Scientific Research Publishing

Open Journal of Radiology, 2024, 14, 74-82
https://www.scirp.org/journal/ojrad
ISSN Online: 2164-3032
ISSN Print: 2164-3024

Life Time Attributable Cancer Risk Estimated Using Scanner Reported Dose Length Product during Chest Computed Tomography Imaging in Young Children

Mousa Bakkari[1], Khaled Soliman[1*], Abdullah Alrushoud[1], Marwan Fahad Alosaimi[2], Hanaa Alsheikh[1], Abdelwahed Alhejaili[2]

[1]Medical Physics Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia
[2]Radiogiadnostic and Medical Imaging Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia
Email: *khaledsoliman61@gmail.com

How to cite this paper: Bakkari, M., Soliman, K., Alrushoud, A., Alosaimi, M.F., Alsheikh, H. and Alhejaili, A. (2024) Life Time Attributable Cancer Risk Estimated Using Scanner Reported Dose Length Product during Chest Computed Tomography Imaging in Young Children. *Open Journal of Radiology*, **14**, 74-82.
https://doi.org/10.4236/ojrad.2024.142008

Received: April 20, 2024
Accepted: May 28, 2024
Published: May 31, 2024

Abstract

This study aims to estimate the lifetime attributable cancer risk (LAR) for pediatric chest computed tomography (CT) examinations in five age groups using recently published age and region-specific conversion coefficients multiplying the widely available scanner registered dose length products (DLP) displayed on the CT console and hence calculating the Effective Dose (ED). The ED is then multiplied by the International Commission on Radiological Protection (ICRP) published risk factor for LAR. The obtained LAR values are compared with the international literature. Factors that may affect the LAR value are reported and discussed. The study included one hundred twenty five chest CT examinations for both males and females aged from less than one year to fifteen years. The patients' reported data are from one single medical institution and using two CT scanners from June 2022 to December 2023. The results of this study may serve as benchmark for institutional radiation dose reference levels and risk estimation.

Keywords

Cancer Risk, LAR, Chest CT, Pediatric Radiology, Radiation Dose, DLP

1. Introduction

Children are generally considered to be at higher risks of developing radiation-induced tumors because of the young age of exposure and increased tissue radio sensitivity in some of the organs [1]. Children are clearly more likely to

develop one of a quarter of these types, including leukemia, brain, breast, skin, and thyroid cancer [2].

For a range of x-ray examinations, including radiography and CT, average lifetime risks of cancer incidence per [Sv] may be around two or three times higher for exposures at age 0 - 9 yr than at age 30 - 39 yr. For patients exposed in their 60 s, the estimated lifetime risks are about half those for patients in their 30 s, falling to about one-tenth for those in their 80 s [3].

Monitoring radiation doses from medical exposures is highly recommended by international radiation protection standards [4].

The stochastic risk is the estimation of the potential increase in the number of cancers resulting from the CT diagnostic examinations of the chest in young children. The risk is proportional to the calculated Effective dose (ED) of the chest CT and the dose length product (DLP), the age and the gender of the patient. The ED will depend on the radiation received by the irradiated organs during the CT scan and the radio-sensitivity of the organs.

the weighted sum of the tissue-specific dose equivalents, called the effective dose, should be proportional to the total estimated detriment from the exposure, whatever the distribution of equivalent dose within the body [5].

The LAR estimates are based on the same epidemiological data as ICRP uses for the risk coefficients related to effective dose, and differentiate the cancer risk into age and gender specific subgroups and have also a clearly defined detriment in the form of either the excess risk of receiving a cancer or the excess risk to die from the received cancer.

In this study we examine the stochastic risk form radiation exposure of chest computed tomography (CT) examinations routinely performed on pediatric patients in a tertiary care medical institution.

2. Methods

Data were collected using the Radiology information system (RIS) hospital information system (HIS) and the DICOM dose report files for each chest CT examination included in this study. The data collected were for both genders and for ages from less than a year to fifteen years of age. Technical parameters such as tube kilo-voltage (kV) and volumetric computed tomography dose index ($CTDI_{vol}$) are included in the analysis along with the gender and the age group. The study included 125 patients in total. The data analyzed are from two scanners.

To generate effective dose per unit dose length product (ED/DLP) conversion factors incorporating ICRP Publication 103 tissue weighting factors must be used.

Calculating organ doses using software for each patient is laborious and time consuming; as an alternative, scanner-derived exposure outputs, volume CT dose index (CTDIvol), and dose-length product (DLP) that are recorded for each examination have been used to approximate effective dose according to

DLP, using DLP-to–effective dose (ED) conversion coefficients (k factors) [6] [7].

$$\text{ED in [mSv]} = \text{DLP in [mGy·cm]} * \text{k in [mSv·mGy}^{-1}\text{·cm}^{-1}\text{]} \quad (1)$$

$$\text{LAR} = \text{ED in [Sv]} * \text{risk coefficient in [Sv}^{-1}\text{]} \quad (2)$$

ICRP nominal risk coefficient for detriment-adjusted cancer is 5.5% per Sv [5]. The k factors are taken from Table 1. The ED and LAR calculations in this work were conducted using Equations (1) and (2) above.

The statistical analysis and plots in this work was conducted using Matlab version R2016b, statistical and machine learning toolbox.

3. Results

The results for each one of the two CT scanners used in this study are included in Table 2 and Table 3.

The LAR values can be compared with the Values reported in Table 4. The-most significant parameters in the form of distributions are included in Figure 1 in the form of histogram. Figure 1(a) showing the DLP distribution for our data in the form of histogram. Figure 1(b) showing the ED values distribution. And Figure 1(c) contains the kV values used in chest CT examinations with 100 kV as the most common value used in our institution followed by 80 kV and finally few exams are done with 120 kV. The LAR values distribution are in Figure 1(d).

The summary of our results can be expressed in Figure 2 which illustrates an incresing value of the DLP with age. And Figure 3 showing that smaller values of $CTDI_{vol}$ and DLP corresponds to lower LAR value. Figure 4 showing the LAR values obtaine for the 4 age groups, the difrence is quite small among the groups. Figure 5 clearly demostrates that an increase in the kV value will increase the LAR estimate. Therfore it is important to specifiy the used kV value in order to compare published reserch results reporting ED of LAR.

4. Discussion

Effective dose calculation is more complex and prone to error in children compared with adults because of the use of various correction factors to convert adult to pediatric dose [10].

The k coefficient method usually under estimate the real ED value and the need to improve the LAR assessment reside in the fact that ED must be calculated using MC based software to calculate organ doses and the corresponding ED for the chest CT exam for example. The coefficients will decrease in magnitude with increasing age.

Adopting a retrospective study in a large database, the authors' findings demonstrated consistency that organ doses are the best quantity to assess radiation risks, emphasizing that risk estimations must be interpreted as average estimations applicable to patient groups and not for individuals [11]. In all cases, this outlines the importance of patient-based radiation dose monitoring for

Table 1. Normalized effective dose (ED) in mSv per dose-length product (DLP) in $mGy^{-1}\cdot cm^{-1}$ for pediatric patients of various ages for chest CT examinations published in [7].

Age at exposure [years]	K [$mSV\cdot mGy^{-1}\cdot cm^{-1}$]
0	0.039
1	0.026
5	0.018
10	0.013
Adult	0.014

Table 2. Data are for scanner.1 (Siemens, N = 49) the reported values are the calculated average ± (standard deviation).

Age group (years)	Gender (M/F)	Number of patients	DLP (mGy·cm)	ED (mSv)	LAR per 100,000 persons
<1	F	3	21 ± 2.6	0.82 ± 0.10	467 ± 59
	M	3	65 ± 23	2.55 ± 0.90	1452 ± 515
1 - 5	F	6	64 ± 37.1	1.67 ± 0.96	953 ± 550
	M	13	53 ± 32	1.37 ± 0.83	780 ± 474
5 - 10	F	5	195 ± 123	3.51 ± 2.21	2001 ± 1262
	M	12	100 ± 74	1.80 ± 1.33	1024 ± 760
10 - 15	F	4	172 ± 116	2.24 ± 1.51	1276 ± 860
	M	3	147 ± 50	1.92 ± 0.65	1092 ± 369

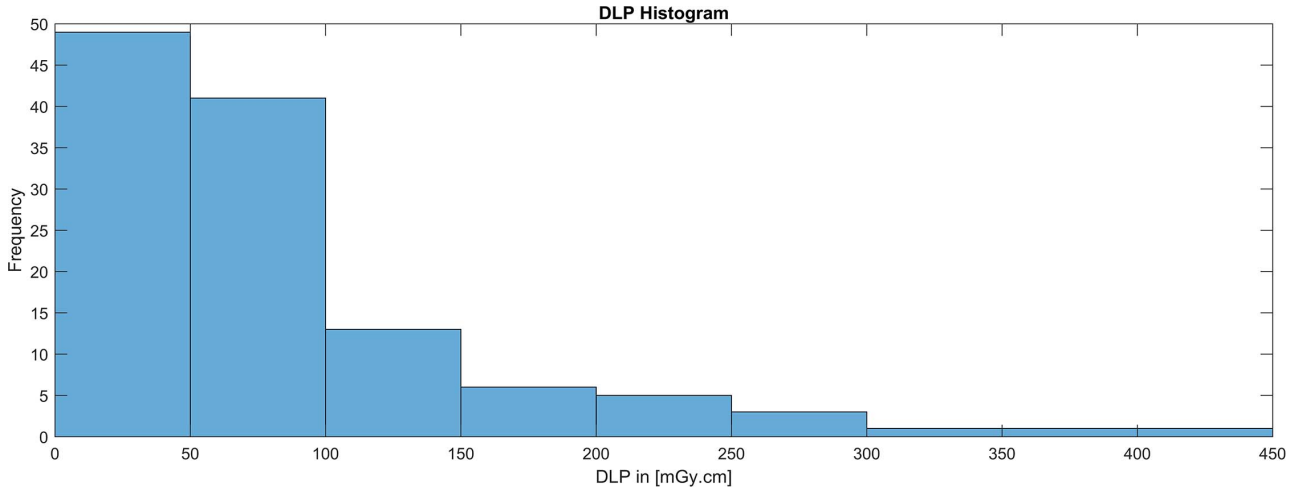
Table 3. Data are for scanner.2 (GE, N = 76) the reported values are the calculated average ± (standard deviation).

Age group (years)	Gender (M/F)	Number of patients	DLP (mGy·cm)	ED (mSv)	LAR per 100,000 persons
<1	F	0			
	M	8	36.2 ± 32.6	1.41 ± 1.27	804 ± 725
1 - 5	F	19	57.2 ± 0.9	1.49 ± 0.90	848 ± 514
	M	21	48.2 ± 27.9	1.25 ± 0.73	714 ± 413
5 - 10	F	5	113.9 ± 1.2	2.05 ± 1.16	1169 ± 662
	M	10	97.9 ± 71.4	1.76 ± 1.29	1005 ± 733
10 - 15	F	3	188.3 ± 69.1	2.45 ± 0.90	1396 ± 512
	M	5	215.3 ± 142.2	2.80 ± 1.85	1596 ± 1054

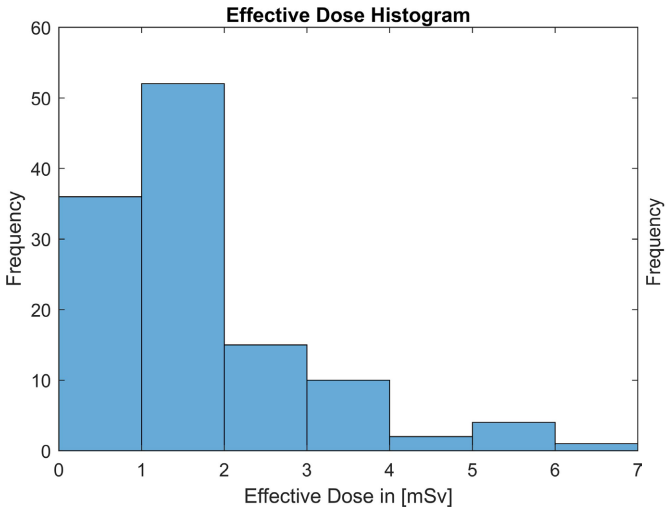
Table 4. Lifetime attributable risk of cancer incidence (LARCI) per 100,000 persons exposed to a single dose of 0.1 Gy [8].

Age at exposure [years]	LAR (all cancers)*
[0 - 1]	4777
[1 - 5]	3377
[5 - 10]	2611
[10 - 15]	2064
[15 - 20]	1646

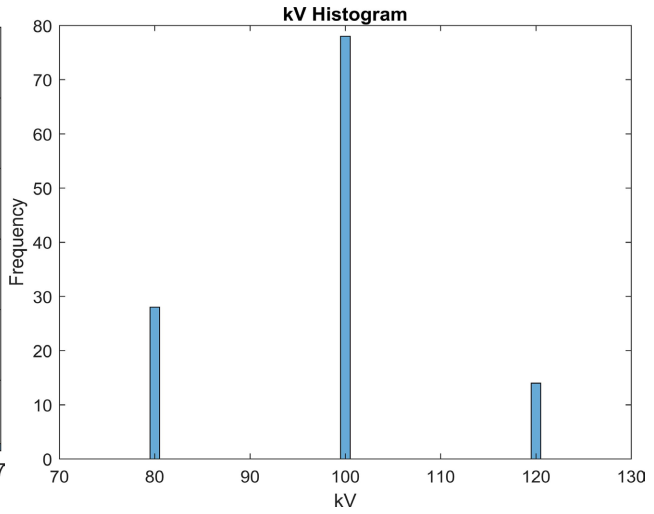
*values reported in BEIR VII, 2006 report [9].



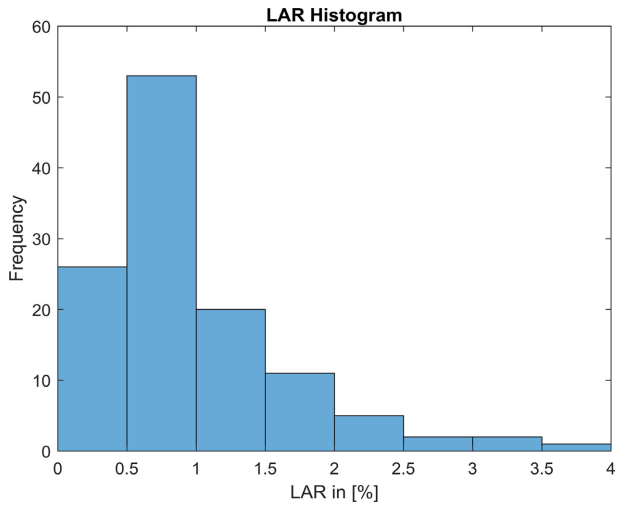
(a)



(b)



(c)



(d)

Figure 1. (a) Obtained DLP values for chest CT examinations in young children; (b) Obtained ED values for chest CT examinations in young children; (c) kV values for chest CT examinations in young children; (d) The estimated LAR values for chest CT examinations in young children.

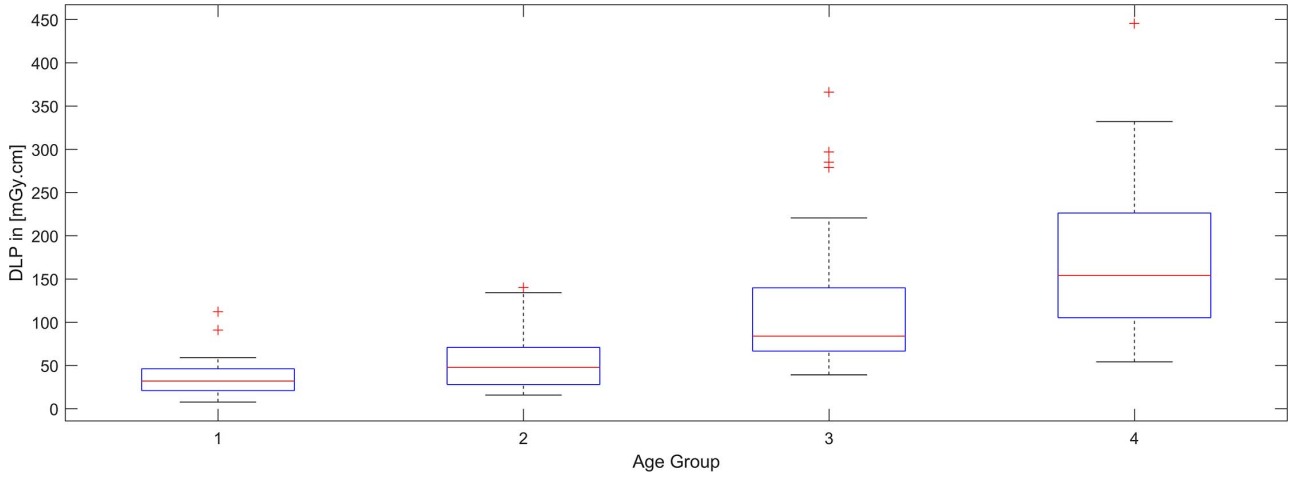


Figure 2. Boxplot of the DLP values per age group 1 (from 0 to 1) years, group 2 (more than 1 and less than 5), group 3 (more than 5 and less than 10), group 4 (more than 10 and less than 15.

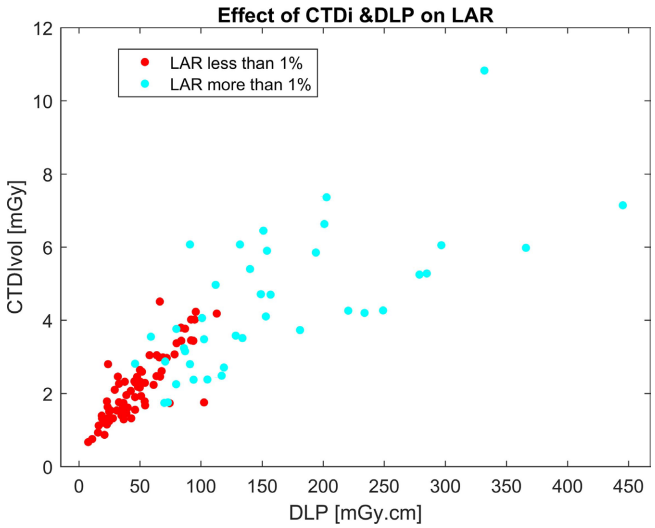


Figure 3. The combined effect of $CTDI_{vol}$ and DLP on the LAR values grouped as more than 1% and less than 1%.

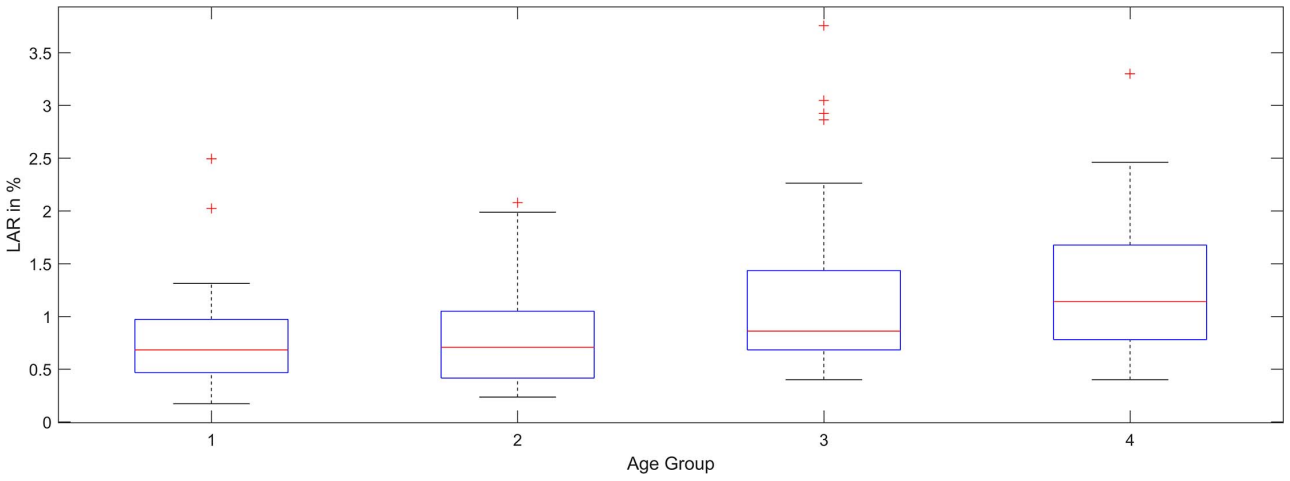


Figure 4. Boxplot of the obtained LAR value per age group.

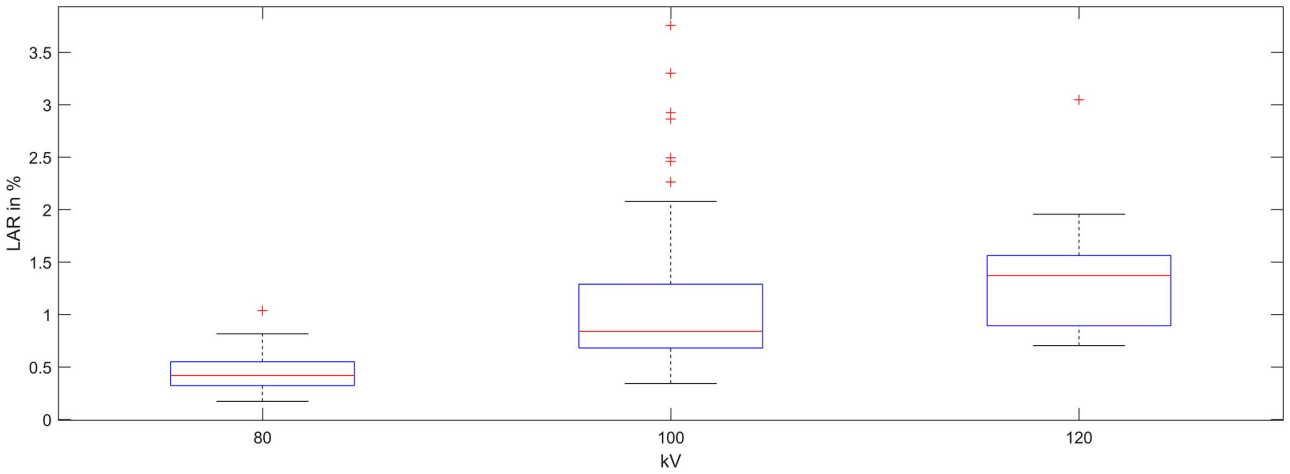


Figure 5. Boxplot of the LAR values in (%) as a function of the kV.

patient risk assessment, in particular for CT exams [12]. However, the *k* factors are estimated with a sexless, ageless, uniform phantom and do not represent the varied attributes and organ distributions seen in patient populations [13].

The obtained results are comparable with other published studies and contribute to the existing literature about radiation dose estimates and analysis of chest CT examination in young children [14] [15] [16] [17].

Among the examined scanning parameters only the kV used had a significant effect on the estimated LAR as seen in **Figure 5**.

Multiplying the universally reported DLP by scalar coefficient offers a simple, rapid method for clinicians to estimate ED, which can be included in the medical record and tracked over time [18].

5. Conclusion

The DLP based method used to estimate the excess cancer risk from radiation exposure occurring during medical chest CT examinations is straightforward and provide practical approach to risk estimation and a method to monitor radiation dose levels applied to pediatric patients. In order to obtain a better ED and LAR estimations organ doses must be calculated using commercially available softwares based on Monte-Carlo simulation considered the gold standard in clinical dosimetry; we recommend the use of such approach in another research work similar to this one. Also analyzing a larger number of CT dose data will improve the accuracy of the estimation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Gao, Y., Quinn, B., Mahmood, U., Long, D., Erdi, Y., St. Germain, J., Pandit-Taskar, N., Xu, X.G., Bolch, W.E. and Dauer, L.T. (2017) A Comparison of Pediatric and

Adult CT Organ Dose Estimation Methods. *BMC Medical Imaging*, **17**, Article No. 28. https://doi.org/10.1186/s12880-017-0199-3

[2] UNSCEAR (2013) Sources, Effects and Risks Of Ionizing Radiation, UNSCEAR Publications. United Nations Scientific Committee on the Effects of Atomic Radiation, New York, Vol. II.

[3] Harrison, J.D., Haylock, R.G., Jansen, J.T., Zhang, W. and Wakeford, R. (2023) Effective Doses and Risks from Medical Diagnostic X-Ray Examinations for Male and Female Patients from Childhood to Old Age. *Journal of Radiological Protection*, **43**, Article No. 011518. https://doi.org/10.1088/1361-6498/acbda7

[4] International Atomic Energy Agency (2023) Patient Radiation Exposure Monitoring in Medical Imaging. IAEA Safety Reports Series, IAEA, Vienna.

[5] (2007) The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. *Annals of the ICRP*, **37**, 1-332.

[6] Deak, P.D., Smal, Y. and Kalender, W.A. (2010) Multisection CT Protocols: Sex and Age-Specific Conversion Factors Used to Determine Effective Dose from Dose-Length Product. *Radiology*, **257**, 158-166. https://doi.org/10.1148/radiol.10100047

[7] Valentin, J. and ICRP (2007) Managing Patient Dose in Multi-Detector Computed Tomography (MDCT). ICRP Publication 102. *Annals of the ICRP*, **37**, 1-79.

[8] International Atomic Energy Agency (2014) Dosimetry in Diagnostic Radiology for Paediatric Patients, IAEA Human Health Series No. 24, IAEA, Vienna.

[9] National Research Council of the National Academies (2006) Health Risks from Expo-sure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. The National Academies Press, Washington, DC, 245 p. https://doi.org/10.17226/11340

[10] Newman, B., Ganguly, A., Kim, J.E. and Robinson, T. (2012) Comparison of Different Methods of Calculating CT Radiation Effective Dose in Children. *American Journal of Roentgenology*, **199**, W232-W239. https://doi.org/10.2214/AJR.10.5895

[11] Costa, P.R., Tomal, A., de Oliveira Castro, J.C., Nunes, I.P., Nersissian, D.Y., Sawamura, M.V., Leão Filho, H. and Lee, C. (2023) Diagnostic Reference Level Quantities for Adult Chest and Abdomen-Pelvis CT Examinations: Correlation with Organ Doses. *Insights into Imaging*, **14**, Article No. 60. https://doi.org/10.1186/s13244-023-01403-y

[12] Tsalafoutas, I.A., Harita, M.H., Al-Naemi, H.Y., and Kalra, M.K. (2020) Radiation Dose Monitoring in Computed Tomography: Status, Options and Limitations. *Phys Med*, **79**, 1-15. https://doi.org/10.1016/j.ejmp.2020.08.020

[13] Fu, W., Ria, F., Segars, W.P., Choudhury, K.R., Wilson, J.M., Kapadia, A.J. and Samei, E. (2021) Patient-Informed Organ Dose Estimation in Clinical CT: Implementation and Effective Dose Assessment in 1048 Clinical Patients. AJR. *American Journal of Roentgenology*, **216**, Article No. 824. https://doi.org/10.2214/AJR.19.22482

[14] Kim, J.E. and Newman, B. (2010) Evaluation of a Radiation Dose Reduction Strategy for Pediatric Chest CT. *American Journal of Roentgenology*, **194**, 1188-1193. https://doi.org/10.2214/AJR.09.3726

[15] Li, X., Samei, E., Segars, W.P., *et al.* (2011) Patient-Specific Radiation Dose and Cancer Risk Estimation in CT: Part II. Application to Patients. *Medical Physics*, **38**, 408-419. https://doi.org/10.1118/1.3515864

[16] Bernier, M.O., Rehel, J.L., Brisse, H.J., Wu-Zhou, X., Caer-Lorho, S., Jacob, S., *et al.* (2012) Radiation Exposure from CT in Early Childhood: A French Large-Scale Multicentre Study. *British Journal of Radiology*, **85**, 53-60.

https://doi.org/10.1259/bjr/90758403

[17] Strauss, K.J., Somasundaram, E., Sengupta, D., Marin, J.R. and Brady, S.L. (2019) Radiation Dose for Pediatric CT: Comparison of Pediatric Versus Adult Imaging Facilities. *Radiology*, **291**, 158-167. https://doi.org/10.1148/radiol.2019181753

[18] Chu, P.W., Kofler, C., Mahendra, M., Wang, Y., Chu, C.A., Stewart, C., Delman, B.N., Haas, B., Lee, C., Bolch, W.E. and Smith-Bindman, R. (2023) Dose Length Product to Effective Dose Coefficients in Children. *Pediatric Radiology*, **53**, 1659-1668. https://doi.org/10.1007/s00247-023-05638-1