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ESTABLISHMENT OF LOCAL DIAGNOSTIC REFERENCE LEVELS FOR TYPICAL RADIOGRAPHY EXAMINATIONS IN THE WEST REGION OF CROATIA

by

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Majority of health institutions in Croatia do not have medical physicists in diagnostic radiology. Regarding this, in the west region of Croatia collaboration between public health institution and University Hospital Rijeka was initiated in 2015.
Quality Assurance program was implemented in these public health institutions during 2015 and 2016 and the next step was to assess patient doses for the most frequent X-ray examinations. This included five public health institutions: 1 university hospital, 1 general hospital, 1 special hospital, 2 public health institutions with 13 facilities. The aim of this study was to carry out assessment of patient doses and to establish local diagnostic reference levels of entrance surface air kerma for every institution for six most frequent X-ray examinations. Also, local diagnostic reference levels for the whole west region of Croatia were established and compared with the national diagnostic reference levels and latest published data. Median entrance surface air kerma values for thorax PA, thorax LAT, cervical spine AP, thoracic spine AP, lumbar spine AP, pelvis AP and sinuses are 0.14 mGy, 0.50 mGy, 0.52 mGy, 1.50 mGy, 2.52 mGy, 2.03 mGy, and 1.03 mGy, respectively. Diagnostic reference levels proposed for our region were comparable with other studies.

Key words: diagnostic reference level, radiography, X-ray

INTRODUCTION

Despite technological advances in other imaging techniques, number of diagnostic X-ray examinations is increasing every year. Even though the stochastic risk of low doses of ionizing radiation is very small, each exposure to ionizing radiation needs to be justified and optimized in terms of benefits and risks [1]. The diagnostic reference level (DRL) represents an efficient guideline for optimization of radiographic procedure and for radiation protection of patients [2]. Although terms on use of ionizing radiation for medical purposes are defined by the Croatian regulatory body since 2009 [3] in diagnostic and interventional radiology, this is still not fully implemented in most facilities. Majority of health institutions in Croatia do not have a functional quality assurance (QA) program and there is a lack of DRL of X-ray examinations as well. The need for medical physicist in diagnostic radiology has been recognized by international organizations and professional societies [4-6] but there is still a lack of medical physicists in radiology departments. At this moment in Croatia, eight medical physicists are involved in this field.

The concept of DRL was introduced by the International Commission on Radiological Protection in 1996 [7]. Entrance surface air kerma (ESAK) was proposed to be monitored in conventional radiography. Croatia has DRL values proposed by legislation [8] but they were adopted from the European guideline RP 109 [9]. This study was carried out to assess patient doses and to establish local DRL for the most frequent X-ray examinations during 2016 and 2017 in the west region of Croatia, where comprehensive QA program is established in majority of public health institutions [10]. Local DRL is defined in ICRP135 publication [11] as a DRL set in a particular healthcare facility or several local healthcare facilities for most common procedures.

West region of Croatia encloses two counties with 504250 inhabitants (11.7 % of Croatia population). The study included public health institutions in this region. These institutions do not have medical physicist on-site but collaborate with University Hospital Rijeka, Medical Physics Department in particular, which has medical physicist dedicated to diagnos-

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tic and interventional radiology. QA programme was implemented in these regional institutions during 2015 and 2016 [10].

MATERIALS AND METHODS

The study was carried out in five public health institutions: 1 university hospital centre, 1 general hospital, 1 special hospital, and 2 public health institutions with 13 facilities. In this work, radiography practice for 5 digital radiography (DR) units, 7 computed radiography (CR) units, and 5 film-screen (FS) radiography units was analyzed. Periodical Quality Control (QC) tests are regularly performed on all units. Reproducibility and linearity of respective X-ray tubes are tested twice per year and for some units even four times per year. Prior to analyzing data for ESAK calculations, quality control tests were performed and all results were within criteria [10].

In this study six most frequent X-ray examinations performed in this region were included. All examinations are performed in each facility. Data for different examination anatomies and projections were analysed: thorax posteroanterior (PA) and lateral (LAT), pelvis anteroposterior (AP), sinuses AP, cervical spine AP, thoracic spine AP, and lumbar spine AP. For each projection included in the study, following data were collected: patient mass, patient height, tube voltage (kV), current-time product (mAs), dose area product (DAP) – if available, focus to image receptor distance (FDD), focus to skin distance (FSD) and field size. Image quality acceptability was verified by the radiologist. Data were collected in the period from February 2017 till November 2017. Where possible, only standard patients (70 10 kg) [11] were included – 30 patients for every category. The ESAK value for each patient was calculated using following expression

$$ESAK \quad Y_D \,\text{mAs} \left(\frac{D}{FSD}\right)^2 BSF$$

where Y_D is X-ray tube output at distance, D, normalized by mAs (Gy/mAs), mAs is the product of the tube current and the exposure time, FSD is distance between the tube focal spot and patient surface and BSF is the backscatter factor [12]. Dose output (Y_D) was measured at 1 m distance for different X-ray tube voltage in 10 kVp steps in the range of 50-120 kV using a calibrated solid state detector Black Piranha (RTI Electronics, Sweden). To obtain ESAK value from air kerma, the backscatter factor used was 1.35 as suggested in European Guidelines [13].

Local DRL for ESAK values were calculated as medians for each involved institution as recommended in the latest ICRP 135 Publication [11]. This is also a method for dealing with the lack of patient mass information from some facilities. Local DRL for the whole west region of Croatia were calculated as a median value of the distribution of median ESAK values for each facility. Derived values were compared with the national DRL and latest data published in the document Radiation Protection 180 (RP180) – DRL in thirty-six European Countries [14]. Comparison with other publications calculating local DRL values was also made.

RESULTS

Median values of ESAK for all X-ray units and every projection for examinations of interest with the range and max/min ratio are presented in tab. 1.

Median ESAK values for thorax PA, thorax LAT, cervical spine AP, thoracic spine AP, lumbar spine AP, pelvis AP and sinuses are 0.14 mGy, 0.50 mGy, 0.52 mGy, 1.50 mGy, 2.52 mGy, 2.03 mGy, and 1.03 mGy, respectively. Calculated DRL values for west region of Croatia and comparison with the national DRL and latest European published data are presented in tab. 2. Our data is compared both to the European DRL and the available national DRL values of the countries that were included in the RP180 publication.

The ESAK values for all examinations of interest did not exceed national and latest European published data.

Local DRL values from our region were also compared with calculated local DRL and studies from other countries. The results are given in tab. 3. Comparison was made with mean values of ESAK distribution from Serbia and Montenegro [12], Italy [15], Iran [16], and Turkey [17]

The local DRL proposed for our region were comparable with other studies. The ESAK value from this study for thorax LAT was higher from Serbia and Montenegro and Italy studies. The ESAK value for pelvis was slightly higher than value from Serbia and Montenegro. All other values were below values published elsewhere. Other studies do not propose DRL values for sinuses so there were no data to compare it with. This examination is performed very often in our region which motivated us to investigate practice related to this examination.

The range of the ESAK values is high: max/min ratio for thorax PA, thorax LAT, cervical spine AP, tho-

Table 1. Median ESAK values for typical examinations

Examination	Median [mGy]	Range [mGy]	Max/min
Thorax PA	0.14	0.06-1.80	30.0
Thorax LAT	0.49	0.27-1.42	5.2
Cervical spine AP	0.52	0.16-1.24	7.6
Thoracic spine AP	1.50	0.77-3.61	4.7
Lumbar spine AP	2.52	1.12-7.22	6.4
Pelvis AP	2.03	0.91-5.00	5.5
Sinuses	1.03	0.56-3.21	5.7

Table 2. Comparison of DRL of west region of Croatia with the national DRL and examination

	Thorax PA	Thorax LAT	Cervical spine AP	Thoracic spine AP	Lumbar spine AP	Pelvis AP	Sinuses
Local DRL (this study) [mGy]	0.14	0.5	0.52	1.5	2.52	2.03	1.03
National DRL [mGy] [8]	0.3	1.5	n/a	7	10	10	n/a
RP180 [mGy] [14]	0.3	1.5	n/a	7	10	10	n/a
Belgium [14]	0.25	1.2					
Bulgaria [14]	0.5						
Switzerland [14]	0.15	0.75					
Cyprus [14]	0.3	1.5					
Czech Republic [14]	0.4	1.5					
Spain [14]	0.3	1.5					
Finland [14]	0.2	0.8					
France [14]	0.3	1.2					
Ireland [14]	0.3	1.5					
Italy [14]	0.4	1.5					
Lithuania [14]	0.3	1.7					
Moldova [14]	0.6	2					
Romania [14]	0.3	1.5					
Slovakia [14]	0.4	1.5					
United Kingdom [14]	0.2	1					

Table 3. Comparison of local DRL of ESAK values in mGy with other publications

Examination	This study	Serbia and Montenegro (2005) [12]	Italy (2005) [15]	Iran (2016) [16]	Turkey (2018) [17]
Thorax PA	0.14	0.4	0.15	0.34	0.33
Thorax LAT	0.50	0.30	0.45	–	0.73
Cervical spine AP	0.52	1.30	–	3.02	–
Thoracic spine AP	1.50	1.50	–	–	–
Lumbar spine AP	2.52	2.80	3.14	3.26	–
Pelvis AP	2.03	2.00	4.41	3.21	–
Sinuses	1.03	–	–	–	–

Table 4. Range of exposure factors and FDD for each projection across all radiological departments for adult patients an comparison with EG [13]

Examination	Tube voltage [kV]	Tube current-exposure time product [mAs]	Focus to image receptor distance [cm]	European guidelines	
				Tube voltage [kV]	FDD [cm]
Thorax PA	65-125	1.24-47	150-200	125	180 (140-220)
Thorax LAT	65-125	4.3-64	180-200	125	180 (140-220)
Cervical spine AP	58-80	8.8-25	100-150	n/a	n/a
Thoracic spine AP	60-85	12-80	100-150	n/a	n/a
Lumbar spine AP	70-85	16-90	100-115	75-90	115 (100-150)
Pelvis AP	65-85	16-80	100-150	75-90	115 (100-150)
Sinuses	65-80	12-64	100-150	n/a	n/a

racic spine AP, lumbar spine AP, pelvis AP and sinuses is 30, 5.2, 7.6, 4.7, 6.4, 5.5, and 5.7, respectively. Altogether local DRL from 4 facilities exceeded national DRL only for PA chest. ESAK values recorded were 0.96 mGy, 0.41 mGy, 1.80 mGy, and 0.76 mGy. In order to investigate the reason for this large variability in ESAK values, a comparison of radiographic techniques was performed. It showed a lot of variety regarding exposure parameters. Range of exposure factors used per examination are given in tab. 4. For each facility exposure parameters used were compared with recommendations given in European Guidelines on Quality Criteria for Diagnostic Radiographic Images (EG) [13].

DISCUSSION

The DRL are a part of the quality criteria as described in EG [13]. Their establishment, regular revision and comparison with the recommended national and European DRL are stated in 'Euratom Basic Safety Standards' [2]. The importance of DRL is also emphasized by the International Commission on Radiological Protection and by the International Atomic Energy Agency [1, 6, 18, 19].

All the calculated DRL in west region of Croatia were well below national values and in good agreement with the recently published European data. The values for thorax PA and thorax LAT were slightly higher than the values published in some other studies. The differences can be seen also in cervical spine which is far below available values. This comparison showed also that the local DRL values from different countries were quite different. Wide range of ESAK values could be due to different technologies and different radiographic techniques used.

Even though our local DRL were in good agreement with the published data, comparison between facilities showed a great variation of ESAK values for the same examination. The ESAK values calculated in this region ranged from a factor 4.7 to a factor 30. The first assumption for this wide range in ESAK values between facilities was that it is related to technical limitations of the equipment since some X-ray units where rather old. However, further investigation showed that higher doses are not always related to the technological level of the equipment, so comparison of radiographic techniques was performed. Therefore, for each facility kV, mAs, and FDD for every examination were analyzed and compared with European Guidelines. The highest variation was found for thorax PA (30). Analysis of techniques used for thorax, both PA and LAT showed that different radiographic techniques are used in different facilities and some of them are not in accordance with the EG recommendations. Namely, 38 % of the facilities were using soft radiation qualities for thorax examination and in one facility FDD was far below 150 cm. The main reason for this is lack of continuous education of the staff in some radiological departments. Besides incorrect technique used, few institutions did not use automatic exposure control even though the units were equipped with this system. At facilities that had considerably higher doses than the others due to inappropriate technique used, corrective actions were performed immediately, and additional education of the radiographers was provided. Also, their practice is adjusted according to recommendations so now it is more standardized across the region. In contrast to thorax, the examination of sinuses showed the lowest variation in radiographic techniques, probably because it is easier to standardize due to small differences in anatomical dimensions across the patients. Radiographic techniques used for cervical spine, thoracic spine, lumbar spine, pelvis and sinuses were similar and mostly in accordance with European Guidelines.

CONCLUSION

The DRL are a useful tool in the optimization process which can contribute to improvement in quality of diagnostic procedures. The most important purpose of DRL is to verify that most of radiological examinations are having ESAK values below nationally defined values and to identify those departments that are not performing appropriately having ESAK values much higher than recommended. This study showed the importance of establishing DRL values at each diagnostic radiology department. Also, it pointed out the importance of periodical revision of patient doses and radiographic practice as well. The results also showed the influence of different practice and technology to patient dose. As such this made medical staff more aware of their responsibilities and the need for continuous education.

AUTHORS' CONTRIBUTIONS

The idea was initiated by D. Šegota. Data collection and statistical analysis was carried out by D. Šegota and A. Diklić. S. Jurković supervised presented research and helped with its development that resulted in this paper. All the authors participated in the discussion of the presented results.

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УСПОСТАВЉАЊЕ ЛОКАЛНИХ ДИЈАГНОСТИЧКИХ РЕФЕРЕНТНИХ НИВОА ЗА ТИПИЧНЕ РАДИОГРАФСКЕ ПРЕГЛЕДЕ У ЗАПАДНОЈ РЕГИЈИ РЕПУБЛИКЕ ХРВАТСКЕ

Већина здравствених установа које се баве радиолошком дијагностиком у Републици Хрватској нема запослене медицинске физичаре. Из тог разлога је 2015. године започета сарадња јавно-здравствених установа у западној регији Републике Хрватске и Клиничко – болничког центра Ријека.

У сарадничким установама је током 2015. и 2016. године имплементиран Програм осигурања квалитета те је следећи корак био регистровање доза пацијената за најучесталије радиографске прегледе. То је укључивало пет јавно-здравствених установа: једну свеучилишну болницу, једну општу болницу, једну специјалну болницу и два жупанијска дома здравља са тринаест испостава. Циљ овог истраживања био је да се процене дозе пацијената и утврде локални дијагностички референтни нивои за улазну керму у ваздуху, за сваку установу и шест најучесталијих радиографских прегледа. Такође, успостављени су локални дијагностички референтни нивои за целу западну регију Републике Хрватске који су упоређени с националним дијагностичким референтним нивоима и новије објављеним међународним подацима. Вредности медијана за улазну керму у ваздуху за торакс PA, торакс LAT, цервикалну кичму AP, торакалну кичму AP, лумбалну кичму AP, карлицу AP и синусе су 0.14 mGy, 0.50 mGy, 0.52 mGy, 1.50 mGy, 2.52 mGy, 2.03 mGy, и 1.03 mGy, респективно. Дијагностички референтни нивоу предложени за нашу регију су у складу с нама доступним подацима из других међународних студија.

Кључне речи: дијагностички референтни ниво, радиографија, X-зрачење