Method of Multislice CT Effective Doses Estimation on the Basis of Dose Distribution Curves

Sergey Kruchinin and Mikhail Zelikman
Research and Practical Centre of Medical Radiology, Srednyaya Kalitnikovskaya, 28/1, Moscow, Russia

Keywords: CT, Effective Dose, Scattered Radiation.

Abstract: Conventional dose-length product method for CT effective dose evaluation in case of multislice scanners with comparatively large X-ray beam collimation leads to underestimation of effective doses due to partly neglecting of scattered in patient body radiation. It is possible to avoid this problem taking into account "tails" of dose distribution on the length exceeds zone ±50 mm relative to the beam centre. Method of DLP evaluation on the basis of dose distribution curves with "tails" estimated on full length (±200 mm or more) is presented.

1 PURPOSE

Modern multislice CT scanners use X-ray beam collimation of 30 – 40 mm or more and this leads to increasing of scattered in patient body radiation and its contribution to the effective dose as a result.

Traditionally effective doses evaluation for various computed tomography exams is performed on the basis of dose-length product (DLP) parameter and conversion factors, specified for study type and patient age by European Commission: as a rule adult or child but sometimes child conversion factors are presented more detailed (European Commission's Study Group, 1999); (Deak et al., 2010). DLP in this case is calculated using CT dose index (CTDI) measurements on the length of 100 mm but when the value of scattered radiation is significant this length of dose integration becomes insufficient and results in effective dose underestimation. Taking into account dose distribution along z-axis on the length of approximately ±200 mm (or more) relative to the center of X-ray beam, provides an opportunity to estimate CTDI and respectively DLP more correctly.

Features of method concerning DLP evaluation on the basis of dose distribution curves with "tails" estimated on the length of 200 mm or more (on each side from X-ray beam centre) are described in the paper.

2 METHODS AND MATERIALS

All the experiments (chest study parameters setting) were conducted on the basis of two 64-slice CT scanners: Aquilion 64 (Toshiba Medical Systems) and Light Speed VCT (GE Healthcare). X-ray beam collimation for CT units has been chosen in the range from 32 to 40 mm.

Measuring of absorbed dose distribution along z-axis has been performed utilizing CTDI cylindrical phantoms (PMMA, "body" – 32 cm in diameter, about 15 cm in length) and specially designed cylindrical containers into each of which a set of thermoluminescent dosimeters (TLDs) has been placed. For experimental evaluation of absorbed dose distribution on both sides from X-ray beam centre (and plotting of corresponding curves) two phantoms have been positioned close to each other and this made possible to estimate in two steps "tails" of absorbed dose distribution at the interval of approximately ±200 mm along z-axis relative to the beam centre. To plot a complete curve it is necessary to combine the data obtained for the right and the left sides of distribution.

Attention must be given for TLDs calibration because utilized TLDs have a sensible dependence of measured values on X-ray energy. It must be taken into account that energy spectrum of scattered radiation differs from that of the main beam. For this reason the traditional calibration in air using standard irradiation source (for example ^{137}Cs) or

Kruchinin S. and Zelikman M..
Method of Multislice CT Effective Doses Estimation on the Basis of Dose Distribution Curves.
DOI: 10.5220/0004184400910094
In *Proceedings of the International Conference on Biomedical Electronics and Devices* (BIODEVICES-2013), pages 91-94
ISBN: 978-989-8565-34-1

CT scanner X-ray beam leads to substantial distortions in dose estimates despite the fact that the last method takes into account beam rotation. TLDs (LiF:Mg, Ti; 4.5±0.12 mm in diameter, 0.9±0.1 mm thickness) from chosen group were placed inside a container in which 22 – 24 sensors are housed simultaneously. As a reference dosimeter Unfors Xi with pencil type ionization chamber has been used. Container with TLDs as well as Unfors Xi detector were installed at the central and periphery holes of CTDI phantom located in the centre of scanner gantry and after this several exposures for one tube rotation and with fixed table position have been made. Multiple exposures are needed in order to reliably exceed the sensitive threshold of thermoluminescent dosimeters. Considering reference device (Unfors Xi) readings and TLDs measurements (estimates of an integral under absorbed dose distribution curve on ±50 mm interval) two values of the weighted CTDI have been calculated and their ratio gives the calibration factor for testing TLDs group.

Effective doses on DLP basis have been calculated in respect that conversion factor for adult chest studies in accordance with appropriate document is equal to 0.017 $mSv \cdot mGy^{-1} \cdot cm^{-1}$ (European Commission's Study Group, 1999).

An adult (hermaphrodite) anthropomorphic body phantom consists of 25 mm elements simulating human body organ sections with different densities. This phantom with TLDs (about 100 sensors) placed inside was chosen for reference measurements. One phantom section with thermoluminescent sensors housed in is shown on Fig.1, as an example. TLDs distribution in phantom was the following: red bone marrow – 7; colon – 5; lungs – 24; stomach – 4; breast – 2; gonads – 2; bladder – 2; liver – 5; esophagus – 8; thyroid – 6; skin – 11; bone surface – 10; remind organs – 13. Using an anthropomorphic phantom+TLDs, effective dose evaluation has been made on the basis of weighting factors for different organs and tissue presented in International Commission on Radiological Protection (ICRP) documents: ICRP Publication 60 and ICRP Publication 103 recommendations (ICRP, 1991); (ICRP, 2007).

3 RESULTS AND DISCUSSION

The right parts of absorbed dose distribution curves received at the central and periphery holes of doubled CTDI "body" phantom are presented on Fig.2 and Fig.3 respectively. Fig.4 shows the right parts of weighted distribution curves. Full length weighted curves have been used for weighted CTDI calculation on the basis of integrals under the curves on the interval from –200 to +200 mm). Weighting has been made using weighted factors 1/3 and 2/3 for centre and periphery zones respectively. It follows from the received data that the integrals under the absorbed dose distribution curves at the central hole of doubled CTDI phantom (in the range of ±200 mm) differ from the integrals on the interval from –50 to +50 mm (traditional CTDI method) approximately by (53 – 65)% for both scanners. For periphery holes this difference is not so significant and is about (11 – 13)%. Mentioned above means that ignoring of scattered radiation outside ±50 mm zone along z-axis leads to underestimation of the effective dose up to approximately 20% in average when using the traditional method on the basis of single CTDI "body" phantom and 100 mm ionization chamber (weighted CTDI) in case of collimation 32 – 40 mm.

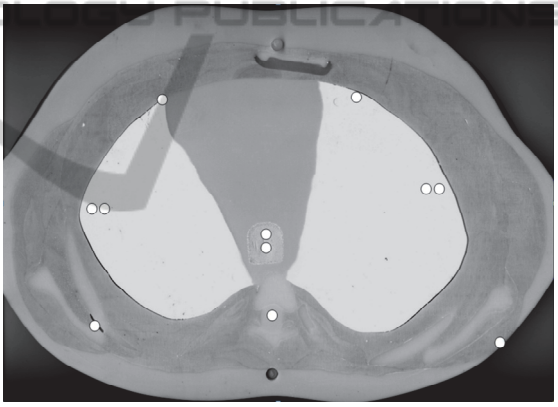

Figure 1: Anthropomorphic phantom section with TLDs housed in.

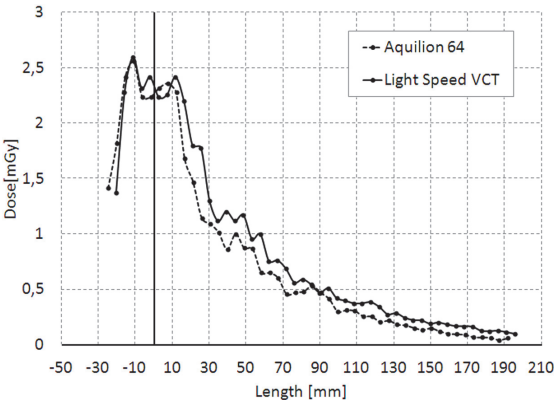

Figure 2: The right part of absorbed dose distribution at the centre hole of doubled CTDI phantom.

Table 1: Effective dose estimates obtained on the basis of various methods.

CT scanner type	X-ray beam collimation, mm	Effective dose estimates, mSv			
		Anthropomorphic body phantom + TLDs		DLP parameter method	Dose distribution curves method
		60 ICRP Recommendations	103 ICRP Recommendations		
Aquilion 64	32	6,98	7,98	6,47	7,57
Light Speed VCT	40	6,53	7,61	5,54	6,66

After the experimental receiving of weighted CTDI for one tube rotation and with fixed patient table position (taking into account dose distribution outside ±50 mm zone along z-axis), knowing pitch and scanning length, it is possible to calculate DLP parameter and patient effective dose as a result.

Effective dose estimates achieved on the basis of conventional DLP method, anthropomorphic body phantom+TLDs (60 and 103 ICRP Publications recommendations) and proposed method utilizing dose distribution curves are presented in Table 1. Electrical parameters settings for both devices have been chosen as close as possible (X-ray tube voltage, current and time of one tube rotation).

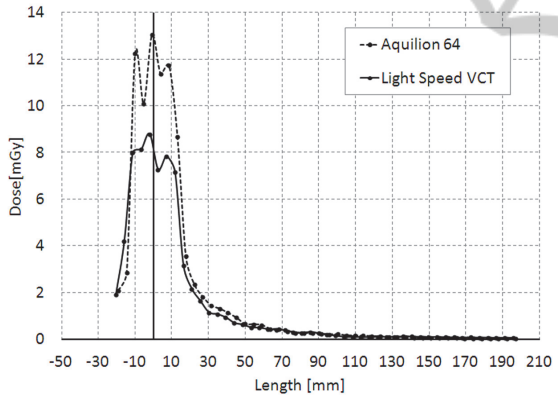

Figure 3: The right part of absorbed dose distribution at the periphery hole of doubled CTDI phantom.

The results obtained using presenting method are very close to reference estimations based on anthropomorphic phantoms+TLDs measurements. Difference for chest exams on both CT scanners does not exceed 8%. When compared it must be taken into account that doses evaluated using weighted factors from ICRP 103 Publication recommendations exceed those based on ICRP 60 Publication recommendations by approximately 14 – 16% (15% in average) and that effective dose conversion factors recommended by European Commission have been calculated using Monte-Carlo simulation method in 1999 when there were ICRP 60 Publication recommendations only. Up to now for ICRP 103 Publication recommendations appropriate conversion factors are calculated for CT scanner Somatom Sensation 64 (Siemens Healthcare) only (Deak et al., 2010).

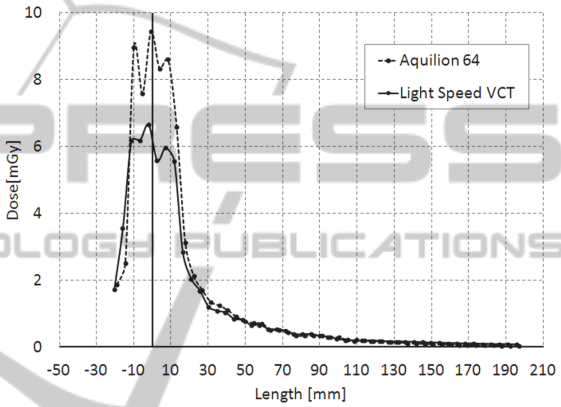

Figure 4: The right part of weighted dose distribution in doubled CTDI phantom.

4 CONCLUSIONS

The presented method allows estimating of CT effective doses more accurately in comparison with traditional DLP procedure by taking into account of scattered in patient body radiation outside ±50 mm scanning zone along z-axis.

In this case patient effective dose evaluation accuracy increases by approximately 20% (chest exams) for considered models of 64-slice CT scanners.

Since the use of traditional DLP method for multislice CT scanners with large beam collimation (30 – 40 mm and more) leads to underestimation of patient effective dose, it seems necessary to utilize presented method or, as an alternative, to calculate a set of correction factors for widely used now weighted CTDI values which are displayed on scanner's console for various types of CT studies. Additionally these correction factors should take into account differences in dose evaluation using ICRP 103 Publication and ICRP 60 Publication

recommendations.

REFERENCES

Deak, P., Smal, Y. and Kalender, W. 2010, 'Multisection CT protocols: sex- and age- specific conversion factors used to determine effective dose from dose-length product', *Radiology,* vol. 257, no.1, pp. 158 – 66.

European Commission's Study Group 1999, *European Guidelines on Quality Criteria for Computed Tomography (EUR 16262 EN)*, Luxembourg, European Communities.

ICRP 1991, *1990* Recommendations of the International Commission on Radiological Protection (Publication 60), ann. *ICRP 21*, no. 1 – 3.

ICRP 2007, *2007* Recommendations of the International Commission on Radiological Protection (Publication 103), ann. *ICRP 37,* no. 2 – 4.