TOWARDS ESTABLISHMENT OF NATIONAL REFERENCE DOSE LEVELS FROM COMPUTED TOMOGRAPHY IN CROATIA – FIRST RESULTS

Branimir Klasić[1], Klaudija Višković[2], Zoran Brnić[1], Dario Posedel[3], Jelena Popić[1] and Mirela Šoštarec-Crnić[2]
[1]"Merkur" University Hospital, Zagreb
[2]University Hospital for Infectious Diseases "Dr. Fran Mihaljević", Zagreb
[3]EKOTEH dozimetrija d.o.o., Zagreb, Croatia
bklasic@net.amis.hr

INTRODUCTION

Computed tomography (CT) is a sectional imaging technique that uses a collimated X-ray beam perpendicular to the body axis to acquire image of a body slice of desired width. Attenuation of the beam on its way through the body is measured by crystal detectors situated on the opposite side from the X-ray tube. Based on the recorded attenuation values, a mathematically reconstructed image is obtained. Each CT image consists of separate elements (pixels) with a specific gray scale value.

CT is playing an increasingly important role in the diagnosis of a wide variety of disorders [1]. Since its introduction, it has been known that CT is related to high radiation dose to the patient. Expanding the use of this diagnostic modality resulted in making it a major source of radiation exposure to population from diagnostic X-rays. In countries with developed healthcare it contributes up to 41 % of the annual collective dose from medical radiation exposures [2].

Many ways are found in the literature to describe [3,4] and measure [5–8] radiation dose from CT. In an effort to further improve dose management in CT, European Commission published European Guidelines (EG) on quality criteria for CT [9]. EG proposed two dose descriptors normalized weighted computed tomography dose index ($_nCTDI_W$) and dose – length product (*DLP*), as reference dose levels (RDLs). The weighted CT dose index, $CTDI_w$, for a single slice in serial scanning or per rotation in helical scanning is (1):

$$CTDI_w = (1/3\ CTDI_c) + (2/3\ CTDI_p) \quad (1)$$

The subscript "n" ($_nCTDI$) is used to denote when these measurements have been normalized to unit radiographic exposure (mAs).

The second reference quantity is the dose – length product (*DLP*), which includes the patient, or the phantom volume irradiated during a complete examination (2):

$$DLP = \sum_i CTDI_{w}i\ Ti\ Ni \qquad (2)$$

where, for each of *i* helical sequences forming part of an examination, *T* is the nominal irradiated slice thickness (cm) and *N* is the total number of slices for the sequence.

To compare radiological examinations in terms of radiation risk, taking into account the relative radio sensitivities of body regions involved, it is necessary to estimate effective dose *E*, which is the sum of the products of organ doses and corresponding weighting factors [9]. The effective dose estimate (3) was determined by using *DLP* measurements and appropriate normalized coefficients found in the European guidelines for CT [9] where E_{DLP} is the region specific normalized effective dose.

$$E = E_{DLP}\, DLP \qquad (3)$$

Those coefficients were 0.0023 mSv mGy^{-1} cm^{-1} for head CT, 0.017 mSv mGy^{-1} cm^{-1} for chest CT, and 0.015 mSv mGy^{-1} cm^{-1} for abdominal CT [9].

To our knowledge, there are no data currently available concerning nationwide patient doses from CT examinations in Croatia. The aim of the present work is to contribute to the establishment of diagnostic reference levels (DRLs) for various CT examinations in our country.

MATERIALS AND METHODS

Our survey was performed on the helical CT scanner Shimadzu X-ray CT system SCT-7800 T (Shimadzu, Japan). All measurements were performed during 2009 and 2010.

105 adult patients took part in our survey, 44 women (42 %) and 61 men (58 %). Mean patient age was 58, ranging from 21 to 94. Each patient signed the informed consent form.

Typical CT examinations, namely routine head, chest and abdomen, were selected for the study. For each examination, the parameters, such as kVp, mAs, number of slices, slice thickness, pitch and length of examined body segment were recorded.

$CTDI_{100}$ was measured with standard ionization chamber and Unfors Xi (Unfors, Sweden) measurement system. Radiation dose in mGy was multiplied with 10 cm length, equaling *CTDI* in mGy·cm. Results were normalized to 10 mm slice width. For our measurements we used standard polymethyl – methacrylate (PMMA) phantoms: body (320 mm in length and 160 mm in diameter) and head (160 mm in length and 160 mm in diameter). The ionization chamber used for measurements of air kerma was placed in holes extending through the length of the phantom at 3, 6, 9 and 12 hours and at the phantom's central axis.

Table 1. Protocols for typical CT examinations

	kV	**mAs**	***T***	***l***
ABDOMEN	120	250	10	1
THORAX	120	150	10	1
HEAD	120	250	5	1
		190	10	1

kV – kilovoltage, mAs – tube current – exposure time product, *T* – slice thickness, *l* – slice increment

We used standard exposure technique factors (kVp, mAs and slice thickness) that remained constant for each type of the examination, whereas only the number of slices varied from patient to patient.

RESULTS

The slice numbers, scanning length and number of phases are provided in Table 2 and measurement results are summarized in Table 3. For CT examinations performed with *i.v.* contrast media, the radiation dose was multiplied with a number of phases. The scanning length *L* was longest for abdominal CT scans, which was expected, since abdomen is the largest anatomical region. In the abdominal protocol, *L* also had a broadest range of values (22 – 66 cm), probably because of a variable size of the field of interest. *L* for thorax had narrower range (25 – 44 cm), mostly because of the difference in patient size. For head protocol, *L* was relatively constant (15 – 26 cm). Here we have to emphasize the importance of optimization of CT practices.

Table 2. Values of total number of slices *N* and irradiation length *L* (mm), with a number of phases *P* for each examination.

	N	***L*** (mm)	***P***
ABDOMEN	41	410	1 – 4
THORAX	32	320	1 – 2
$HEAD_{5mm}$	14	70	1 – 2
$HEAD_{10mm}$	10	100	1 – 2

Table 3. The dose to patients expressed in terms of $CTDI_w$ (mGy), *DLP* (mGy·cm) and effective dose *E* (mSv)

	$\boldsymbol{CTDI_w}$	**3rd quartile**	***DLP***	**3rd quartile**	***E***	**3rd quartile**
ABDOMEN	35	40	1435	1640	21.53	24.6
THORAX	8.8	11.3	281.6	361.6	4.79	6.15
$HEAD_{5mm}$	61	80	854	1120	1.96	2.58
$HEAD_{10mm}$	27.6	35	276	350	0.63	0.81

Starting point for that is the training of radiology personnel. Properly educated technologist can adjust technical parameters and length of an irradiated part of the body, therefore reducing the dose burden. Radiologists are obliged to establish and use appropriate examination protocols. Through better cooperation with other clinical specialties, it is possible to narrow down the scanning area and lower the number of examination phases. That can also contribute to dose reduction.

Some examinations were performed in phases, before and after intravenous contrast media application. For such patients we doubled or tripled the radiation dose, depending on weather scanning was done in two or three phases.

The abdominal CT examination was significantly above the EC RDL concerning *DLP*, and slightly higher with *CTDI* values. That can probably be attributed to longer then needed examined body segment.

Table 4. Proposed European Commission *RDLs* and region specific normalized effective dose for some routine CT examinations

EXAMINATION	$CTDI_w$ (mGy)	*DLP* (mGy·cm)	E_{DLP} (mSv)
ABDOMEN	35	780	11.7
THORAX	30	650	11.05
HEAD	60	1050	2.42

Higher RDL-s were also recorded with a head CT. Since RDL-s act as parameters to help identify relatively poor or inadequate use of the technique, the exposure settings and the extent of the scan should be further investigated to lower the dose without affecting image quality. The large irradiation volume of investigations seems to be an important factor, since CTDI values are only slightly higher than RDL-s. Reducing the extent of the scanning area as much as possible, without missing any vital anatomical region, is required to lower *DLP* and *E*. Reducing mAs of the examination protocol is also important, especially for patients with slender physique and pediatric patients. Mayo et al. [11] presented a study regarding the minimum tube current required for good image quality with least radiation dose on chest CT examinations. Our $CTDI_w$ and *DLP* values of investigated chest examination protocol were below the EC RDL. It should be noted that CT RDL-s should be monitored at certain time intervals to constantly assure optimization of the procedure.

CONCLUSION

We believe that our measurements provide a good basis for further investigation of radiation doses from CT scanners in Croatia. We hope to expand our survey in near future to include more radiology departments in Zagreb and other regional medical centers in Croatia.

REFERENCES

[1] Castellano IA, Dance DR, Evans PM. CT dosimetry: getting the best from the adult Cristy phantom. Radiat Prot Dosim 2005;114(1-3):321-325.

[2] UNITED NATIONS. Sources and Effects of Ionizing Radiation, Volume I: Sources. United Nations Scientific Committee on the Effects of Atomic Radiation. 2000 Report to the General Assembly, with scientific annexes. United Nation Sales Publication, Sales No E.00.IX.3, New York, 2000.
[3] Spokas JJ. Dose descriptors for computed tomography. Med Phys 982;9:288-292.
[4] Shope TB, Gagne RM, Johnson GC. A method of describing the doses delivered by transmission X-ray computed tomography. Med Phys 1981;8:488-495.
[5] Shope TB, Morgan TJ, Showalter CK. Radiation dosimetry survey of computed tomography systems from ten manufacturers. Br J Radiol 1982;55:60-69.
[6] Calzado A, Ruiz Sanz S, Melchor M, Vano E. A comparison of measured and calculated organ doses from CT examinations. Radiat Prot Dosim 1995;57:381-385.
[7] Jones AP, Mott DJ, Parkinson L. Experience with a new simple method for the determination of doses in computed tomography. Radiat Prot Dosim 92;43:139-142.
[8] Shrimpton PC, Wall BF. Assessment of patient dose from computed tomography. Radiat Prot Dosim 1992;43:205-208.
[9] EUROPEAN COMMISSION. European Guidelines on Quality Criteria for Computed Tomography, Report EUR 16262. Brussels: EC, 1999.
[10] Tsapaki V, Aldrich JE, Sharma R, Staniszewska MA, Krisanachinda A, Rehani M, Hufton A, Triantopoulou C, Maniatis PN, Papailiou J. Dose reduction in CT while maintaining diagnostic confidence: diagnostic reference levels at routine head, chest, and abdominal CT-IAEA-coordinated Research Project. Radiology 2006;240(3):828-834.
[11] Mayo JR, Hartman TE, Lee KS, Primack SL, Vedal S, Müller NL. CT of the chest: minimal tube current required for good image quality with the least radiation dose. AJR Am J Roentgenol 1995;164(3):603-607.