PHYSICS

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Reduction of Unwarranted Patient Exposure in X-ray Examinations

Background/Objective: Protecting patients from unwarranted radiation is a great safety concern to radiology practitioners, as medical X-rays are the largest source of public exposure to ionizing radiation.

Materials and Methods: The entrance skin exposure (ESE) was measured by solid state dosimeter for five common types of radiography. Dosimetery for a human of average size was performed in the radiology centers. The results of first ESE measurements together with recommendations according to CRCPD and NRPB were returned to the radiology centers. Two months later, all ESE measurements were repeated.

Results: The mean, maximum and 3rd quartile ESEs were significantly decreased compared with the first measurements. This quality control program managed to decrease the patient doses (ESEs) of AP and lateral lumbar spine, AP cervical and lateral skull radiographs by about %10, 25%, 30% and 25% respectively.

Conclusion: This survey indicates that in X-ray examinations of the lumbar, thoracic and cervical spine, skull and chest the patient dose can be significantly reduced without ruining the imaging quality.

Keywords: Radiation Protection, X-ray Radiology, Diagnostic, Health Physics

Introduction

The largest single man-made source of X-ray exposure is the medical diagnostic radiography. Recent estimates by NRPB have stated that the X-ray examinations are the source of nearly 90% of total effective-dose-per-capita irradiation in the UK. The diagnostic nuclear medicine procedures contribute a further 8% (radiotherapy exposures are excluded from this analysis). [1-3] It is generally agreed that medical X-ray exposure can be reduced substantially without compromising the quality of radiological images. Therefore, it is essential that patients are not subject to unnecessary radiological examinations, and are protected from excessive exposures when the radiological procedures are required.[3, 4]

The recommendations and guidelines on patient protection must be provided to the clinician, the radiologist and the operator. They are expected to observe the guidelines to avoid unnecessary radiological procedures and to minimize their exposures. [4, 6] The worldwide interest in patient dose measurement was stimulated by the 1990 publication of "Patient Dose Reduction in Diagnostic Radiology" by the UK National Radiological Protection Board (NRPB),[7, 8] and took effect in the form of patient exposure databases, data collation centers, and yearly reviews. [17]

Several major dose surveys have been conducted especially in the developed countries. [9, 10] In1991-2, Harrison et al conducted a pilot study using the indirect method to investigate the potentials for reducing the radiation dose to patients and to make recommendations on effective methods.[13] In Malaysia (1992), the quality assurance program in radiology extended from 16 major hospitals to 103 hospitals, and they conducted a national survey,(1993-1995) to establish baseline patient dose data for seven routine types of X-ray examinations.[7]

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Although it was confined to quality control activities such as tube potential (kV), mAs, sensitometry, and image quality tests; the importance of patient dose monitoring was also recognized as an important aspect of the overall program. In regard to its impotence, we accomplished a second patient dose survey in the public hospitals of Yazd province.

Materials and Methods

Similar to our previous survey [12], the entrance skin exposure (ESEs) measurements were again performed, namely by solid state dosimeter (Unfors 6001) in 26 X-ray rooms of 17 public hospitals in 8 cities of Yazd province. The dosimeter was placed at the center of the beam with a fixed field size (10×10 cm) on the table during the examinations, so the exposure values were from measurements free-in-air, *i.e.*, without backscatter. The source-to-detector distance was selected the same as the source-to– patient's skin. The mean number of patients per month for each X-ray examinations room was considered as a weighting factor for ESE statistical calculations. The exposure data such as kV_P, mAs, the type of cassette, FSD and ESE for each radiograph were recorded. The patient was considered to be of standard size. Specific data such as the type of device, film-screen speed, the type of cassette and exposure time for each X-ray unit were recorded.

The results of ESEs for five routine X-ray examinations (10 projections) together with the standard levels were returned to each radiology center. The methods for reducing the patient dose, such as increasing kV_P, decreasing mAs, increasing focus- film distance (FFD), using speed film-screen, increasing processor cycle time were all provided to the radiography staff. After two months' time, the ESEs measurements were repeated. The quality of the image *i.e.* resolution, contrast and optical density with the new exposure settings (lower patient dose) were enquired from the radiologists. Data were analyzed by SPSS 11.0. The ESEs of the two exposure settings were compared by t- test.

Results

The 26 participant X-ray rooms were equipped with stationary X-ray units of the following types: Varian 500, 600, 1000; Ziemens 500, 1000, 1200; Parspad 500, 650, 800; Toshiba 500, 650; and Shimadzu 500, 1000. The ESE statistics are shown in table 1.

Table 1: The distribution of individual entrance skin exposure (ESE) for five routine x-ray examinations (10 projections) before and after the quality control. The median, 3rd quartile and maximum (max.) ESEs before and after quality control are significantly different.

Radiograph	Projection	Entrance Surface Exposure (mR) (before)					Entrance Surface Exposure (mR) (after)				
		First quartile	Median	Mean	Third quartile	Max.	First quartile	Median	Mean	Third quartile	Max.
Different		no	P < 0.04	no	P<0.02	P<0.02	no	P < 0.04	no	P<0.02	P<0.02
Lumbar spine	AP	218	285	343.9	462	1093	196	242	282.3	422	570
	LAT	522	881	880	1224	1861	570	723	716.4	811	1180
Thoracic spine	AP	159	214	242.6	288	924	180	228	240.7	290	592
	LAT	250	447	500	643	1462	250	447	500	643	1462
Cervical spine	AP	78	105	131	177	298	70	82	90	107	188
	LAT	45	64	89.3	144	260	40.5	53	70.5	83.8	164
Skull	AP	174	232	275	365	534	150	156	182.5	216	380
	LAT	102	129	155	191	336	102	103	111	121	269
Chest with grid	PA	30.5	38	39.6	48	62	24	25	27.7	35	49
Chest without grid	PA	7	8	14.4	23	39	12	16	16.4	19	30

Table 2: The exposure parameters for five routineX-ray examinations (10 projections) after quality control. Means and ranges (in parentheses) are given.

Radiograph	Projection	kV	mAs
Lumbar spine	AP	71.6 (60-90)	44 (20-90)
	LAT	82.4 (68-100)	64.5 (25-150)
Thoracic spine	AP	69.4 (55-90)	42 (16-100)
	LAT	75 (60-94)	65.5 (25-150)
Cervical spine	AP	65 (55-80)	34 (13-79)
	LAT	64 (50-82)	29 (7-63)
Skull	AP	70 (57-90)	34 (20-79)
	LAT	65 (53-85)	27.7 (13-79)
Chest with grid	PA	76 (59-90)	14.3 (4-30)
Chest no grid	PA	62.5 (48-70)	13 (8-30)

A 5 to 40% reduction in mAs lowered the second-time values of maximum, third quartile and median for ESEs significantly ($p<0.05$, table 1). The exposure parameters *i.e.* kV_P and mAs are given in table 2. Most mAs values measured after the intervention (the recommendations) were lower than before but the kV_P values generally were the same. The ESEs of AP lumbar and lateral thoracic spine and lateral and AP skull were lower than the standard levels after 2 months of applying the recommendations.

Discussion

In recent years, radiation protection has received increasing attention in diagnostic radiology in developed country where patient dose monitoring and audit procedures are being widely practiced. [3]

In our first survey we measured the entrance skin exposures (ESEs) of the standard size patients for the routine radiographs in the public hospitals of Yazd province.[12] In that study we observed the very wide variations of the patient dose in the similar X-ray examination in the different hospitals [12]. That wide variation in the patient doses was shown in the other studies from different countries as well. [2,3,5,7]

Some of the contributing factors to the observed variation in the patient exposure can be attributed to the use of suboptimal imaging equipment, poor choice of technical factors and/or incorrect film processing procedures. It is suggested that a significant reductions in the radiation dose is possible without adversely affecting the image quality. Using fast film-screen combination was probably one of the main factors in reducing the ESE by 30 to 40%.[2, 14] .Almost all of the radiology centers that participated in our study were using the fast film-screen combination and good quality development drugs; so the patient dose spread was mainly due to the choice of exposure factors, focus-film distance and the X-ray units output.

As the chest and skull mAs and kV_P of our first study were respectively higher and lower than the NRPB measurements; we recommended that they increased kV_P and deceased mAs. These changes would decrease the patient dose without major effects on the quality of the image.

It has been estimated that increasing the tube potential from 60 to 90 kVp will result in an ESE saving of 60%. [15] Martin et al, found that increasing tube potential by 8-13 kVp in lumbar and thoracic spine examinations resulted in a dose reduction of 26-30%.[16] Also we observed that reduction in mAs alone decreases the film optical density and patient dose by 10 to 50%, without noticeably reducing the quality images. It means that the contrast or resolution of a white radiograph may be equal to that of a black radiograph.

Conclusion

X-ray exposure is minimized and image quality is improved when X-ray systems and operators perform properly. Radiation Control Rules require regular inspection of X-ray units. Operators of X-ray equipment designed for human use must be also controlled for their technical skills.

We hope this survey raises an interest among X-ray professionals to reduce the patient dose of the radiological procedures in Iran.

Acknowledgments

We would like to acknowledge the co-operation of radiographers and radiologists at all the participating radiological departments.

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