Diagnostic reference levels (DRLs) for routine X-ray examinations in Lorestan province, Iran

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ABSTRACT

Background: In diagnostic radiology there are two reasons for measuring or estimating radiation doses to patients. Firstly measurements provide a means for setting and checking standards of good practice as an aid to the optimization of patient protection. Secondly estimates of the absorbed dose to tissue and organs in the patients. ***Materials and Methods:*** A total of 2382 patients were studied to calculate the Entrance Surface Air Kerma (ESAK) following seven radiographic examinations including: chest (PA, Lat), lumbar spines (AP, Lat), pelvis (AP), abdomen (AP), skull (PA, Lat), thoracic spine (AP, Lat) and cervical spines (AP, Lat). The ESAKs values were measured according to x- ray tube output, optimized exposure parameters and body thickness (t_p) for each technique. ***Results:*** The parameters such as, 1st quartile, mean, median, 3rd quartile, minimum, maximum and standard deviation of each ESAK values are reported and compared to NRPB guide levels. The results showed that the ESAK$_s$ values in the lumbar spines and chest X-ray examinations were 30% above the guide levels. However, for the pelvis (AP), skull (PA) and abdomen (AP) examinations, these values were below than those reported by the NRPB. ***Conclusion:*** Periodic quality control and monitoring the technical performance of radiographers might effectively improve the image quality and eventually reducing the dose received by patients.

Keywords: *Diagnostic radiology, ESAK, patient dose, Lorestan province, quality control.*

INTRODUCTION

The radiation protection for patients in diagnostic radiology is governed by principles of justification and optimization, including the consideration of diagnostic reference levels (DRLs). Therefore, a diagnostic radiological procedure is justified if the benefits to the individual patient balance the individual damage from the exposure. Once a medical exposure has been justified, the principle of optimization is applied-that is, the radiological examination must be carried out with equipment and exposure parameters that ensure doses to patients as low as reasonably practicable, consistent with the intended diagnostic purpose (1). For radiological examinations, this value is interpreted as being the lowest dose possible, which is consistent with the required image quality that is necessary for obtaining the desired diagnostic information. From these principles, dose limits for radiological examinations have not been established, in contrast to occupational and public exposure restrictions. Substituting for dose limits, DRLs are used in diagnostic radiology: dose levels in medical radiodiagnostic examinations for patients or efficient and powerful tool in optimization of diagnostic X-ray examinations. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied (2). However, exceeding this level does not automatically mean an examination is inadequately performed, and meeting this level does not automatically equate with good practice, as the image quality may be poor. The goal is apparently to use DRLs to control the level of optimization of the procedures.

Many studies carried out to measure entrance surface dose in different countries and their results were compared with dose levels recommended by relevant organizations. Also, organizations such as the National Radiological Protection Board (NRPB) and International Atomic Energy Agency (IAEA) (3) recommended the use of dose constraints or investigation levels to provide guidance for medical exposures. In the United States (4), Greece (5, 6), Brazil (7) and Bangladesh (8) investigations showed that patients dose from common X-ray examinations were below the reference levels set by the International Commission on Radiological Protection (ICRP). In contrast, in China (9) and Tanzania (10) researchers reported that the average entrance surface doses were comparatively high for X-ray examinations. In addition, many researchers showed that a quality control program to reduce patient dose and increase radiographic image quality is necessary to ensure that all radiological examinations are performed under the terms of less received dose for the patients and the received images have good quality (11, 12). Many countries have regulation controlling the use of ionizing radiation and although different legal systems; the dose levels recommended by ICRP, together with its general philosophy and recommendations are common factors (13). This study was the first investigation which carried out and conducted with the aim of measuring the patient doses for routine radiographic examinations in eight public hospitals crowded in Lorestan Province. Knowledge of the corresponding patient doses will help to determine whether these X-ray radiation doses to patients are as low as reasonably achievable, as required by the ICRP or other relevant organizations.

MATERIALS AND METHODS

The 12 stationary X-ray units including: Varian (620), Shimadzu (800, 1200, 1600), Italray (620, 800, 820) and Toshiba (500, 800) in the eight Public hospital of Lorestan province were participated in this study.

Up to now, ninety three X-ray units (stationary and portable) have been installed in 48 radiology imaging centers in all hospitals and clinics in Lorestan province. Furthermore, 411013 patients have been undergoing radiographic examinations just in public hospitals in 2011. In this study a total of 2382 patients were studied to calculate the ESAK of following seven radiographic examinations (12 projections): chest (PA, Lat), lumbar spine (AP, Lat), pelvis (AP), abdomen (AP), skull (PA, Lat), thoracic spine (AP, Lat) and cervical spine (AP, Lat).

One of the most common methods to estimate patient doses in diagnostic radiology is measuring the X-ray tube output. The tube output should be measured using a calibrated ionization chamber at a known distance from the focus and the same technique factors.

In this regard, entrance surface air kerma (ESAK) is the air kerma on the central X-ray beam axis at the point where X- ray beam enters the patient or phantom. ESAK is determined on the basis of X- ray tube output measurements, X-ray exposure parameters and body thickness for each technique according equation (1). The contribution of the backscattered radiation is also included. Entrance surface air kerma for each patient is calculated using real examination data by using equation

$$ESAK = Y(kV_p, FFD)mAs.\left(\frac{FDD}{FFD - t_p}\right)^2 .BSF \quad (1)$$

Where: $Y(KVp, FDD)$ is tube output for actual

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kVp used during examination (adapted from output chart), *mAs* is actual tube current-time product used during examination and *FFD* is focus-to-film distance (typically 100 cm).

In this study a calibrated solid - state dosimeter (the Barracuda dosimeter Model: SE-43137) was used. To calculate the ESAK for each projection, *Y(KVp, FDD)* was measured at distance 100 cm, field size 10×10 cm and voltage range from 40 to 120*KV*, in 10*KV* steps. BSF is the backscatter factor that depends on *kVp*, the X-ray field size, the thickness of the patient (t_P) or phantom and total filtration of X-rays. Reasonably good approximation for X-ray beam qualities used in diagnostic radiology BSF is 1.4.

In radiology imaging centers with several radiographers, the selection of exposure factors (kVp, mAs and FFD) by each radiographer for the same projection was different, so the radiographers of radiology centers were selected randomly and requested them to select their exposure factors. In this study the SPSS software (version 17) was used for data analysis.

RESULTS

The distribution of individual entrance surface air kerma for seven routine X-ray examinations (12 projections) from eight hospitals in Lorestan province are shown in table 1. As seen for the chest X-ray (AP and Lat) the ESAK values were 0.56±0.46 and 1.76±1.43 mGy. In addition, for the lumbar spines (AP and Lat), the values were 9.99±8.73 and 24.73±23.89 mGy respectively. However, in other examinations the values were lower. For example for the abdomen (AP), pelvic (AP), skull (PA) and thoracic (Lat), the values were 5.58±4.56, 3.34±3.31, and 2.98±2.87 and 9.50±8.69 mGy respectively. The variations in the exposure range of different procedures were obvious (table 2). The mean and ranges of kVp values were 70 (50-90) and 78 (50-100) for lumbar spines (AP, Lat) respectively. In addition, mean and ranges of mAs for lumbar spines (AP, Lat) were 44 (15-173) and 58 (20-200).

The number of patients for each projection; mean and range of patient's characteristics and exposure parameters for selected dataset are shown in table 2 are also shown in figure 1.

DISCUSSION

Diagnostic reference levels (DRLs) were first introduced by the International Commission on Radiological Protection (ICRP) in 1990 [14] and subsequently recommended in greater details in 1996 [15]. The use of DRL as an important dose

Table 1. The distribution of individual entrance surface air kerma for seven routine X- ray examinations (12 projections) from eight hospitals in Lorestan province.

Radiograph	Projection	1st quartile	Median	Mean	3rd quartile	Min	Max	Std. Dev	NRPB* 2000
Abdomen	AP	1.42	3.04	5.58	6.22	0.12	46.01	4.56	6.0
Cervical spine	AP	0.64	1.40	1.90	2.13	0.04	3.29	1.80	-
	Lat	0.18	0.57	1.18	1.53	0.03	12.37	1.06	-
Chest	PA	0.11	0.33	0.56	0.74	0.02	4.30	0.46	0.2
	Lat	0.42	1.51	1.76	2.71	0.03	8.66	1.43	1.0
Lumbar spine	AP	1.57	3.23	9.99	9.57	0.86	166.53	8.73	6.0
	Lat	4.31	8.70	24.73	18.99	0.22	798.08	23.89	14
Pelvis	AP	0.86	2.09	3.34	3.72	0.06	44.25	3.31	4.0
Skull	PA	0.69	1.66	2.98	3.48	0.05	19.54	2.87	3.0
	Lat	0.44	1.13	1.94	2.73	0.02	14.30	1.34	1.5
Thoracic spine	AP	1.80	3.14	3.82	4.61	0.06	13.36	3.14	3.5
	Lat	2.51	4.99	9.50	12.47	0.11	61.22	8.69	10.0

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Table 2. Mean and range of patients characteristics and exposure parameters for selected dataset in Lorestan province.

Radiograph	Projection/ Patients	Tube potential (kVp)	Exposure setting (mAs)	Patient thickness (cm)	Patient weight (kg)	Patient height (cm)
Abdomen	AP/198	69(46-100)	46(14-176)	27(11-65)	68(7-115)	162(60-200)
Cervical spine	AP/154	64(44-80)	23(10-150)	22(6-25)	66(7-100)	163(60-186)
	Lat/162	61(43-82)	19(10-50)	23(6-15)	65(5-100)	163(60-186)
Chest	Lat/137	71(45-99)	29(8-100)	32(14-65)	69(11-110)	165(69-200)
	PA/382	63(30-94)	22(8-90)	26(6-35)	65(5-127)	162(50-195)
Lumbar spine	AP/277	70(50-90)	44(15-173)	33(11-45)	70(22-110)	163(68-187)
	Lat/234	78(50-100)	58(20-200)	43(12-60)	73(25-110)	166(90-190)
Pelvis	AP/229	66(45-85)	39(10-170)	23(7-57)	64(10-110)	161(78-205)
Skull	Lat/221	60(42-75)	25(10-75)	20(10-25)	60(8-95)	158(60-190)
	PA/199	64(44-76)	32(10-90)	23(10-28)	60(6-95)	159(60-190)
Thoracic spine	AP/90	66(42-80)	33(3-80)	27(13-50)	65(13-95)	163(85-185)
	Lat/99	73(50-95)	37(6-80)	38(15-60)	65(14-95)	162(85-185)

optimization tool is confirmed by many professional and regulatory organizations, including the ICRP, American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), United Kingdom Health Protection agency, International Atomic Energy Agency (IAEA) and European Commission (EC).

The distribution of individual entrance surface air kerma for seven routine X-ray examinations (12 projections) are shown in table 1. In the chest X-ray (AP and Lat) and lumbar spines (AP and Lat), the ESAK values were greater than those reported by guideline levels [16].

However, in other examinations such as abdomen (AP), pelvic (AP), and skull (PA) and thoracic (Lat), the values were lower than the guideline levels. Comparing the ESAK values of the lumbar spines and chest X-ray examinations with the guide levels of NRPB references showed that the values are 30% above the guide levels. On the other hand, in the pelvis (AP), skull (PA) and abdomen (AP) examinations, these values were below than those reported by the NRPB. Fortunately in the thoracic spines (AP, Lat) examinations, there was no significant difference. It has been estimated that increasing the tube potential from 60 to 90 kVp and decreasing the mAs will result in an entrance skin exposure saving of 53% [17]. The use of reference levels has been shown to reduce the overall dose and the range of doses observed in clinical practice. For example, U.K. national dose surveys demonstrated a 30% decrease in typical radiographic doses from 1984 to 1995 and an average drop of about 50% between 1985 and 2000 [18, 19]. One of the important means to decrease the ESAK is using the high speed film. These films can reduce the dose up to 40 % [20]. In this regard, all of diagnostic radiology centers in Lorestan province had used fast speed film-screen.

The results of this study provide valuable information about the patient dose in Lorestan province. The wide variations in the patient dose levels, even in the same procedures carried out by different radiographers is mainly due to the choice of different exposure setting, focus to film distance and finally output of the X-ray units.

In conclusion it seems most of the radiographers are not interested in practicing what learned! Therefore, periodic quality control testing and monitoring the technical performance of radiographers might effectively improve the image quality and reducing the dose to patients.

Conflict of interest: *Declared none*

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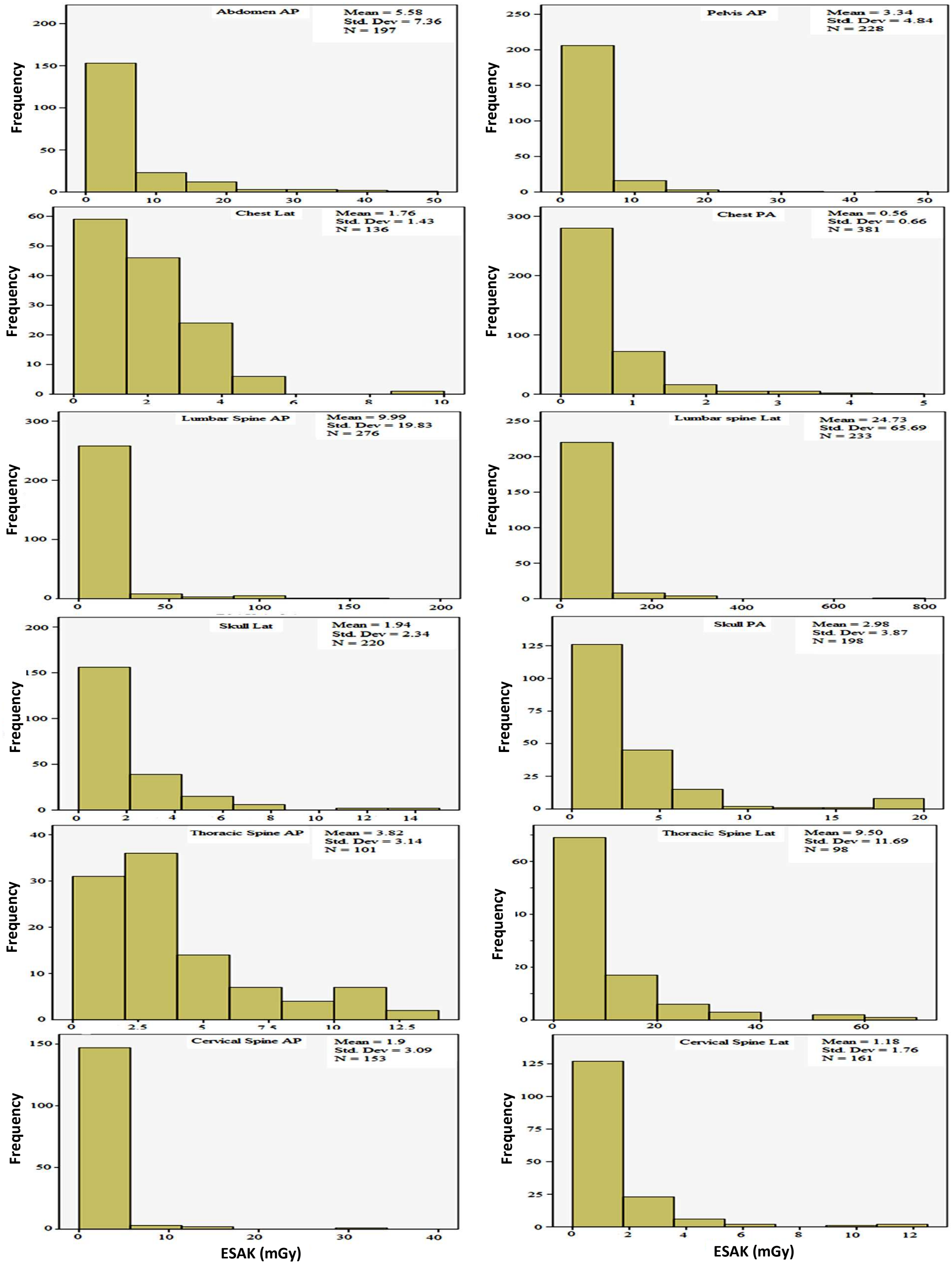

Figure 1. Histograms of entrance surface air kerma per radiograph for selected common x-ray projections in Lorestan province.

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REFERENCES

1. Freitas MB and Yoshimura EM (2009) Diagnostic reference levels for the most frequent radiological examinations carried out in Brazil. *Rev Panam Salud Publica,* ***25(2)****: 95–104*.
2. Commission of the European Communities. Health protection of individuals against the dangers of ionizing radiation in relation to medical exposure and repealing Directive 84/466/Euratom. Council Directive 97/43/ Euratom. Official Journal of the European Communities, L180/22; 1997.
3. International Atomic Energy Agency (1996) International basic safety standards for protection against ionizing radiation and for the safety of radiation sources. I*AEA safety series,* ***No. 115****, Vienna: Austria*.
4. Michel R and Perle SC (2002) Effective dose equivalent estimates in diagnostic radiology with single dosimetry. *Health Phys,* ***79:*** *17-19*.
5. Yakoumakis E, Tsalafoutas IA, Nikolaou D, Nazos I, Koulentianos E, Proukakis C (2001) Differences in effective dose estimation from dose area product and entrance surface dose measurements in intravenous urography. *Br J Radiol,* ***74****: 727-734*.
6. Makri T, Yakoumakis E, Papadopoulou D, Gialousis G, Theodoropoulos V, Sandilos P, Georgiou E (2006) Radiation risk assessment in neonatal radiographic examinations of the chest and abdomen: a clinical and Monte Carlo dosimetry study. *Phys Med Biol,* ***51****: 5023-33*.
7. Freitas MB and Yoshimura EM (2003) An overview of doses to patients and irradiation conditions of diagnostic chest X ray examinations carried out in hospitals of the city of Sao Paulo, Brazil. *Radiat Prot Dosimetry,* ***103****: 141-148*.
8. Begume Z (2001) Entrance surface, organ and effective doses for some of the patients undergoing different types of X -ray procedures in Bangladesh. *Radiat Prot Dosim,* ***95****: 257-262*.
9. Li LB, Wang JP, Yu XR, He SS, Yu FH, Ding CH (2001) Medical radiation usage and exposures from medical X-ray diagnosis in Shandong province of China. *Radiat Prot Dosim,* ***93****: 261-266*.
10. Muhogora WE and Nyanda AM (2001) The potential for reduction of radiation doses to patients undergoing some common X-ray examinations in Tanzania. *Radiat Prot Dosim,* ***94****: 381-384*.
11. Keikhahi Farzaneh MJ, Shirin Shandiz M, Vardian M, Deevband MR, Kardan MR (2011) Evaluation of image quality and patient dose in conventional radiography examinations in radiology centers in Sistan and Baluchestan, Iran and comparing with that of international guidelines levels. I*ndian Journal of Science and Technology,* ***4*** *(11):1429-1433*.
12. Bouzarjomehri F (2004) Patient dose in routine X-ray examinations in Yazd state. *Iran J Radiat Res,* ***1****(4): 199-204*.
13. Kim Y-H, Choi J-H, Kim C-K, Kim J-M, Kim S-S, Oh Y-W, Lee C -Y, *et al*. (2007) Patient dose measurements in diagnostic radiology procedures in Korea. *Radiation Protection Dosimetry,* ***123*** *(4): 540-5*.
14. International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection. ICRP Publication 60, Ann. ICRP 21. Oxford: Pergamon Press; 1991.
15. International Commission on Radiological Protection (1996). Radiological protection and safety in medicine. ICRP Publication 73, Ann. ICRP 26, Oxford: Pergamon Press, UK.
16. Hart D, Hillier MC, Wall BF (2002) Doses to patients from medical X-ray examinations in the UK- 2000 Review. National Radiological Protection Board, NRPB- W14, Chilton Didcot, UK.
17. Warren Forward H.M, Millar J.S (1995) Optimization of radiographic technique for chest radiography. *Br J Radiol,* ***68****(815): 1221-9*.
18. Hart D and Wall BF (2004) UK population doses from medical X-ray examination. *Euro J Radiol,* ***50 (3)****: 285-291*.
19. Shrimpton PC, Wall BF, Hart D (1999) Diagnostic medical exposure in the UK. *Applied Radiation and Isotopes,* ***50****(1): 261-9*.
20. Hart D, Hillier MC, Wall BF, Shrimpton PC, Bungay D (1996) Doses to patients from medical X-ray examinations in the UK- 1995 Review. National Radiological Protection Board NRPB-R289. London: HMSO, UK.

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