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Local Diagnostic Reference Levels for Some Common Diagnostic X-Ray Examinations In Sabzevar County of Iran

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ABSTRACT

Introduction: Diagnostic reference level (DRL) is a useful tool for the promotion of optimization. The national DRLs (NDRLs) are useful, brief, and robust guidelines for optimizing radiation protection in a country. The aim of this study was to extract the local DRLs (LDRLs) for some common radiologic examination in Sabzevar county.

Materials and Methods: There are eight radiology departments in Sabzevar County, Iran. The entrance skin dose (ESD) distributions were determined by use of thermoluminescence dosimeter (TLD) chips for 10 standard projections (i.e., anterioposterior [AP] abdomen, AP and posteroanterior [PA] chest, AP and lateral [LAT] lumbar spine, AP pelvis, cervical AP, cervical LAT, as well as AP and LAT skull). The third quartiles of the measured ESDs were compared with the previously published data.

Results: In the present study, the third quartile of the measured ESDs for the patients undergoing specific examination were selected as LDRLs. The calculated LDRLs for the chest PA, chest AP, lumbar spine PA, lumbar spine LAT, pelvis AP, abdomen AP, cervical AP, cervical LAT, skull PA, and skull LAT were 0.54, 0.64, 1.99, 3.83, 1.47, 2.15, 0.54, 0.78, 1.22, and 1.01 mGy, respectively.

Conclusion: Our results were compared with the DRLs reported in Iran, UK, and Japan as well as those reported by the National Radiological Protection Board (NPRB) for the UK. The ESDs obtained in this study for the chest PA, cervical AP, cervical LAT, AP and LAT skull, abdomen AP, pelvis AP, lumbar PA, and lumbar LAT examinations did not exceed the DRL values reported by NPRB.

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Introduction

Radiation has the potential to both induce harmful effects on patients and provide a powerful tool for diagnostic purposes. The optimization of patient protection in diagnostic radiology requires the application of specific protocols ensuring the remaining of patient doses at a reasonably achievable low level. Diagnostic reference level (DRL) is one of the most effective means for the optimization of radiation protection in the patients undergoing diagnostic radiology examinations.

The DRLs were first established for conventional radiography in the 1980s and gradually expanded for other imaging modalities in the 1990s. The International Commission on Radiological Protection Report 60 emphasizes on justification, protection optimization, and dose limitation as fundamental principles for protection in diagnostic radiology [1]. The radiographic examinations should be optimized so that the patient dose does not exceed the diagnostic information obtained from the examination.

Regarding this, it is essential to measure patient dose regularly in all radiological departments and evaluate DRLs to optimize patient protection [2]. The concept of DRLs was defined by the Royal College of Radiologists and the National Radiological Protection Board (NRPB) as a 75th percentile of the mean entrance surface dose (ESD) distribution observed for a particular examination on a representative sample of patients at each center [3-5]. This concept was targeted toward patient dose reduction in diagnostic radiology.

The aim of the reference dose is to set the first step of a chain of actions that leads to the optimization of patient dose. These measurements will also help the radiation protection officers to identify and investigate whether in normal conditions, the patient dose in a specified radiology examination is unusually high or low. In some countries, the establishment of DRLs has been useful for the improvement of patient safety and reduction of patient dose in clinical practice. Accordingly, in the UK, a dose survey

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program caused about 50% reduction in patient dose during 1985-2000 [6-8].

The DRLs for diagnostic imaging examinations can be categorized into the national DRLs (NDRLs) and local DRLs (LDRL). The NDRLs for each examination and patient group are determined based on the distributions of the doses observed in national scale studies. On the other hand, the LDRLs demonstrate the typical practice at a region, such as a province and county or maybe in a single large center or group of healthcare departments. This measurement is defined as the 75th percentile of the median doses received by the patients in different imaging departments.[9-11].

Materials and Methods

Equipment Description

In this study, patient dosimetry was performed using LiF:Mg,Ti dosimeters (TLD-100) with dimensions of 3×3×1 mm^3 (manufactured by M/s HARSHAW, USA), programmable electrical oven for thermal treatment to TLDs, Harshaw 3500 TLD reader (manufactured by M/s HARSHAW, USA), and the associated software. The calibration of thermoluminescence dosimeters (TLD) was performed by exposing a number of TLDs to a specific dose of diagnostic X-ray (80 kV, total filtration of 3.0 mm Al), measured by a Radcal monitor (model 9015, Monrovia, California 91016, USA).

Quality Control of X-ray Machines

In order to enhance the patient protection in the diagnostic examinations, some operations should be performed. For this purpose, the implementation of a regular quality control program for the radiology machines is an issue of significant importance. In this study, the kVp accuracy, exposure time accuracy, exposure reciprocity, and reproducibility of exposure were evaluated in 11 conventional radiology devices of 8 radiology centers in Sabzevar County. In order to fulfill the quality control program according to the standard protocols mentioned in the book entitled 'Quality Management in Imaging Sciences' [12], we used a calibrated Mult-O-Meter Model 303 (Unfors, Sweden).

Patients and Dosimetric Systems

This study was carried out in eight radiology centers in Sabzevar, Iran. We evaluated 11 X-ray units, 485 patients, and more than 950 views. The parameters, including gender, age, weight, height, tube potential (kVp), and mAs, were individually recorded for each patient and X-ray unit. The measurements were performed on all adult patients referred to these centers with a weight range of 40-107 kg.

The patients were subjected to eight typical X-ray examinations, namely chest posteroanterior (PA), chest anterioroposterior (AP), lumbar spine (AP), lumbar spine lateral (LAT), pelvis (AP), abdomen (AP), and cervical (AP and LAT). For each measurement, two TLDs, inserted in separate specified plastic bags, were placed on the patient's skin surface at the center of the radiation field. To minimize uncertainty in dose measurements, the two TLDs were used simultaneously [13-15]. The mean value of the two ESDs was considered as the measure signifying the dose at the point of interest.

Results

In this study, 485 adult patients were examined. As the results indicated, the chest X-ray was the most prevalent examination. The patients' information, such as age, weight, exposure mean and range, as well as exposure parameters, like kVp and mAs settings, are illustrated in Table 1. The speed of screen-film combination is a factor that may lead to obtaining different patient doses among various studies.

Table 2 presents the statistical distributions of DRLs for different radiography examinations in this study, and our results were compared with DRLs reported by NRPB for the UK in 2000 as well as NDRLs obtained for Iran, UK (2005), and Japan (2015). According to Table 2, the 3rd quartile of the measured ESD for the chest PA radiography is higher in this study than those reported in the other two studies.

However, for the other examinations, the ESDs obtained in this study were lower than those presented in the other studies. Despite no significant difference in the machine settings between this study and the other for the abdomen, pelvis, and lumbar spine, the patient dose was lower in this study.

Table 1. The average and range of exposure values, age, and weight of patients in the present study

Examinations	Average (Range)			
	kVp	mAs	Age	Weight
Chest (PA)	67.82 (57-86)	18.40 (6.3-45)	49.78(15-82)	62.82 (42-87)
Chest (AP)	65.59 (51-79)	29.54 (6.3-160)	60.18(25-88)	64.64(45-90)
Abdominal (AP)	69.54(56-76)	29.72 (12.5-80)	40.39(20-76)	67.68 (50-82)
Pelvic (AP)	66.95 (60-81)	40.27(16-75)	44.04 (22-81)	61.63 (45-78)
Lumbar (AP)	71.45 (80-60)	43.90 (10-90)	38.30(15-88)	61.63 (45-78)
Lumbar (Lat)	78.32 (63-90)	68.08 (20-180)	38.08 (15-81)	63.04(45-78)
Cervical (AP)	60.67 (54-70)	17.33 (6.3-30)	51.32(16-80)	67.60 (45-97)
Cervical (LAT)	63.26 (58-73)	16.49 (6.3-30)	48.85 (16-76)	66.55(45-97)

Table 2. Third quartile of mean ESDs in this study, iran and NRPB

	This study	Iran	Japan	UK	NRPB
Chest PA	0.54	0.41	0.3	0.15	0.2
Chest AP	0.64	0.97	-	-	1
Abdominal AP	2.15	4.06	3.0	4.0	6
Pelvic AP	1.47	3.18	3.0	4.0	4
Lumbar PA	1.99	3.43	4.0	5.0	6
Lumbar Lat	3.83	8.41	11.0	11.0	14
Cervical PA	0.58	1.83	-	-	-
Cervical Lat	0.74	0.93	0.9	-	-
Skull PA	1.22	2.85	3.0	2.0	3
Skull Lat	1.01	1.93		**1.3**	1.5

Discussion

Due to the fact that there is no safe dose of ionizing radiation, limiting the potential risk of radiation in any procedures is of fundamental importance [16-18]. According to the linear no-threshold theory, the reduction of the doses received by population from medical exposures is an important step toward radiation protection, which consequently mitigates the radiation risk.

It should be mentioned that all the investigated centers had conventional radiology machines that used carbon fiber cassettes with film-screen combination speed of 400 and total filtration of > 2.5 mm Al. Moreover, most of the devices were old-built facilities. Based on the quality control, the reproducibility of radiation output was above the acceptable range in 18% of the centers.

Regarding the reciprocity variance among different centers, 45.4% did not pass the test and were rejected. In case of kVp accuracy test, 27% of the centers were rejected. Finally, in terms of timer accuracy test, 36% of the machines exceeded the standard limitations and were rejected. The X-ray tube voltage and exposure time are the parameters directly affecting the X-ray tube output. If a machine does not have an appropriate reproducible output, it will have adverse impacts on both image quality and patient dose.

In diagnostic radiology, ESD is a helpful parameter for evaluating patient dose and should be optimized against image quality. The application of a DRL could be a practical method for this purpose. The optimization of radiographic parameters for reducing patient dose is a significant issue. The parameter optimization would facilitate the preservation of image quality while reducing patient dose. The LDRL extraction is so important as it enables the users to compare their LDRLs with NDRLs helping them change and improve their manner and choose the convenient method having reduced dose levels.

The NDRLs for Iran was reported for the first time in 2008. Therefore, as can be seen in Table 2, our results were compared with DRLs reported by NRPB for the UK in 2000 as well as NDRLs obtained for Iran, UK (2005), and Japan (2015) [3, 10, 18, 19].

It is evident that the LDRLs obtained in this study for the chest PA, cervical AP, cervical LAT, AP skull, abdomen AP, pelvis AP, lumbar AP, and lumbar LAT examinations did not exceed the DRL values reported in other studies.

On the contrary, for the chest PA examination, higher values were acquired in this study in comparison with the NDRLs suggested by the other researchers [3, 10, 18, 19]. It seems that the main reason for this discrepancy is due to the foremost application of a low-kVp technique instead of high-kVp technique. The tube potentials of 58-86 kVp with the mean of 67.82 kVp were used in the present study in spite of the recommendation for using a high-kVp technique of 120 kVp and higher.

Conclusion

The comparison of our findings with those of the other studies demonstrated that the machine setting parameters were among the most important causes of dose variation. Regarding the significance of machine setting parameters in image quality and patient dose, these parameters can be set in a way that patient dose decreases as low as possible, and the image quality remains intact.

In the present study, the LDRLs were lower than the other NDRLs of Iran and the DRLs of the other studies in all imaging examinations, except for the chest examination. Consequently, we recommended to the radiation workers in the investigated county to use the high-kVp techniques according to the NRPB recommendations to decrease the patient dose.

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