry in terms of entrance skin air kerma, ESAK
4. Rectify the problem from QC results in 2
5. Repeat patient dosimetry to obtain the changes in patient doses
6. Compare the results with GL of BSS.

RESULTS

I. Film retake rate and image quality

This work is performed in two parts: one at the radiographer's level and the second at the radiologist's level.

1. Radiographer: Keep daily record of total number of films used and films rejected in a particular room; estimate the repeat rate at radiography room and dark room level and complete the radiographer's part of the form.
2. Radiologist: Grade the remaining radiographs using Table 2 according to:

A: radiograph clearly accepted without any remarks

B: radiograph accepted with some remarks, and

C: radiograph should be rejected

TABLE 2 Retake analysis at Out-Patient-Department (Hitachi 1989) and at Emergency Room (Toshiba 2005).

Room No.	OPD Room 5	
Time period of the analysis (mm.yy)	From_04,06 to __05,06__	
At the level of RADIOGRAPHER		
Number of films used during 2 weeks	**489**	
Number of films rejected by radiographer	**37**	
Percentage of films rejected by radiographer	**7.57**	
At the level of RADIOLOGIST (use Table 1)		
	Number	**Percentage**
A grade films	244	49.9
B grade films	208	42.5
C grade films	37	7.6
TOTAL	**489**	**100%**
Cause analysis (B and C graded films)		
Over- & under-exposure	2	0.82
Artefacts	5	2.04
Field size misplacement	1	0.41
Processing problems	3	1.22
Other, Positioning, etc.	234	95.5
TOTAL	**245**	**100%**

Room No.	Emergency	
Time period of the analysis (mm.yy)	From_04,06 to __05,06__	
At the level of RADIOGRAPHER		
Number of films used during 2 weeks	**610**	
Number of films rejected by radiographer	**44**	
Percentage of films rejected by radiographer	**7.2**	
At the level of RADIOLOGIST (use Table 1)		
	Number	**Percentage**
A grade films	255	41.8
B grade films	311	51.0
C grade films	44	7.2
TOTAL	**610**	**100%**
Cause analysis (B and C graded films)		
Over- & under-exposure	5	1.4
Artefacts	5	1.4
Field size misplacement	2	0.56
Processing problems	3	0.84
Other-Positioning	340	95.8
TOTAL	**355**	**100%**

II Quality Control of x-ray equipment and ESAK measurement

Use a suitable detector (e.g.: ionisation chamber) to measure air kerma (mGy) at 1m focus-detector-distance for different kVp settings. Divide the resulting dose by the applied mAs in order to get mGy/mAs as in Table 3 and plot these values against the kVp as in figure1. From this curve we can determine for a given kVp and mAs the air kerma at 1m AK(100cm). The ESAK can be calculated using AK (100 cm) and the focus-patient surface-distance FSD as in the following equation:

$$\mathbf{ESAK = AK(100cm)*(100/FSD,cm)^2}$$

TABLE 3 Air Kerma, AK measurement at 1 meter and AK/mAs determination at Out-Patient-Department (Hitachi 1989)

kVp	mAs	AK in 1 m (mGy)	AK/mAs (mGy/mAs)
40	25	0.245	0.0098
50	25	0.488	0.0196
60	25	0.93	0.0373
70	25	1.29	0.0518
80	25	1.75	0.07
90	25	2.184	0.0874
100	25	2.652	0.106
110	25	3.141	0.126
120	25	3.465	0.139

Figure 1 The linear response of the kilovoltage and the air kerma per milliampere-sec

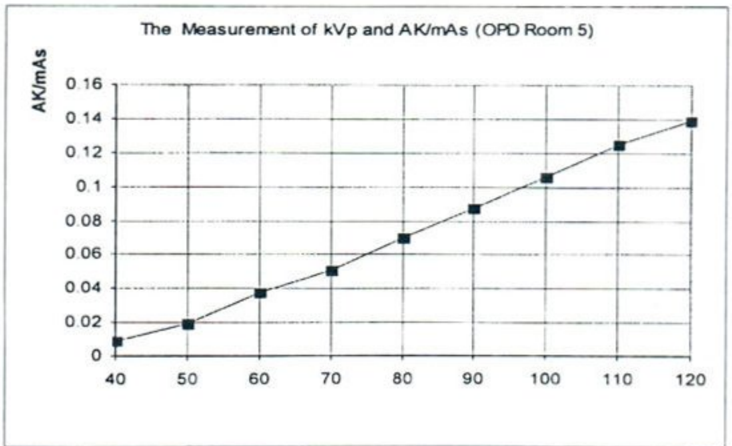

TABLE 4 Evaluation of ESAK for patient chest, lumbar spine, abdomen, skull and pelvis at OPD room 5.

Room No.	OPD Room 5		
Chest PA/ Patient ID	**kVp**	**mAs**	**ESAK, mGy**
1. 10279847	80	20	0.540
2. 3175549	77	16	0.407
3. 3916749	80	16	0.427
4. 11137047	80	16	0.421
5. 4533128	80	14	0.388
6. 4973649	80	16	0.438
7 .11049348	80	16	0.438
8. 3224049	80	20	0.550
9. 12348239	80	14	0.364
10.10969443	80	20	0.554
Lumbar spine AP/ Patient ID	**kVp**	**mAs**	**ESAK, mGy**
1. 1304437	80	64	5.919
2. 3175549	70	50	3.197
3. 2603449	80	64	6.349
4. 8195647	75	50	4.056
5. 11705444	75	64	5.315
6. 421845	75	64	5.574
7. 9434832	75	64	5.574
8. 3175549	80	50	4.96
9. 5236438	80	64	6.349
10.3928249	80	64	6.503
Lumbar spine lateral/ Patient ID	**kVp**	**mAs**	**ESAK, mGy**
1. 1304437	85	126	13.717
2. 3175549	80	64	6.663
3. 2603449	85	126	14.765
4. 8195647	80	100	10.937
5. 11705444	80	126	15.270
6. 421845	80	126	15.270
7. 9434832	80	100	11.216
8. 3175549	80	126	15.939
9. 5236438	85	126	17.0
10.3928249	80	126	14.132
Pelvis AP/ Patient ID	**kVp**	**mAs**	**ESAK, mGy**
1.121667	75	50	5.629
2.11938	75	52	5.262
3.122503	70	40	2.974

4.40853	70	42	3.452
5.23003	75	50	5.478
6.36432	75	50	4.444
7.58964	75	50	5.951
8.21193	75	50	5.06
9.11605	67	40	2.439
10.81977	70	40	2.5
Abdomen/ Patient ID	**kVp**	**mAs**	**ESAK, mGy**
1. 9969347	80	64	5.919
2. 6765843	75	50	3.622
3. 3631649	75	50	3.874
4. 13016233	80	64	6.349
5. 451947	80	64	6.662
6. 3926349	75	50	4.408
7. 11282048	75	64	5.507
8. 13100143	80	64	6.503
9. 9436429	75	64	6.15
10.7668243	75	64	6.0
SkullPA/ Patient ID	**kVp**	**mAs**	**ESAK,mGy**
1. 9182745	67	40	2.363
2. 94272	70	32	2.267
3.134998	70	32	2.267
4.126008	70	32	2.322
5.59645	75	40	3.75
6.125003	75	50	4.355
7.61786	70	32	2.379
8.128828	70	32	2.379
9.129416	70	40	2.903
Skull LAT/ Patient ID	**kVp**	**mAs**	**ESAK, mGy**
1.9182745	63	32	1.518

As the retake rates were higher than 5 percent for both OPD Room 5 and Emergency X-ray room as in Table 2, the major causes, patient positioning were discussed among radiologist, medical physicist and radiographers to overcome the problem. The ESAK determined from Hitachi X-ray at OPD room 5 at Chest PA was also high, the high kVp technique was recommended. The results are shown in Table 4.

TABLE 5 The result after education for the improvement of retake rate and the use of high kVp technique at OPD room 5.

Room No.	**OPD Room # 5**	
Time period of the analysis (mm.yy)	**From_19/06/06 to 30/06/06**	
At the level of RADIOGRAPHER		
Number of films used during 2 weeks	78	
Number of films rejected by radiographer	0	
Percentage of films rejected by radiographer	0	
At the level of RADIOLOGIST		
	Number	**Percentage**
A grade films	62	79.4
B grade films	16	20.6
C grade films	0	0
TOTAL	78	100%
Cause analysis (B and C graded films)		
Over- & under-exposure	0	0
Artifacts	0	0
Field size misplacement	0	0
Processing problems	0	0
Other -Positioning	16	100
TOTAL	**16**	**100%**

TABLE 6 ESAK determination from patient data of chest, lumbar spine and abdomen AP with the high kVp technique.

Room No.	OPD Room 5		
Chest PA/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1. 13776046	90	15	0.22
2. 5581849	90	12.5	0.19
3. 11753339	90	15	0.23
4. 6665433	90	15	0.22
5. 1933041	90	15	0.22
6. 5660349	90	17.5	0.25
7. 5588340	90	12.5	0.18
8. 10604568	90	12.5	0.18
9. 7543209	90	15	0.22
10. 4641549	90	15	0.22
Lumbar spine AP/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1. 845225	85	25.6	1.05
2. 8282944	85	51.2	2.19
3. 13270339	85	22.4	0.9
4. 5579249	85	25.6	1.07
5.11945441	85	22.4	0.96
6. 6390039	85	19.2	0.84
7. 5532749	85	12.8	0.52
8. 1943549	90	32	1.76
9. 5540346	90	64	3.79
10. 50719330	85	32	1.51
Lumbar spine lateral/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1. 845225	90	64	3.69
2. 8282944	90	102	7.18
3. 13270339	85	32	1.54
4. 5579249	90	32	1.85
5.11945441	90	32	1.48
6. 6390039	100	19.2	1.41
7. 5532749	100	12.8	0.94
8. 1943549	90	38.4	2.45
9. 5540346	90	102.4	5.11
10. 50719330	90	64	3.19
Pelvis AP/ Patient ID	**kVp**	**mAs**	**ESAKmGy**
1. 11536248	90	19.2	0.96
2. 50057130	90	25.6	1.28
3. 1943549	90	32	1.75
4. 12358448	85	25.6	1.18
5. 8533336	80	25.6	1.32

TABLE 7 After education on the causes of high retake rate, the record on lower retake rate at ER X-ray room.

Room No.	**Emergency(ER)**	
Time period of the analysis (mm.yy)	**From 05/06 to 05/06**	
Describe the corrective actions that were taken	**Arrange a meeting with radiologist, technologist to describe the cause of retake, patient positioning.**	
At the level of RADIOGRAPHER		
Number of films used during 2 weeks	**88**	
Number of films rejected by radiographer	**5**	
Percentage of films rejected by radiographer	**5.68**	
At the level of RADIOLOGIST (use Table 1)		
	Number	**Percentage**
A graded films	42	47.73
B graded films	41	46.59
C graded films	5	5.68
TOTAL	**88**	**100%**
Cause analysis (B and C graded films)		
Over- & under-exposure	1	2.17
Artefacts	4	8.7
Field size misplacement	0	0
Processing problems	0	0
Other -positioning	41	89.13
TOTAL	**46**	**100%**

TABLE 8 Evaluation of entrance surface air kerma (ESAK) at ER x-ray room

kVp	mAs	AK in 1 m (mGy)	AK/mAs (mGy/mAs)
50	25	0.993	0.040
60	25	1.546	0.062
70	25	2.116	0.085
80	25	2.692	0.108
90	25	3.374	0.135
100	25	4.107	0.164
110	25	4.9	0.196
120	25	5.722	0.229
130	25	6.609	0.264
140	25	7.610	0.304
150	25	8.401	0.336

FIGURE 2 The linear response of kVp and ESAK per mAs from Toshiba at ER room.

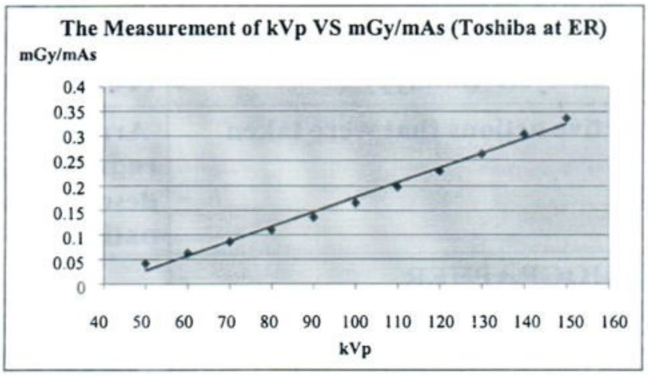

TABLE 9 The entrance skin air kerma determination from patient studies of chest, lumbar spine, abdomen and skull.

Room No.	Emergency		
Chest PA/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1. 9263529	90	3.2	0.067
2. 4981837	90	3.6	0.073
3. 3572949	90	4.8	0.105
4. 915333	90	2.4	0.05
5. 7797444	90	3.2	0.073
6. 6445346	90	2.8	0.057
7. 4223849	90	4	0.084
8. 4869849	90	2.4	0.049
9. 12764145	90	2	0.041
Lumbar spine AP/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1. 9343848	75	51	2.948
Lumbar spine lateral/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1.9343848	85	39.7	3.41
Abdomen/ Patient ID	**kVp**	**mAs**	**ESAK mGy**
1.1067447	81	11.5	0.794
2.5429644	81	5.1	0.31
3.4696932	81	13.4	0.925
4.10842042	81	10.2	0.622
5.12476548	81	8.3	0.531
6.12154348	81	9.6	0.6
SkullPA/ Patient ID	**kVp**	**mAs**	**ESAKmGy**
1.4932349	70	25	1.161
2.9239348	70	25	1.190
Skull Lat/ Patient ID	**kVp**	**mAs**	**ESAKmGy**
1.4932349	66	22	0.913
2.9239348	66	22	0.913

DISCUSSION AND CONCLUSION

The surveys of the radiographic image quality from 2 X-ray equipment at King Chulalongkorn Memorial Hospital show the highest percentage of film rejected by radiographers of 7.57 and 7.2% at the OPD and the ER of KCMH. The major cause of film rejection is from patient positioning commented by a radiologist. The meeting was arranged to inform the radiographers and the 2 week survey was followed up showing the reject rate reduce to 3.37 and 5.67% respectively of the same cause.

The measurement of kVp and AK/mAs showed the good linearity of 2 x-ray equipment at KCMH. The ESAK of chest PA at OPD (Table 5) was most likely higher than the guidance level (GL) from BSS as shown in Table 10.

TABLE 10 IAEA Guidance Levels of dose for diagnostic radiography for typical adult patient.

Examination		Entrance surface dose per radiograph[a] (mGy)
Lumbar spine	AP	10
	LAT	30
LSJ		40
Abdomen, intravenous urography and cholecystography	AP	10
Pelvis	AP	10
Hip joint	AP	10
Chest	PA	0.4
	LAT	1.5
Thoracic spine	AP	7
	LAT	20
Skull	PA	5
	LAT	3

[a] In air with backscatter. These values are for conventional film screen combination in the relative speed of 200. For high speed film- screen combination (400-600) the values should be reduced by a factor of 2 to 3.

The meetings among radiologists, physicists and radiographers were arranged for the discussion on several factors involved in ESAK measurement. It was concluded that for chest PA projection the kVp should be increased from 80 to 90 and mAs reduced from 14-20 to 12.5-15 for the machine of nearly 20 years old, a single phase generator. As the high kVp technique is set for all studies, these results in the reduction of ESAK to 0.18-0.25 in the chest PA projection which is less that GL of chest PA (Table 6). The other projections show the ESAK are within the GL. The maximum patient skin doses from the studies are shown in Table 11.

TABLE 11 The comparison of the maximum Entrance Surface Dose from our study to proposed Guidance Level (GL).

Examination		Entrance surface dose, mGy	Proposed GL, mGy
Chest	PA	0.25	0.4
Lumbar spine	AP	3.79	10
	LAT	7.18	10
Pelvis	AP	2.5	10
Abdomen	AP	3.4	10
Skull	PA	2.4	5

From the table, the proposed lumbar spine lateral can be reduced from the original value of 30 mGy to 10 mGy. The exposure techniques play the important role in the patient dose reduction and the meeting for the review of image quality with the patient dose should be arranged regularly at the radiology department as the part of quality assurance program. It is recommended that the patient dose from all simple radiographic studies and the routine retake rate analysis should be determined at the department level, then at the national level later in order to recruit the national guidance level of diagnostic imaging.

REFERENCES

1. International Atomic Energy Agency. International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Standards Sources. Safety Series No. 115. Vienna Austria 1996.
2. EUR 16260 European Guidelines on Quality Criteria for Diagnostic Radiographic Images. European Commission, Brussels 1996.