PATIENT DOSES IN COMPUTED TOMOGRAPHY: AN ASSESSMENT OF LOCAL DIAGNOSTIC REFERENCE LEVELS IN A LARGE TEACHING HOSPITAL

by

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This paper presents an estimation of local diagnostic reference levels in computed tomography in a large teaching hospital. Local diagnostic reference levels, expressed in terms of volume weighted computed tomography dose index and dose-length product, were estimated for three most frequent adult computer tomography examinations: head, abdomen and pelvis combined, and thorax. The established local diagnostic reference levels values were similar or slightly higher compared to the available guidelines, indicating the possibility for optimization of current practice. Analyzing the protocols used here and recently published studies on dose reduction in computed tomography, a dose-reduction technique, was proposed to decrease tube current values in all three examinations. However, the optimization should be restricted only to standard-sized patients.

Key words: computed tomography, patient doses, diagnostic reference levels

INTRODUCTION

Since the introduction of computed tomography (CT) in clinical practice, this important imaging technology has undergone explosive growth both in terms of a number of CT scanners available and the frequency of CT examinations [1-3]. CT scanning represents a contribution of just over 44% to the global collective effective dose from medical exposures [3]. Furthermore, the organ doses delivered from a common CT scan result in an increased risk of radiation induced cancerogenesis [4, 5]. Monitoring of trends in CT patient doses is currently particularly important. It was the subject of many investigations over the past decade [6-10].

The concept of diagnostic reference levels (DRL) was introduced as a tool that identifies the practices with abnormally high patient doses [11]. DRL are defined as dose levels for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied [12]. Recommendations concerning achievable standards of good practice in CT were developed by the European Commission in 1999 [13]. The document provided image quality criteria and DRL for CT examinations. Since then, the CT scanning technology has developed rapidly indicating the need for re-evaluation of these guidelines. Another recent report has been published focusing on well established clinical applications of CT for adults and pediatric patients, image quality and radiation dose, providing updated key information for good multislice CT (MSCT) imaging techniques [14].

Local DRLs are defined as the values established by organizations, as the level at which they are set is decided locally within the organization [15]. By taking responsibility for establishing and setting their own DRL, organizations should have the ability to adapt to a local practice and optimize exposures more effectively.

Although many studies related to patient doses were published [16-18], a systematic data collection for patient exposure in CT has never been carried out in Serbia. Therefore, there are no national DRL for patient doses in CT. The aim of this study was to establish local DRL in a large teaching hospital for three most frequent and standard CT procedures: head, thorax

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and abdomen and pelvis combined. The estimated values were compared with the available reference levels [13, 14].

MATERIALS AND METHODS

Data were collected on 2 CT units at the Clinical Center of Vojvodina for three standard procedures: head, thorax and abdomen and pelvis combined.

Dose quantities

Dosimetry concept in CT is well-established and based on the practical dose quantities: weighted CT dose index ($CTDI_w$), volume weighted CT dose index ($CTDI_{vol}$) and dose-length product (DLP) [7, 13, 19]. CT dose index, as a quantity, does not provide integral dose information, relevant for risk assessment and does not account for patient specific parameters, since it is only an indication of average dose in the central part of a scanned region when slices are contiguous [20]. However, it enables comparisons between scanners, and can be easily measured. Another directly measurable quantity, the DLP is an indicator of overall radiation burden to a patient [21]. All CT vendors are now required to display CTDI and DLP values on the user interface.

CT units

Two CT units are currently used in the hospital investigated in the study. Their characteristics are given in tab. 1. Both units are from the same manufacturer (Siemens, Erlangen, Germany) with automatic exposure systems available, although with a different number of detector rows. The frequency of examinations on CT units is taken from the hospital archive. The number of examinations performed on these units in 2010 is presented in tab. 2. Frequency of examinations is equally distributed among scanners, while head CT represents more than 40% of the total number of examinations.

Prior to data collection the CTDI values were verified by measurements, using a well-established protocol [22]. Values obtained from CT console differed by less than 10% of measured values.

Table 1. Characteristics of CT units at the Clinical Center of Vojvodina

Manufacturer	Model	Number of detector rows	Year of installation	Automatic exposure control
Siemens	Somatom Emotion 16	16	2007	yes
Siemens	Somatom Sensation	64	2006	yes

Table 2. Number of examinations in 2012 at the Clinical Center of Vojvodina

Manufacturer/ Model	Number of examinations			
	Head	Thorax	Abdomen + pelvis	Total number (all examinations)
Siemens/Somatom Emotion 16	2872	371	245	6912
Siemens/Somatom Sensation	2697	374	120	6140

Data collection

Data were collected in terms of $CTDI_{vol}$ and DLP. According to definition of these quantities, $CTDI_{vol}$ for one patient was estimated as a mean value of all phases while DLP were taken as a sum of DLP for a phase. Data on patients were also collected, such as patients age, height, weight and gender. In this investigation a total of 179 standard-sized patients were included. Data on patients are given in tabs. 3 and 4. Exposure parameters in terms of tube voltage (u), tube current and rotation time product (I) and rotation time (t_{rot}), and technique used (scout image, mode, gantry angle, collimation, and pitch), were also recorded for each patient.

Table 3. Patient data (gender distribution)

	Male	Female	Together
Head	30	28	58
Thorax	37	24	61
Abdomen + pelvis	24	36	60
Total number			179

Table 4. Patient data (age, weight, and height)

Age [year]	Weight [kg]	Height [cm]
Mean value sd (min-max)		
55 13 (23-85)	70 10 (45-87)	171 9 (148-196)

Local DRL

In computed tomography DRL are expressed in terms of computed tomography dose index (CTDI) and DLP for adults for each examination [13].

Local DRL for particular examination were established as a mean value of the values estimated for CT units. Dose values for a procedure were estimated as mean values of at least 10 patients. Individuals whose weight exceeded 70 kg by more than 20 kg have been excluded from the sample (15).

RESULTS

Exposure parameters and technique used on patients in this study are given in tab. 5. Dose values in

Table 5. Exposure parameters and techniques used

	Head		Thorax		Abdomen + pelvis	
Parameter	Siemens/Somatom Emotion 16	Siemens/Somatom Sensation	Siemens/Somatom Emotion 16	Siemens/Somatom Sensation	Siemens/Somatom Emotion 16	Siemens/Somatom Sensation
Scout image	Lat	Lat	AP	AP	AP	AP
Mode	H	H	H	H	H	H
Gantry angle	0	0	0	0	0	0
Collimation	16 1.2	64 0.6	16 1.2	64 0.6	16 1.2(0.6)	16 1.2(0.6)
Pitch	0.55	0.8	0.8	/	0.8	1.2/1.4/1
u [kV]	130	120	130	120	130	120
I [mAs_{mean}]	240	380	56	89	66	111
t_{rot} (s)	1.5	1	0.6	0.5	0.6	0.5

Table 6. Dose values in terms of $CTDI_{vol}$ and DLP, estimated local DRL and European reference levels [13]

Examination		$CTDI_{vol}$ [mGy]	DLP [$mGycm^{-1}$]
		mean value sd (min – max)	
Head	Siemens/Somatom Sensation	59 0 (59 – 59)	1060 ± 180 (936 – 2030)
	Siemens/Somatom Emotion 16	60 ± 2 (59 – 66)	1066 35 (1037 – 1135)
	lDRL	59.5	1063
	EUR 16260 [13]	60	1050
Thorax	Siemens/Somatom Sensation	13 ± 6 (6 – 22)	350 170 (63 – 894)
	Siemens/Somatom Emotion 16	11 ± 4 (5 – 16)	360 140 (143 – 560)
	lDRL	12	355
	EUR16260 [13]	30	650
Abdomen + pelvis	Siemens/Somatom Sensation	8.5 ± 2.5 (3.9 – 15)	1330 590 (236 – 3132)
	Siemens/Somatom Emotion 16	12 ± 7 (3 – 30)	1560 760 (953 – 3263)
	lDRL	10.25	1445
	EUR16260 [13]	35	1350

terms of $CTDI_{vol}$ and DLP for both scanners are presented in tab. 6. The estimated local DRL for each examination and European DRL in CT is also given in tab. 6.

DISSCUSION

Scout images on both CT units are performed as recommended in available guidelines [13, 14]. For head examination it is lateral projection since the eye lens dose has to be as low as possible. All three examinations on both scanners are performed in a helical mode. On some model of CT units it is recommended to use axial mode and gantry angle (10-12º) for a better image quality [13, 14].

For helical CT scanners, a pitch is defined as the ratio of a table feed per gantry rotation to the nominal width of the X-ray beam [22]. Recommendations for pitch values depend on examination type. For examination types enrolled in this study the pitch value should not be less than 0.9 [13, 14]. An increase in the pitch decreases the duration of radiation exposure to the anatomic part being scanned. Faster table speed for a given collimation, resulting in a higher pitch, is associated with a reduced radiation dose because of a shorter exposure time, especially if other scanning parameters, including a tube current, are held constant. No significant difference was observed in image quality of scans obtained at a pitch of 1.5 compared to those obtained at a pitch of 0.75, saving 50% radiation dose in abdominal and pelvic imaging [23]. However, this is not true for scanners using an effective milliampere-second setting, defined as milliampere seconds divided by pitch. In such scanners, the effective milliampere-second level is held constant irrespective of a pitch value, so that radiation dose does not vary as pitch is changed [24]. CT units participating in this study (Siemens scanners) work in this kind of setting.

Dose values obtained in terms of $CTDI_{vol}$ and DLP were very similar for the same examination type, comparing 16 and 64 detector rows systems. However, there are published results that show increased trend in patient dose with multidetector CT technology [25-27]. The increase in dose with MSCT is partly associated with the need to scan a slightly larger volume than planned in order to get sufficient data interpolated to reconstruct the first and last slice. Usually there is an additional half rotation at the beginning and at the end of the intended scan length, which may account for an increase in dose 10-20% for head–neck and trunk studies and may reach up to 30-35% for chest and abdomen pelvis studies [25-27]. On the other hand, there are also investigations showing a different trend in a dose while increasing number of detector rows. Moore *et al*. [28] reported that a 4-detector array showed statistically significantly higher radiation dose compared with a 16-detector array when near-identical techniques were applied. In accordance to that finding, Mori *et al*. [29] comparing a 256-slice CT and a 16-slice CT for clinical conditions, concluded that a 16-slice CT resulted in an increased dose. Additionally, Arthurs *et al*. [30] concluded that a 64-slice CT gives a better image and a lower dose than a 16 slice CT unit of the same manufacturer, for thoracic scans of young adults.

The estimated local DRL for CTDI in this study were below the reference levels proposed by European Commission [13]. However, DLP were slightly above recommended values for head and abdomen plus pelvis exams. Due to the definition of DLP, a dose multiplied by length of a region scanned, the higher values can be explained by extended scan length. Therefore, special attention must be paid when performing an examination, taking into account achievable standards of good practice in CT.

The purpose of local DRL is to help the organizations to optimize their own practice in a more effective way. In many studies, the possibility for dose reduction was investigated [31-35]. Dose optimization techniques can reduce doses. The results of the 2003 UK CT dose survey [7] show that there has been a 15-60% reduction in average patient doses from CT examinations since the time of the previous survey taken in 1991, including all scanners.

Cohnen *et al*. [31] reported that dose reduction up to 40% may be possible without loss of a diagnostic image quality in a head CT by decreasing kVp and mAs values. Dose reduction in a head CT was also investigated by Mullins *et al*. [32]. The conclusion of their study was that although 90 mAs CT images were moderately noisier than 170 mAs images, thay still had acceptable diagnostic quality.

Abdominal CT scan quality appears to be acceptable even with a 50% reduction in radiation dose. However, patient's weight and abdominal dimensions has to be taken into account while optimizing tube current [33].

Regarding the thorax CT, there are many studies showing dose reduction while decreasing mAs [34, 35]. Prasad *et al*. [34] reported the possibility for 50% dose reduction by decreasing a tube current from 220-880 mAs to 110-140 mAs, stating that image quality appears to be acceptable for evaluating normal anatomic structures. Ravenel *et al*. [35] in their study presented the reduction in a tube current from 280 to 120 mAs without compromising image quality.

In line to those mentioned above, there is a need to review scanning parameters at the examined hospital. The optimization process in CT practice presented here should start with decreasing tube current values, where possible, with constant monitoring of image quality. The need to review scanning parameters was also emphasized in a recent CT dose survey conducted by the international atomic energy agency (IAEA) in developing countries. The survey showed that DLP and CTDI values varied up to a factor of 13 and 16 for pelvis and abdomen examinations, respectively [6].

CONCLUSIONS

The results of this study provided local DRL for three most frequent CT exams in a large teaching hospital. The local DRL in terms of CTDI and DLP values were similar or slightly higher compared to available reference level. The use of DRL has been proposed as an optimization tool, as it identifies high dose practices where dose-reduction techniques would have had the greatest impact [13]. If organization value exceeds the reference value, the current practice should be investigated in terms of the exposure parameters setting and the technique used in particular procedure.

However, prior to the implementation of dose-optimized protocols, the organization should ensure that the justification principle is well-established in CT practice. The best way of controlling doses is by eliminating non-indicated CT examinations, making sure the examination is limited only to the area of interest.

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ПАЦИЈЕНТНЕ ДОЗЕ У КОМПЈУТЕРИЗОВАНОЈ ТОМОГРАФИЈИ: ОДРЕЂИВАЊЕ ЛОКАЛНИХ ДИЈАГНОСТИЧКИХ РЕФЕРЕНТНИХ НИВОА У УНИВЕРЗИТЕТСКОЈ БОЛНИЦИ

У раду су приказани резултати успостављања локалних дијагностичких референтних нивоа у компјутеризованој томографији (*CT*) на нивоу једне болнице. Референтне вредности успостављене су у форми $CTDI_{vol}$ и *DLP* вредности за три стандардне процедуре: снимање главе, снимање торакса и снимање абдомена са карлицом. Добијене вредности биле су веома сличне или незнатно више у односу на препоручене вредности. У складу са до сада објављеним могућностима за смањивање пацијентних доза у компјутеризованој томографији, анализирајући протоколе за три наведене процедуре утврђено је да постоји могућност за оптимизацију смањивањем јачине струје.

Кључне речи: компјутеризована томографија, пацијентне дозе, дијагностички референтни нивои