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ESTIMATION OF PATIENT DOSES FROM X-RAY EXAMINATIONS IN THE BRYANSK REGION HOSPITALS

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Abstract**:** During 2012 - 2013 a study to evaluate conventional X-ray procedures and patient doses in Klintzi and Novozibkov areas of Bryansk region, Russia, was conducted. X-ray operation parameters included quality assurance of equipment, collection of procedure parameters and clinical practice evaluation. Effective doses were calculated for each selected procedure and dose distributions were established. 75-percentiles of the dose distributions were selected as a preliminary regional diagnostic reference levels (DRL). The DRLs were comparable to the St-Petersburg diagnostic reference levels, except for the skull, abdomen and pelvis areas. High dose spread is explained by differences in radiological practice and unit condition.

Keywords**:** X-ray examinations, radiation protection, optimization, diagnostic reference level, effective dose

1. Introduction

In 2009, St-Petersburg Institute of Radiation Hygiene (IRH) started a project for implementation and adaptation of Diagnostic Reference Level system into Russian Health care practice. During the following four years, system for data collection and methods for dose assessment were developed. Data was collected from 46 hospitals in St Petersburg, providing us with enough information to establish the first dose distributions, for 2012. The 75-percentile of those dose distributions was selected to be our DRL value. Recommendations for local practice optimization were also prepared. However, the state of practice and equipment in St-Petersburg varies much with the rest of the Russian Federation. Therefore, we needed to assess the state of practice and the patient's doses in other, preferably country-side regions for comparison.

For this assessment, Klintzi and Novozybkov areas of Bryansk region, were selected (the main areas contaminated after the Chernobyl accident). The hospitals in those areas were representative for the rest of the Russian Federation in terms of equipment, staff training and state of radiological practice.

IRH has a long-term connection with the local healthcare authorities in the Bryansk region, assessing the local population doses from internal and external exposure since 1986. That allowed us to gain friendly access to the X-ray departments with full support from the local practitioners during data collection. The small size of the area allowed us to investigate and monitor all hospitals.

The study was conducted as a part of joint Russian-Swedish project between IRH and the Medical Radiation Physics group in Malmö, Lund University (MRPM). It was divided into two parts, which were performed in 2012 and 2013, respectively. Each part was divided into steps, each step being fulfilled as a separate expedition. Only conventional X-ray practice was evaluated. During 2012 the following steps were conducted: 1) introduction to the local state of radiology practice 2) initial QA and data collection in X-ray departments 3) preliminary dose assessments 4) identification of X-ray units with excessive doses and continued investigations in those units. At the end of the year we presented the preliminary results of our study to the stakeholders and performed an optimization training course for the practitioners, providing them with recommendations on how to improve their current state of practice. During 2013 some additional hospitals were inspected in the same area. At the same time we also re-collected the data from the hospitals to evaluate the effects of the previously given recommendations and equipment replacement. Doses were re-assessed and new dose distributions were created for 2013.

2. Material and methods

A total of 9 hospitals with 17 X-ray units were inspected during 2012. Overall data about of the X-ray units is presented in table 1.

Table 1. Surveyed X-ray unit characteristics.

Hospital type	Unit type	Analogue /digital	Film type	Film processing	Total filtration
General practice	Siemens Multix Pro	Analogue	Blue	Manual	2,5 mm Al+ 0,1 mm Cu
	Fluorograph KRT-OKO	Digital	-	-	3 mm Al + 0,2 mm Cu
General practice	Listem REX-550 RF	Analogue	Blue	Machine	2,5 mm Al
	Italray Clinodigit Pixel HF	Analogue	Blue	Machine	2,5 mm Al
General practice	Italray Clinodigit Pixel HF	Analogue	Blue	Machine	2,5 mm Al
	Opera G500 C	Analogue	Blue	Machine	2,5 mm Al
	KRT-OKO	Digital	Blue	Machine	3 mm Al
	Fluorograph RENEX	Digital	-	-	3 mm Al
General practice	Magnum C	Analogue	Blue	Manual	2,5 mm Al
Tuberculosis prophylactic center	ARC-OKO	Digital	-	-	3 mm Al
	Fluorograph FC Maxima	Digital	-	-	3 mm Al
	Omnix-300 ST	Analogue	Blue	Manual	3 mm Al
General practice	Siemens Multix Pro	Analogue	Green	Machine	3,5 mm Al
	RDK-000-35RE	Digital	-	-	3 mm Al
General practice	KRD-OKO	Analogue	Blue	Manual	3 mm Al
Tuberculosis prophylactic center	RUM-20	Analogue	Blue	Manual	3 mm Al
General practice	Medix-R	Analogue	Blue	Manual	3 mm Al

For each X-ray unit we performed basic QA procedures according to current legislation of the Russian Federation. That included determination of the tube voltage stability, exposure time setting and half-value-layer (HVL) for different tube voltages. In order to assess these parameters the Unfors Xi Platinum system (Unfors, Sweden) was used. For basic image quality tests (field size consistency, low and high contrast) NKP and RSR test-object kits (DOZA, Russian Federation) were used. For analogue X-ray units we also collected information about the film (manufacturer & type) and type of image intensifier. Clinical dosimeters mounted on the X-ray units (DAP-meters) were tested using the DRK-1 reference ionization chamber (DOZA, Russian Federation).

According to our current regulations, DRLs are set individually for each procedure. However, they are not set for specific examinations due to the fact there are no standards of practice. A total of 13 conventional X-ray procedures were selected for studying the DRLs: Skull (AP and LAT projections), Chest (PA and LAT), Ribs (AP), Cervical spine (AP and LAT), Thoracic spine (AP and LAT), Lumbar spine (AP and LAT), Abdomen (AP), Pelvis (LAT). For each procedure we collected the following set of parameters: tube voltage (kV), tube current (mA), exposure time (s), focal-image distance (cm), image field size (cm^2). Radiation output was calculated for each tube voltage setting, using the data from the QA. For analogue X-ray equipment the parameters were acquired for a standard patient (174 cm height, 70±5 kg weight, average constitution) by questioning the operators of the X-ray unit. A separate set of parameters for each operator was collected if there were more than one operator working at the same unit. For digital X-ray machines procedure, the parameters were extracted from the patient and image database, as an average for 10 standard patients. We were not able to evaluate clinical image quality in this study. Hence, at this stage we considered it to be acceptable for all hospitals and units.

Effective dose (mSv) was estimated for the DRL setting established. It was calculated using the “EDEREX” (Effective dose Estimation in Roentgen Examinations) software, developed at IRH and based upon the Monte-Carlo method. Tissue coefficients were taken from ICRP publication 103. Dose distributions and statistical handling were performed in Statistica 10 and Microsoft Office software.

3. Results and discussion

Figs. 1 and 2 show an example of the dose distribution for chest PA procedure. If there were more than one set of parameters for the unit, they were treated as separate instances. Dose distributions are valid for 2013.

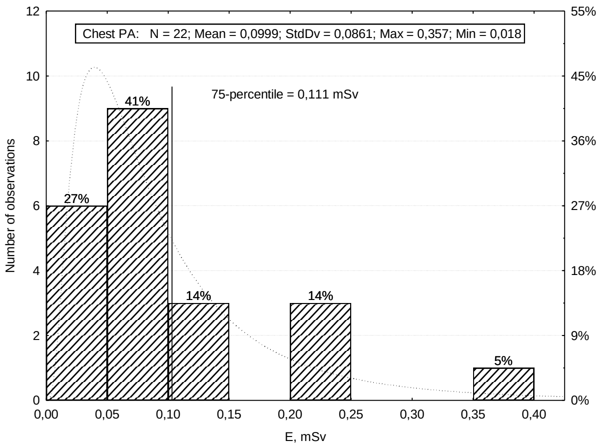

Fig. 1 Histogram of dose distribution (mSv) for Chest PA examinations.

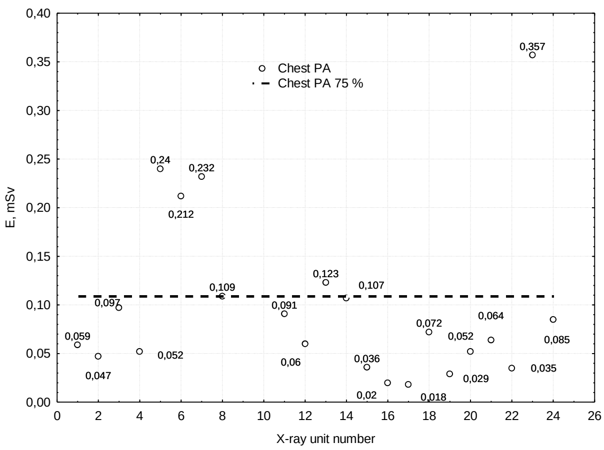

Fig. 2. Dose distribution (mSv) for Chest PA X-ray examinations.

Similar dose distributions were established for all procedures investigated. The results are shown in Fig. 3 and Table 2.

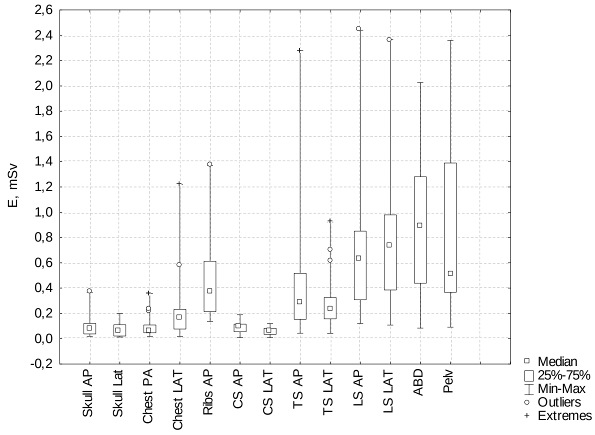

Fig. 3. Dose distributions (mSv) for each procedure. Median values of the effective dose is indicated as a square within the 25%-75% range.

Table 2. Dose (mSv) statistics for each procedure.

	MEAN	MEDIAN	MIN	MAX	_75th%
Skull AP	0,090	0,071	0,019	0,367	0,121
Skull Lat	0,070	0,053	0,013	0,200	0,111
Chest PA	0,100	0,068	0,018	0,357	0,109
Chest LAT	0,237	0,161	0,018	1,218	0,232
Ribs AP	0,450	0,377	0,136	1,371	0,613
CS AP	0,094	0,088	0,010	0,189	0,116
CS LAT	0,063	0,060	0,008	0,120	0,083
TS AP	0,456	0,288	0,044	2,280	0,518
TS LAT	0,295	0,225	0,043	0,923	0,326
LS AP	0,704	0,622	0,120	2,440	0,851
LS LAT	0,735	0,741	0,108	2,365	0,980
ABD	0,904	0,890	0,084	2,026	1,281
Pelv	0,871	0,504	0,092	2,360	1,390

For each examination the DRLs were calculated as the 75-percentile of the dose distributions. Fig. 4 shows the comparison between the local and St-Petersburg 75-percentiles of dose distributions.

Dose distributions in the Bryansk region are comparable to those in St-Petersburg, although there are some deviations. The deviations are explained by absence of standard procedure protocols and differences in equipment and clinical practice.

Procedure doses show a relatively high variation (1,5 to 10 times difference between minimum and maximum), although medians and 75-procentiles are acceptable. Such a difference can be explained by sub-optimal local radiology practice. At the hospitals investigated in the Bryansk area, it is common to use relatively low tube voltage and high tube current and exposure time, thus leading to a very high dose, especially in lumbar spine, abdomen and pelvis regions. We were not able to notice a significant difference between 2.5 and 3 mm of total aluminum filtration, although units with an additional (0.1 and 0.2 mm) copper filter showed the lowest doses. Another problem is that not all the X-ray departments are equipped with the full range of film cassettes. This leads to a situation when thoracic and lumbar spine images are taken using 30x40 cm^2 field sizes, resulting in an unnecessary overexposure. Frequent use of manual film processing leads to a significant changes in procedure parameters connected to the quality and freshness of processing chemicals. Using blue-sensitive film does not indicate any significant change of the dose as compared to the factors mentioned above. Unfortunately, we were not able to perform a film reject and image quality studies.

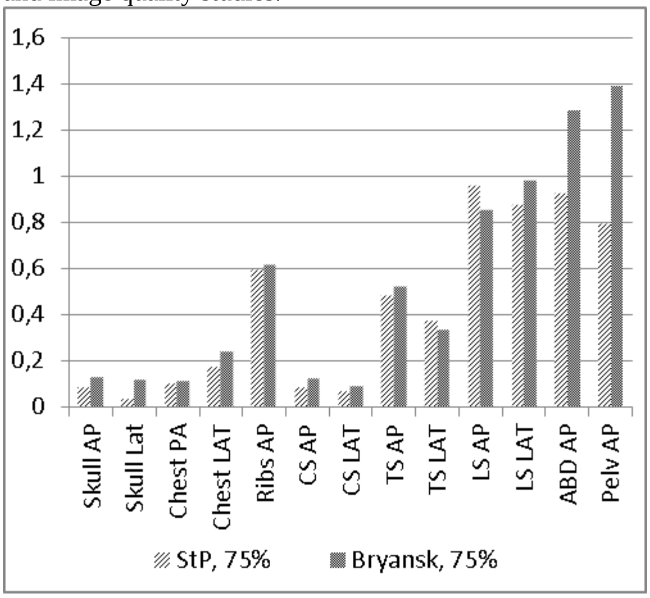

Fig. 4. Comparison of 75-percentiles of dose distributions for St-Petersburg and the Bryansk region divided by the type of examination.

Another issue is the technical condition of the X-ray units. The conducted QA tests did not show any deviations in the tube voltage, exposure time consistency and half-value layer thickness. Malfunctions of the collimation devices were frequent, forcing the operators to use a larger field size than intended or leading to unnecessary exposure. Clinical DAP-meters were present only on 5 out of 17 units (30%), of which 3 were out of order or malfunctioning. The remaining 2 were not used in everyday practice.

The majority of the analogue X-ray units are currently put into a replacement queue. In 2013 two old analogue X-ray units, in a tuberculosis treatment center in Novozibkov, were replaced by modern digital flat-panel X-ray units (ARC-OKO and FC Maxima, Electron, Russian Federation). This modernization resulted in a significant decrease of the dose (Fig. 5).

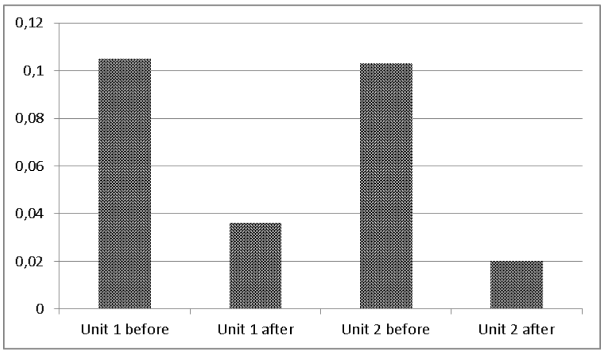

Fig. 5. Doses (mSv) for Chest PA examinations before and after changing from analogue to digital equipment.

Another main factor influencing the dose is the training, experience and awareness of the operator of the X-ray unit. We were able to observe a very high flow of change of operators in several important X-ray rooms – average work span is about three to six months. As a result of this rapid change of operators, there is generally a lack of experience and training. In addition, the flow of patients is very high too – it is common to have 50 to 60 patients per shift (5 hours). That leads to very limited capabilities for optimization and training. Undertrained operators working on a digital X-ray unit tend to use the maximum field size available (40x40 or 35x35 cm^2), regardless of the area of examination.

We were able to notice the effect of the 2012 training in those X-ray rooms where the staff did not change. In those X-ray rooms it was evident that the operators became more careful with field size and exposure settings. The doses were reduced by 10 to 20 percent.

4. Conclusions

We have studied the state of radiological practice in hospitals in the Bryansk region for period 2012-2013. We were able to gather representative X-ray unit and procedure data, enough to build the dose distributions. 75-percentile of dose distributions was selected to be the local DRL. Although, radiological practice in Bryansk region varied much from the one in St-Petersburg due to objective reasons (old analogue equipment, common manual film processing, underexperienced and undertrained staff, high patient flow, etc.), DRLs were comparable. We were able to identify X-ray rooms with high patient doses and investigate the reasons when exceeding the dose (unnecessary large field sizes, tube current and exposure time, difference in operators practice). We were able to create optimization recommendations for the local healthcare authorities, focusing on staff training and old equipment replacement. Continued studies in Bryansk region will aim to monitor the effect of those recommendations, and evaluate the clinical image quality in connection to the patients doses.

Acknowledgements

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