

## Local Diagnostic Reference Levels for Common Pediatric X-Ray Examinations in Khorasan Razavi Province, Iran

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### Abstract

#### Introduction

Given the fact that children are more sensitive to radiation, compared to adults, special attention needs to be paid to radiation protection in pediatric radiology. Diagnostic reference level (DRL) has been defined to be employed as a practical tool for examining the overall performance of a radiological center in terms of patient dose among a series of similar equipments in an area or an institution as a Local DRL (LDRL).

#### Materials and Methods

To establish DRL for diagnostic X-ray examinations of children in Khorasan Razavi province, data were collected from 627 pediatric patients. The average of entrance surface doses (ESDs), arising from chest and abdomen examinations, were examined for three different age groups.

#### Results

Local DRL (LDRL) were calculated to be 77, 126, and 138  $\mu\text{Gy}$  for chest examinations of <1-month-old, 1-12-month-old, and 1-5-year-old groups, respectively. The corresponding values obtained from abdomen radiographies were 152, 120, and 280  $\mu\text{Gy}$ , respectively.

#### Conclusion

Our findings revealed that local DRLs in this study are higher than the corresponding values, recommended by the Commission of European Communities (CEC) and National Radiological Protection Board (NRBP). Higher ESDs acquired for chest examination were related to the use of low kVp, relatively high mAs in all centers, and use of grid for most of the patients.

**Keywords:** Diagnostic Reference Level; Pediatric; Radiology; Entrance Surface Dose; Iran

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## 1. Introduction

Optimization of pediatric X-ray examinations is of high significance. Although the International Commission on Radiological Protection (ICRP) has not recommended any dose limits for patients, it has highlighted the importance of applying reference levels in the process of optimizing protection in medical exposures. [1]

Risk of lethal cancer from radiation exposure in children is expected to be 2-4 times higher than adults per unit dose. The reason for this difference is not fully understood, but greater cell proliferation rate and longer life expectancy among children may result in a higher risk of long-term side-effects [2].

In a study referenced by the monthly radiology journal of Radiological Society of North America (RSNA), researchers found an increased risk of childhood acute lymphocytic leukemia, attributed to patients' exposure to plain X-rays and an increased risk of breast cancer, associated with scoliosis exams. [3]

The Alliance for Radiation Safety in Pediatric Imaging (The Image Gently Alliance) is a coalition of health care organizations dedicated to providing safe, high-quality pediatric imaging. The primary objective of this alliance is to raise the awareness of imaging communities regarding the need to adjust radiation doses, while performing imaging examinations on children. Similarly, Image Wisely program addresses medical imaging for adults. Moreover, countries included in the Commission of European Communities (CEC) are required to establish and use diagnostic reference levels (DRLs) for X-ray examinations. [4]

The use of DRLs has been shown to reduce the overall dose and range of doses in clinical practice. For instance, national dose surveys in U.K. demonstrated a 30% decrease in typical radiographic doses from 1984 to 1995 and an average drop of about 50% between 1985 and 2000. [5, 6]

DRL is not only the suggested or ideal dose for a particular procedure or an absolute upper limit [7], but is also a helpful tool to optimize patient dose for standard radiographic procedures. [8] Application of DRLs for pediatric examinations

is more complicated than its use for adult patients, since there is no single standard weight range which can be used for all children, aged 0-15 years.

The R318 report by The National Radiological Protection Board (NRPB), entitled "Reference doses and patient size in pediatric radiology", outlines a method for calculating pediatric DRLs [9]. For pediatric patients, smaller sample sizes (2 or 3 children) could be used to determine conformity with DRL for each sample size. [10] According to the statistics provided by 2006 census in Iran, approximately 8.5% of the population, aged less than 15 years, are living in KhorasanRazavi province. [11] Therefore, the aim of this study was to suggest local DRLs (LDRLs) for the most frequent radiographic examinations in this region.

## 2. Materials and Methods

All examinations monitored in this study were performed at 10 radiology centers. Routine radiology examinations such as chest (anterior-posterior and posterior-anterior) and abdomen (anterior -posterior) examinations were evaluated. The study group was selected from patients, who were referred to the selected departments in KhorasanRazavi province, Iran.

Firstly, the statistics of radiology centers in the province were presented by the vice-chancellor for treatment at Mashhad University of Medical Sciences; then, the number of patients per center was calculated. Finally, 10 radiology centers were selected, using the statistical method of probability proportional to size (PPS).

The sampling included various radiology centers of different sizes and activity levels including hospitals affiliated to Islamic Azad University, a maternity hospital, a private center, one charity medical center, government general hospitals, and specialized pediatric hospitals. Patients were selected from three age groups: 0-1 months, 1-12 months, and 1-5 years of age. These age groups were selected since 0-1 year-old infants are at the most sensitive age and radio-sensitivity of 5-year-

old children ranges between that of infants and teenagers. [12]

LDRLs for pediatric patients in neonatal intensive care units have been previously reported [13]. Questionnaires were distributed between radiographers and patients. The questionnaire included patients' information such as age, weight, height, and radiographic parameters, e.g., peak kilovoltage(kVp), exposure setting (mAs), focus-film distance (FFD), and grid usage.

Entrance skin dose (ESD) was directly measured by LiF:Mg, Ti. Thermoluminescent dosimeter (TLD) calibration was provided by the irradiation of a group of TLDs, using diagnostic X-rays (80 kV, total filtration of 3.0 mmAl) with a known dose (mGy range), measured by a 6 cm<sup>3</sup> ion chamber and Radcal monitor (model 9015). [14]

Two TLDs were placed inside a plastic sachet, placed on the skin surface at the point of intersection with the central beam axis. The mean value of the two measured ESDs was taken as the measured dose at the point of interest. To anneal TLD-100 LIF chips, they were heated at 400°C for 1 hour, cooled down slowly to ambient temperature, and then reheated at 75°C for 18 hours. The irradiated chips were later read by Harshaw 3500 TLD Reader.[15]

Microsoft Excel was employed for data manipulation and ESD calculation. LDRLs were represented as the 75<sup>th</sup> percentile ESD, measured during the study period. Data analysis was performed, using SPSS version 13.

### 3. Results

In this study, 627 pediatric patients were examined. Chest X-rays were the most prevalent pediatric examination. Chest and abdomen X-rays were performed for all three age groups in all departments included in this study, except the maternity hospital (patients were only neonate), which is represented by No. 4 in figures.

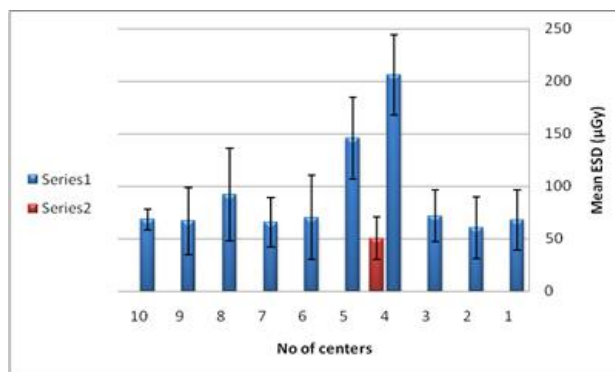


Figure 1. Mean ESDs (µGy) for chest examination in group 0 (series 2 is related to the excluded grid)

Figure 1 shows that in center No. 4, the mean ESD was relatively high according to the collected data of 24 pediatric patients. Thereby, by employing the reference text [4], we could show that using an anti-scatter grid for X-ray examinations of newborn is not essential. Therefore, this grid was excluded and ESD was measured for another 30 patients. Consequently, the mean ESD significantly decreased from 206 to 50 µGy - center No. 4 even lower than other centers .

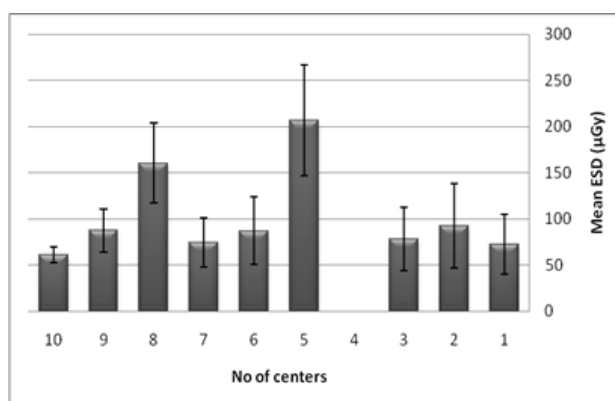


Figure 2. Mean ESDs (µGy) for chest examination in group 1

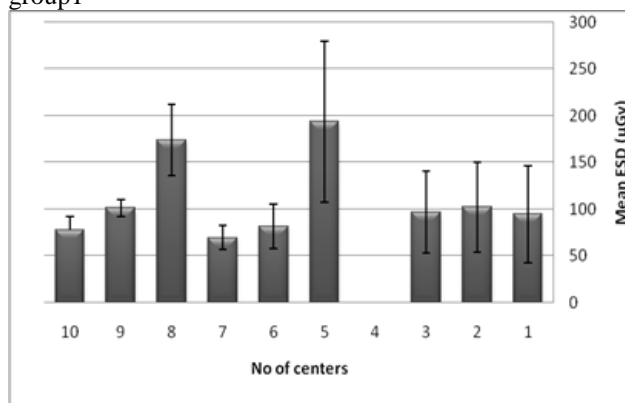


Figure 3. Mean ESD (µGy) for chest examination in group 5

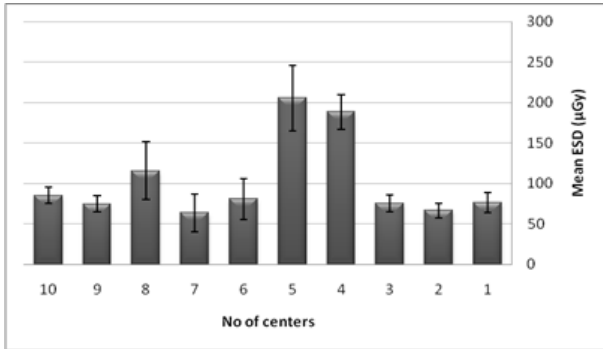


Figure 4. Mean ESDs (µGy) for abdomen examination in group 0

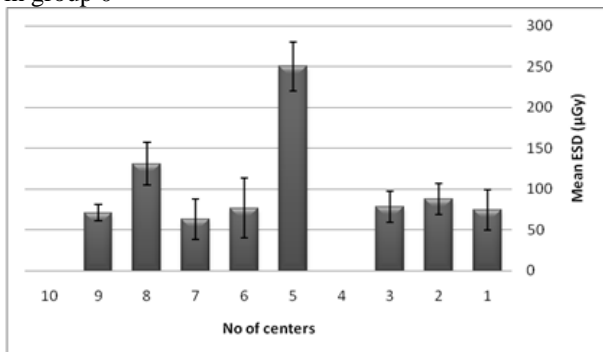


Figure 5. Mean ESDs (µGy) for abdomen examination in group 1

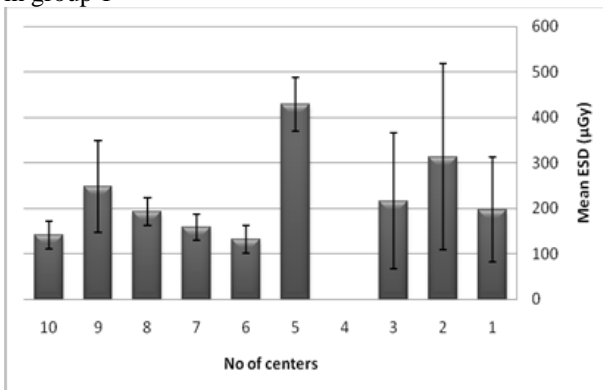


Figure 6 Mean ESDs (µGy) for abdomen examination in group 5

#### 4. Discussion

It should be mentioned that all centers used carbon fiber cassettes with the film speed of 400. Also, based on the quality control tests, all units had total filtration more than 2.5 mmAl; also, most of them were not newly built facilities (more than 10 years since construction).

Figure 1 clearly demonstrates that infants received the highest dose in chest examinations at center No. 4 (before optimization). This is attributed to higher mAs, as a result of using grids. Likewise, in center

No. 5, which is a private center, technologists merely focused on image quality. In fact, for radiologists' satisfaction, they used anti-scatter grids for all patients, regardless of the patient's size (e.g., an infant or an older child).

Mean ESDs, arising from two common X-ray examinations performed on pediatric patients in this study, are summarized in Table 1.

The significant variations in ESD values, observed in this study, indicate that reducing patient dose can be achieved by changing technical parameters (e.g., kVp and mAs), without wering the image quality; also, these variations are influenced by patient's body size. Our findings showed that LDRLs obtained in this study are higher than the corresponding values, recommended by CEC and NRPB for chest examination.

Also, the obtained values were higher than the figures reported by Parviainen *et al.*, who optimized patient dose by adding filtration and not using grids for pediatric patients. [16] However, the LDRL for 0-1-year-old group in this study was lower than the LDRL, reported by NICU. The main underlying reasons for lower values in the current study are short FFD and large X-ray field in the NICU reports.

In contrast, LDRLs obtained for abdomen examinations for 1-5-year-olds did not exceed the previously reported values by other researchers (Table 1). The unusual high doses observed in some departments were related to the use of low kVp and relatively high mAs, due to the application of grids in all examinations. It should be mentioned that all departments in this research were using low kVp (mean kVp= 50-54 for chest examinations), while the CEC recommends 60-65 kVp for neonates, 70-80 kVp for children (up to 5 years of age), and 100-120 kVp for older children. [4]

## LDRL for Pediatric X-Ray Examinations

Table 1. LDRLs suggested for chest and abdomen X-ray examinations of pediatric patients in KhorasanRazavi province and the corresponding values suggested by other studies

Test (view)	Chest (AP*)	Chest (AP)	Chest (AP)/(PA**)	Abdomen (AP)	Abdomen (AP)	Abdomen (AP)
Age group	0	1	5	0	1	5
Mean weight (kg)	3.3	7.0	14.5	2.7	8.1	15.3
Mean height (cm)	51	66	96	52	71	97
Number of patients	109	105	138	81	67	103
Mean ESD ( $\mu\text{Gy}$ )	75.86	102.36	110.33	105.17	104.03	225.21
LDRL (before optimization)	105	126	138	152	120	280
LDRL (after optimization)	77	--	--	--	--	--
DRL ( $\mu\text{Gy}$ ) (NRPB) [9]	50	50	70	0	400	500
DRL ( $\mu\text{Gy}$ ) (CEC) [4]	--	--	100	--	--	1000
DRL ( $\mu\text{Gy}$ ) (Parviainen) [16]	45	42	57	--	--	--
LDRL ( $\mu\text{Gy}$ ) (NICU-Iran) [13]	88	--	--	98	--	--

The outcomes of this study showed that examination technique in pediatric radiology is not yet optimized in KhorasanRazavi province and the non-optimized procedures contribute to the considerable variations in children's radiation dose. Therefore, quantitative methods for the assessment of patient dose should be implemented in all radiology departments. However, the risks versus benefits of each method should be considered, especially as radiation effects are cumulative. Establishment of national reference doses for this group of patients is an important goal if a society is concerned with the safety of future generations. Although there is virtually no previously stated DRL for children in Iran, the current obtained LDRL values for chest examinations are high. Thus, further research is required to achieve lower DRLs in order to have reasonably achievable values that can prevent unjustified radiation exposure.

On the other hand, this study was performed before computed and digital radiographies became widely available in this region. Therefore, we believe that LDRL should be

regularly set in the future, given the high latitude of this region and the potential risks of overexposure to radiation for filmless radiography. [17]

Besides, the Image Gently campaign's message of "Back to Basics" should be considered. This campaign is a comprehensive program designed to educate members of medical imaging teams and the public about the fundamental safety measures, procedures, and parameters of digital radiography. [18]

Studies carried out in other countries have indicated the effectiveness of DRL; in fact, applying DRLs is part of a quality assurance program to optimize patient dose in diagnostic radiology. This program may address the question "Why should one radiology facility use protocols that lead to 10, 20, or 126 times greater dose, compared to other facilities, to produce similar radiographic images?". [19]

Finally, regarding image quality assessment, medical physicists should work hand in hand with radiologists and technologists to determine whether or not the required level of image quality could be attained at lower doses. Based on the recommendations by Image

Wisely program, "Reference levels act as 'trigger levels' to initiate image quality improvement". [7] Therefore, a balance is needed between diagnosis and radiation exposure to protect children.

## 5. Conclusion

Our findings revealed that local DRLs in this study are higher than the corresponding values, recommended by the Commission of European Communities (CEC) and National Radiological Protection Board (NRBP). Higher ESDs acquired for chest examination were related to the use of low kVp, relatively high mAs in all centers, and use of grid for most of the patients.

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