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SURVEY OF COMPUTED TOMOGRAPHY DOSES AND ESTABLISHMENT OF NATIONAL DIAGNOSTIC REFERENCE LEVELS IN THE REPUBLIC OF BELARUS

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Computed tomography dose index (CTDI) was measured on eight CT scanners at seven public hospitals in the Republic of Belarus. The effective dose was calculated using normalised values of effective dose per dose-length product (DLP) over various body regions. Considerable variations of the dose values were observed. Mean effective doses amounted to 1.4 ± 0.4 mSv for brain, 2.6 ± 1.0 mSv for neck, 6.9 ± 2.2 mSv for thorax, 7.0 ± 2.3 mSv for abdomen and 8.8 ± 3.2 mSv for pelvis. Diagnostic reference levels (DRLs) were proposed by calculating the third quartiles of dose value distributions (body region/volume CTDI, mGy/DLP, mGy cm): brain/60/730, neck/55/640, thorax/20/500, abdomen/25/600 and pelvis/25/490. It is evident that the protocols need to be optimised on some of the CT scanners, in view of the fact that these are the first formulated DRLs for the Republic of Belarus.

INTRODUCTION

Today, there are more than 50 computed tomography (CT) scanners installed in the Republic of Belarus and the amount is increasing rapidly. In 2007, there were ~224 000 CT examinations carried out, representing 1.8 % of all X-ray procedures in the country. At the N.N. Alexandrov National Cancer Center in Minsk, there were 33 000 CT examinations carried out in 2008, which amounted to 36 % of all X-ray examinations in this hospital. These figures indicate a large potential for future growth and also underline the special importance of CT diagnostics in oncology. However, diagnostic procedures with CT scanners are often associated with relatively high radiation doses. Although this is well known, no national CT dosimetry survey has previously been carried out in Belarus and the radiation dose to the patients has not been recorded.

The International Commission on Radiological Protection (publication 60[(1)] and 73[(2)]) and the European Directive 97/43/Euratom[(3)] suggested the concept of diagnostic reference levels (DRLs) as a tool to identify situations where patient doses are unusually high and where there is a need for optimisation. The use of DRLs was first promoted by the European Commission by publishing European guidelines in 1999[(4)]. National surveys of CT doses have been conducted in many countries since then, which have resulted in the establishment of national reference levels. The purpose of this study was to investigate radiation doses for different CT examinations at different hospitals in Belarus and, based on this information, propose national DRLs for CT examinations.

MATERIALS AND METHODS

The survey was performed on eight CT scanners in seven different public hospitals in three regional cities, during the period from November 2007 to February 2008. Some characteristics of these scanners are summarised in Table 1. Two of the three multislice scanners (MSCT) used in the survey allowed for simultaneous acquisition of 4 slices and the third scanner allowed for acquisitions of 6 slices per tube rotation. The selection of scanners was representative of the scanner population in the country.

Five typical CT examinations, namely routine brain, neck, chest, abdomen and pelvis, were selected for the study. For each examination, data concerning examination parameters (e.g. kVp, mAs, rotation time, nominal slice thickness, number of simultaneously scanned slices and table feed per rotation) were recorded. The dosimetry equipment consisted of a computed tomography dose index (CTDI)-dosimeter (UNIDOS E), dedicated PMMA head-equivalent (16 cm in diameter) and body-equivalent (32 cm in diameter) phantoms and a pencil-shaped ionisation chamber with an active length of 10 cm (PTW Freiburg GmbH, Germany).

Table 1. Characteristics of the CT scanners used.

Scanner	Manufacturer	Scanning technology	Year of installation
Somatom Emotion 6	Siemens	MSCT-6	2005
Light Speed RT	General Electric	MSCT-4	2005
Somatom Volume Zoom	Siemens	MSCT-4	2002
Hi Speed CT/e	General Electric	Spiral	2002
Hi Speed CT/e	General Electric	Spiral	2002
Tomoscan SR 4000	Philips	Spiral	1996
Somatom AR-C	Siemens	Sequential	1995
Tomoscan CX/Q	Philips	Sequential	1990

The head phantom was used for head and neck examinations and the body phantom was used for thorax, abdomen and pelvis examinations.

The CTDI values were measured according to the technique explained in the literature(4). Weighted CTDI ($CTDI_w$), volumetric CTDI ($CTDI_{vol}$) and the dose-length product (DLP) were consecutively calculated. We used the following average scanning lengths for DLP calculation: 12 cm for brain and neck, 25 cm for thorax, 22 cm for abdomen and 20 cm for pelvis.

The dose quantities CTDI and DLP serve as indicators of the average dose over a tomographic section during a single rotation and the overall exposure for an examination, respectively. To estimate the effective dose (E), which is an indicator of the biological risk after exposure to ionising radiation, the measured DLP values were multiplied with normalised values of the effective dose per DLP, as defined in the European guidelines(4).

Finally, DRLs were calculated for all types of CT examinations in the survey as the third quartiles of $CTDI_{vol}$ and DLP value distributions rounded to the nearest multiple of five.

RESULTS

The range of the parameter settings for the five different examination protocols, used in the survey, is presented in Table 2. A large variation in all parameters, except kVp, was observed. This resulted in a considerable variation of the dosimetric quantities, as shown in Table 3. The ratio of the maximal to minimal effective dose was 2.2 for brain, 2.7 for neck, 3.1 for thorax, 3.1 for abdomen and 3.6 for pelvis(5). Nevertheless, our mean values are well in agreement with previously published data(6–8) (Table 4).

The resulting DRLs are presented in Table 3, and also shown in Figure 1 in comparison with the European levels initially approved in 1999(4), and then re-evaluated in 2004(9).

Table 2. Range of parameter values for different examination protocols.

Region of body	kVp	mAs	Nominal slice thickness (mm)	Pitch
Brain	120–130	200–405	2.5–10	1
Neck	110–130	150–405	2.5–5	1–1.38
Thorax	120–140	105–345	2.5–10	1–1.5
Abdomen	120–130	143–495	2.5–10	1–1.5
Pelvis	120–140	158–495	2–10	1–1.5

DISCUSSION

The most important parameters during a CT examination in terms of the radiation dose to the patient are kVp, mAs, pitch and the scan length. A CT scanner equipped with mA modulation has a potential to reduce the dose by reducing the mAs per rotation. Detector configuration (number of detector rows, geometric efficiency and nominal slice thickness) is also important since thinner slices are usually associated with higher doses. Our survey revealed a significant discrepancy in examination parameters among the radiology departments included in the study. For example, in the pelvis examination, the use of the same tube voltage (130 kVp) but much higher exposure (300 mAs highest vs. 158 mAs lowest) and lower pitch (1 vs. 1.5) resulted in two extreme values of the effective dose (15.7 vs. 4.3 mSv). Although the obtained values of the mean dosimetric quantities are well in agreement with internationally published data(6–8) (Table 4), the large variability in the parameter settings is of serious concern. It is obvious that the exposure parameters on some scanners have not been adjusted and hence there is a large potential for dose reduction on these scanners.

Inter-institutional CT dosimetry has not been conducted in Belarus till now and the doses from CT examinations have not been known. As a result, it was hardly possible to compare radiation doses between different hospitals and, thus, to prompt for protocol optimisation. We conducted dosimetry on eight CT scanners, which amounted to 20 % of the installed units in the country, at the time of the study. All major manufacturers as well as scanning technologies (sequential, spiral and multislice) were equally represented (Table 1) and the scanners selected for the survey were chosen to represent the total scanner population in the country. This enabled us to propose national DRLs (Table 3) for CT examinations, which were officially approved by the Ministry of Health in June 2009.

Table 3. Mean values, range and proposed DRLs of dosimetric parameters for different examination protocols.

Region of body	$CTDI_{vol}$ (mGy)		DLP (mGy cm)		E (mSv)
	Mean ± SD (range)	DRL	Mean ± SD (range)	DRL	Mean ± SD (range)
Brain	50.2 ± 14.3 (31.9–74.2)	60	597.4 ± 179.3 (382.8–890.4)	730	1.4 ± 0.4 (0.9–2.0)
Neck	39.3 ± 15.6 (23.9–63.7)	55	470.0 ± 188.4 (286.8–764.4)	640	2.6 ± 1.0 (1.5–4.1)
Thorax	16.4 ± 5.3 (6.8–21.3)	20	407.8 ± 130.4 (170.0–532.5)	500	6.9 ± 2.2 (2.9–9.1)
Abdomen	21.4 ± 7.1 (9.4–29.4)	25	469.9 ± 156.4 (206.8–646.8)	600	7.0 ± 2.3 (3.1–9.7)
Pelvis	23.1 ± 8.5 (11.3–41.2)	25	462.1 ± 169.2 (226.0–824.0)	490	8.8 ± 3.2 (4.3–15.7)

Table 4. Comparison of mean dosimetric values for CT examinations with internationally published levels.

Region of body	Dosimetric parameter	Belarus, 2009[5]	UK, 2005[6]	Greece, 2003[7]	Poland, 2006[8]
Brain	$CTDI_w$ (mGy)	50	57	58	19
	$CTDI_{vol}$ (mGy)	50	56	—	—
	DLP (mGy cm)	597	690	677	527
	E (mSv)	1.4	1.5	1.6	—
Thorax	$CTDI_w$ (mGy)	19	14	19	—
	$CTDI_{vol}$ (mGy)	16	10	—	14
	DLP (mGy cm)	408	400	401	447
	E (mSv)	6.9	5.8	6.8	—
Abdomen	$CTDI_w$ (mGy)	24	16	22	—
	$CTDI_{vol}$ (mGy)	21	12	—	16
	DLP (mGy cm)	470	350	464	550
	E (mSv)	7.0	5.3	7.0	—
Pelvis	$CTDI_w$ (mGy)	25	—	22	—
	$CTDI_{vol}$ (mGy)	23	—	—	—
	DLP (mGy cm)	462	—	336	—
	E (mSv)	8.8	—	6.4	—

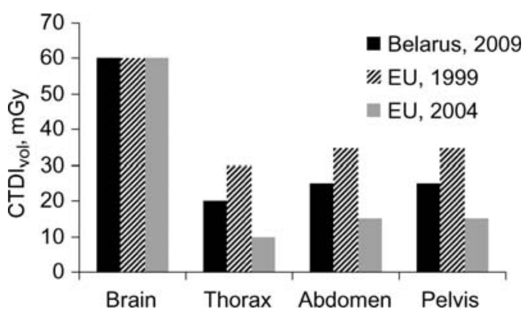

Figure 1. Proposed diagnostic reference levels for $CTDI_{vol}$ in comparison with European Union reference levels.

As shown in Figure 1, Belarusian reference levels for body CT are below those approved by the European guidelines in 1999[4] but above the re-evaluated levels[9] from 2004. This is explained by the technological state of the equipment at the time of making the guidelines. Indeed, the guidelines of 1999 are relevant only for sequential and spiral scanners (as multislice systems first appeared in 1998). Since then, in addition to improved spatial and time resolution, lower radiation dose became an important competitive advantage in the view of both consumers and equipment vendors. As a result, we see a trend of gradual decrease in exposure levels for newer CT scanners. For example, $CTDI_{vol}$ during thoracic CT on a newly installed 40-slice scanner in the N.N. Alexandrov National Cancer Center of Belarus is equal to 7.9 mGy compared with 12 mGy on a 4-slice CT of the same vendor installed in 2002. However, today only half of all CT scanners in Belarus are multislice.

A possible shortcoming of our study is that we used uniform scanning volume lengths for each type of CT examination, for all scanners. The reason for this choice was to make DLP and effective dose calculations solely dependent on technical parameters of the scanning. In practice, scanning length depends on many factors, e.g. protocol and patients' cohort. For example in oncology, a thoracic CT usually includes the adrenals (as it is a regular site of metastases) or even the liver, while in general diagnostic CT the posterior costophrenic recesses is usually the lower limit of target volume. Another usual situation with 'non-standard' scanning length is the whole body CT (e.g. lymphoma staging). These examples show that

$CTDI_{vol}$ might be a more appropriate choice of dosimetric parameter for assessing DRLs than DLP. In particular, the European guidelines for MSCT[9] provide reference levels for $CTDI_{vol}$ only.

CONCLUSION

The results of the first survey of CT doses in the Republic of Belarus have been presented and national DRLs proposed. The survey has revealed a significant variation of the recorded dose values. This discrepancy is explained by different technical scanning parameters. Protocol optimisation is required on some CT scanners although DRLs were in agreement with internationally published values.

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