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Levels of medical exposure of children in St. Petersburg's and the possibility of applying the diagnostic reference levels

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Regional study was conducted in 12 specialized paediatric medical organisations in St. Petersburg to assess exposure levels of paediatric patients (newborns, 1, 5, 10 and 15 years) during the most common radiographic examinations. The average values of effective doses for each age group, as well as the minimum and maximum average effective dose for the X-ray machine for each type of examinations and quantiles of dose distributions are provided. The ratio of the maximum to minimum dose values for the different of X-ray apparatuses, in most cases, was found to be a factor of 15. The average effective doses for the projection in the hospitals of St. Petersburg are compared with the similar data from Italian hospitals.

Key words: *patients, children, medical exposure, X-ray examination, effective dose.*

Introduction

Radiation exposure of pediatric patients may result in an attributable fatal cancer risk three times greater than that for adults [1,2,3]. This is mainly attributed to their higher sensitivity to radiation and longer life expectancy over which any harmful effects may manifest. Therefore, it is vital that exposure with ionizing radiation to pediatric patients be justified and optimized as much as possible. For all radiological examinations the radiation dose of the exposed children should be determined for the purpose of radiation protection.

A valuable and well-accepted instrument in dose optimization are diagnostic reference levels (DRLs) [1]. However, the application of the concept to pediatric radiology has some particular problems. In most cases the primary causes are the difficulties encountered in conducting dose surveys and defining appropriate reference levels for children. Most likely only few data on pediatric doses are available because the number of medical examinations performed on children is generally lower than for adults, and the data need to be split into age groups to reflect physical properties of the patient correctly. However, it is obvious that optimization is extremely important for children undergoing medical examinations.

Objectives of the study

- assessment of the radiation dose for the pediatric patients for the most common conventional x-ray examinations;
- comparison of the collected data with the literature sources;
- proposal of the diagnostic reference levels draft for a number of common conventional x-ray examinations.

Materials and methods

Due to the specifics of the equipment and practice of national X-ray diagnostics, determination of the radiation dose and 75% quantile of the distribution were performed in terms and units of the effective dose.

14 X-ray units in 12 dedicated pediatric hospitals in St. Petersburg were surveyed throughout the study: 8 general practice hospitals, two pediatric polyclinics, 1 maternity hospital, 1 pediatric orthopedics and traumatology rehabilitation center. For 4 x-ray units we collected individual parameters of exainations for individual patients, for other units – the mean values for the each age group, by questioning the doctors and technicians.

The calculation of effective doses was performed according to the data on examination parameters and radiation output of the x-ray unit. The set of parameters necessary for the calculation of typical effective dose included physical and technical parameters of the X-ray machine (tube current and exposure time, tube voltage, filtration, radiation output,) and geometric parameters of examination (size and projection of examination field, source-detector distance, etc.). On the basis of the individual parameters of the procedure we assessed the effective doses of the patients, out of which mean doses were calculated. Mean doses were combined with the results of the calculations of the effective doses for the standard patients using average examination parameters for age groups for other x-ray units and were used for statistical processing, including determination of the 75% quantile of the distribution.

Data collection was standardized. The questionnaires were completed in each radiological department by the radiographers. Before doses calculation, checks for plausibility of the all reported data were carried out. Then the raw data were combined with radiation output measurements.

Out of the extensive list of the conventional X-ray examinations, we selected 8 most frequently performed: skull examination (PA, LAT), cervical spine examination (AP, LAT), thoracic spine examination (AP, LAT), lumbar spine examination (AP, LAT), chest examination (AP / PA, LAT), examinations of the abdomen (AP), pelvis (PA) and hips (AP). It was decided to divide the children into five age groups: newborn (<0.5), 0.5-2, 3-7, 8-12 and 13-18 years – in accordance with the mathematical anthropomorphic hermaphrodite phantom set [4] – and take their anthropometric characteristics for the standard patient in each age group (Table 1) for the subsequent calculation of effective dose values.

Table 1

Anthropometric characteristics for the standard patient in each age group used in this study

Age, years		Weight, kg	Height, cm	Trunk size, cm	
				Anterior-posterior	Lateral
0	0-5 mo.	3.5	51.5	9.8	12.7
1	6 mo.-2	9.3	75	13	17.6
5	3-7	19	109	15	22.9
10	8-12	31.9	138.6	16.8	27.8
15	13-18	54.4	164	19.6	34.5

Typical parameters for the selected examination types of the standard patient were obtained for each of 14 investigated X-ray units from the data collected in nine hospitals in St. Petersburg. Radiation output was measured for all X-ray units. Accordingly, for each x-ray unit we determined effective doses for the standard patients. The results underwent statistical processing and were used to determine the 75% quantile of the distribution. 590 sets of parameters were collected for the types of examinations and age groups mentioned above that were necessary to assess the effective dose.

Effective dose (ED) for the standard patients were assessed for all the 590 sets of parameters using the EDEREX software (Golikov et al. [5]).

Results and discussion

A set of X-ray examinations varies in each hospital depending on its specialization. Table 2 shows the mean values of the effective for each age group, as well as the minimum and maximum mean effective dose for the X-ray unit for each type of examinations and the quantiles of the dose distributions. For several examinations quantiles were not calculated due to the small number of x-ray rooms that provided information.

It was determined that the highest values of the mean effective doses were typical for the examinations of thoracic and lumbar spine and abdomen: 0,14-0,36 mSv, and 0,1-0,55 mSv 0,14-0,4 mSv, respectively. X-ray examinations of the skull (0.02-0.05 mSv), chest (0.03-0.06 mSv) and cervical spine (0,03-0,12 mSv) are associated with low doses. This can be explained by the weight and set of the radiosensitive organs within the irradiation field for those types of examinations. For a number of examinations, such as thoracic spine, lumbar spine, abdomen, pelvis, hip, with age doses increase almost monotonically. For other examinations (skull, chest, cervical spine) effective dose varies slightly.

Table 2

Average, maximum and minimum values and quantiles effective doses

Examination / Projection	Age group	Number of rooms	The effective dose, mSv					
			Mean	Min	max	25% quantile	Median	75% quantile
				Skull				
PA	0	11	0.04	0.01	0.17	0.01	0.02	0.05
	1	10	0.03	0.004	0.07	0.01	0.02	0.07
	5	11	0.04	0.010	0.09	0.01	0.04	0.09
	10	11	0.04	0.019	0.07	0.03	0.04	0.06
	15	11	0.05	0.010	0.14	0.02	0.02	0.09
LAT	0	11	0.03	0.004	0.08	0.01	0.01	0.05
	1	11	0.02	0.002	0.04	0.01	0.02	0.03
	5	10	0.02	0.002	0.04	0.00	0.02	0.03
	10	11	0.02	0.010	0.04	0.02	0.02	0.03
	15	10	0.03	0.010	0.07	0.01	0.02	0.03
				Chest				
AP/PA	0	13	0.03	0.010	0.08	0.01	0.02	0.05
	1	12	0.04	0.010	0.13	0.01	0.02	0.05
	5	13	0.03	0.010	0.14	0.01	0.02	0.03
	10	13	0.03	0.010	0.08	0.01	0.02	0.04
	15	13	0.03	0.005	0.08	0.01	0.03	0.04
LAT	0	11	0.04	0.010	0.14	0.01	0.02	0.05
	1	10	0.04	0.010	0.15	0.02	0.03	0.05
	5	12	0.04	0.010	0.12	0.02	0.02	0.03

Examination / Projection	Age group	Number of rooms	The effective dose, mSv					
			Mean	Min	max	25% quantile	Median	75% quantile
	10	13	0.04	0.010	0.15	0.01	0.03	0.04
	15	12	0.06	0.010	0.24	0.01	0.06	0.08
				Cervical spine				
AP	0	2	0.12	0.020				
	1	5	0.04	0.010				
	5	10	0.05	0.004	0.21	0.01	0.02	0.06
	10	13	0.05	0.010	0.27	0.01	0.03	0.06
	15	10	0.05	0.005	0.16	0.01	0.03	0.08
LAT	0	5	0.03	0.010				
	1	8	0.03	0.010	0.09	0.01	0.02	0.05
	5	12	0.03	0.002	0.20	0.01	0.01	0.02
	10	13	0.04	0.004	0.39	0.01	0.01	0.02
	15	11	0.05	0.003	0.44	0.00	0.01	0.03
				Thoracic spine				
AP	0	3	0.17	0.030				
	1	5	0.24	0.050				
	5	8	0.17	0.020	0.49	0.08	0.11	0.26
	10	9	0.24	0.040	0.72	0.06	0.17	0.32
	15	11	0.36	0.040	0.93	0.14	0.36	0.58
LAT	0	3	0.14	0.020				
	1	5	0.15	0.040				
	5	8	0.14	0.010	0.41	0.05	0.12	0.18
	10	8	0.18	0.030	0.51	0.11	0.13	0.22
	15	11	0.27	0.020	0.72	0.18	0.21	0.32
				Lumbar spine				
AP	0	3	0.14	0.013				
	1	6	0.21	0.010				
	5	11	0.29	0.020	0.73	0.17	0.23	0.36
	10	11	0.33	0.048	0.70	0.25	0.34	0.45
	15	12	0.36	0.040	0.60	0.22	0.40	0.50
LAT	0	3	0.16	0.017				
	1	6	0.16	0.010				
	5	11	0.16	0.017	0.35	0.06	0.16	0.25
	10	11	0.20	0.045	0.35	0.13	0.19	0.30
	15	12	0.40	0.040	1.02	0.20	0.28	0.58
				Pelvis				
AP	0	8	0.06	0.020	0.20	0.02	0.05	0.08
	1	8	0.06	0.010	0.19	0.02	0.03	0.11
	5	11	0.13	0.010	0.51	0.02	0.04	0.21
	10	10	0.25	0.060	0.63	0.06	0.24	0.33
	15	9	0.32	0.030	0.96	0.05	0.23	0.50
				Hip				
AP	0	3	0.02	0.010				
	1	3	0.02	0.010				
	5	8	0.09	0.010	0.46	0.02	0.03	0.06
	10	7	0.23	0.030				
	15	7	0.22	0.020				
				Abdomen				
AP	0	6	0.10	0.020				
	1	9	0.12	0.020	0.44	0.04	0.05	0.07
	5	9	0.14	0.030	0.44	0.05	0.06	0.15
	10	8	0.34	0.135	0.68	0.21	0.31	0.43
	15	9	0.55	0.22	1.80	0.24	0.28	0.64

The ratio of the maximum and minimum effective dose values for the different X-ray units is presented in Table 4. It is significant: the mean ratio factor is 15, with minimum and maximum factors of 4 and 85, respectively.

Table 4

Ratio of maximum to minimum average typical effective dose for the examinations considered in this study

Projections		Ratio of maximum to minimum average typical doses				
		newborn	0.5-2	3-7	8-12	13-18
Skull	PA	17	7	9	4	14
	LAT	8	4	4	4	7
C Spine	AP	11	7	21	27	16
	LAT	10	9	20	39	44
Th Spine	AP	10	8	25	18	23
	LAT	13	8	41	17	36
Chest	AP/PA	8	13	14	8	8
	LAT	14	15	12	15	24
L Spine	AP	28	85	37	14	15
	LAT	15	48	18	9	26
Abdomen	AP	14	22	15	5	8
Pelvis	AP	10	19	51	11	32
Hip	AP	5	4	46	16	22

While assessing the mean effective dose spread between the different x-ray rooms within the individual age groups, we were able to identify regular excesses of the dose in the same x-ray rooms from examination to examination. Identification of such deviations from good clinical practice is an important task of optimization, and the DRLs concept is specifically designed for this task [6]. When such deviations are identified, one should pay attention to them and conduct a detailed analysis of the causes of abnormally high doses. One of the possible and the most likely reason – unsufficient collimation of the beam and the use of large irradiation fields.

Since there is little data in foreign literature on the effective doses from the pediatric medical exposuredue to the fact that DRL establishment in international practice is based on directly measured dose attributes (entrance surface dose, dose-area product), the possibility to compare the results of this study with other published data was limited. Comparison of the mean effective dose per projection in the St. Petersburg hospitals with similar data from Italian hospitals [7] for infants and children up to 5 years is shown in Fig. 7. Effective doses in St. Petersburg hospitals are higher than in Italy and Greece, and the difference can be up to 4 times, but in absolute terms doses does not exceed tenths of mSv.

In this paper we present the 75-quantiles of effective dose distributions for different types of examinations (Table. 1). These values can be used as a basis for establishing pediatric diagnostic reference levels in St. Petersburg similarly to the MR 2.6.1.0066-12 "Application of diagnostic reference levels for the optimization of radiation protection of the patient in conventional x-ray examinations" [6] for adults.

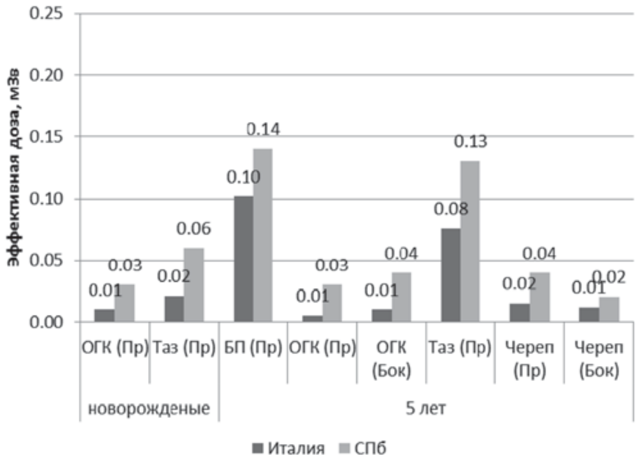

Figure 1. Comparison of mean effective doses per projection in Saint – Petersburg and Italy hospitals

Results

The significant spread of average effective dose values between different X-ray rooms and the presence anomalously high values of effective dose indicate insufficient standardization in the number of cases of radiological examination methods, quality control of the equipment and the procedures.

High exposure levels in St. Petersburg in comparison with reported dose data confirm a real possibility to reduce the levels of exposure of children in routine radiology. One of the first steps in this direction could be the introduction into the practice of diagnostic examinations of the concept of children's diagnostic reference levels.

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