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Radiation Dose Survey of Pediatric Chest Computed Tomography Examinations: A Local Diagnostic Reference Levels Approach to Patient Safety

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Abstract

Objectives: The aim of this work was to initially establish both age and weight driven pediatric diagnostic reference levels (DRLs) for chest computed tomography (CT) examinations performed at tertiary care medical institution. Another aim was to compare the presented data with internationally published ones. This initial data shall serve as basis for establishing a national DRLs values for pediatric diagnostic CT examinations. **Methods:** Dosimetric indexes were collected for the chest examination for 93 patients during the past 2 years in a tertiary care medical city. **Results:** The results are within and below the international reported levels for chest CT in several countries. **Conclusion:** Continuous monitoring of the radiation doses received by the patients in computed tomography is continuous and ongoing process in order to ensure compliance and to optimize clinical imaging protocols. More extensive data acquisition and analysis are required to allow better understanding of the contributing factors leading to less patient radiation dose while preserving the clinical image quality.

Keywords

Computed Tomography, Chest CT, Diagnostic Reference Levels, Monitoring, Optimization

1. Introduction

One of the most important aspects of radiological patient safety is management of radiation doses administered to patients in particular young aged ones. The importance of establishing dose reference levels (DRL) and dose recording and monitoring was recently emphasized by several health care patient safety standards [1].

When found to be necessary, DRLs have been established in order to be used as a tool to optimize the imaging protocols; It has also been observed that only few countries have established DRLs for pediatric imaging including CT examinations [2].

DRLs in pediatric CT examinations are scare, therefore a study contributing to this area in diagnostic radiology is beneficial to the scientific community.

DRLs in CT imaging can be reported using age groups, by weight or by Water Equivalent Diameter as indicators of patient size in children. To be able to report radiation doses as recommended we need to have patient's weight in [kg] and height in [cm] documented in the patients files that we shall review when reporting CT radiation doses in children. If such information is not available, researchers may use alternative approximation methods to report patient's radiation doses based on individual body size.

Comparisons among different DRLs or radiation dose levels reported in different studies can be impracticable or complicated in case of absence of identical grouping information. Dose monitoring software's can solve this issue by collecting enough information about the specific patient size along with the corresponding radiation dose from CT imaging studies [3].

Another important issue to be considered when thinking about reporting DRLs in medical Imaging is the clinical indication of the radiological examination or the purpose of the imaging study, usually the radiological examination is requested to answer a specific clinical question. In order to answer the clinical question the obtained images from the scanner must have certain degree of image quality level which is proportional to the radiation dose delivered by the imaging system. There are some recommendation about considering the clinical indications when DRLs are reported or the commonly called the clinical indication driven DRLs [4].

In order to comply with patient safety standards our medical Center initiated the establishment of local radiation dose reference levels aimed to take a closer look at the radiation doses received by our pediatric patients undergoing computed Tomography (CT) examinations. In this study we will present the initial dose reference levels obtained for the chest CT examinations performed at our center during the past two years starting from January 2021 to December 2022. CT examinations for pediatric patients are significantly much less than adults in numbers, therefore we are presenting in this work a total of ninety three examinations. This study will be considered as the start of a series of radiation dose audits that will be performed in the future. Another aim of this study was to compare the local DRLs to the internationally published ones.

2. Materials and Methods

93 Chest CT scans are included in this survey for children under 15 years old of age [0 - 13] years performed using two CT scanners from two vendors with au-

tomatic dose modulation applied in both scanners. Patient's data included in this retrospective study are from January 2021 to December 2022. We have used both age and size based grouping to analyze the pediatric radiation dose data as shown in the results section of this paper and in accordance to the available information that was available to us during the survey.

Data have been retrieved from the modality work station, and from the Radiology picture archiving and communication system (PACS). These data were used to gather information on the dose length product (DLP), the volumetric computed tomography dose index ($CTDI_{vol}$) and on the size specific dose estimate (SSDE). SSDE was calculated according to AAPM TG-204 [3].

3. Results

We have analyzed 93 patients files the age range was from less than 1 year old to 13 years old. We grouped the data first per age ranges as in **Table 1** below. The CT scanner used in this study is equipped with automatic exposure control and iterative reconstruction algorithm. The use of both features allows radiation dose reduction and maintains good clinical images quality.

The scanners used were: Siemens, Somatom-Defintion AS/128 slices and GE, light-speed VCT/64 slices both equipped with tube current modulation (TCM) capabilities. The used mAs range was [32 - 220]. The patients weights data were not available to us in this study therefore we reported our results per age group and per patient effective diameter (ED) sizes also. The volumetric computed tomography dose index ($CTDI_{(vol)}$), the Dose Area Product (DLP) and the Size Specific Dose Index (SSDE) are reported.

The obtained average radiation dose for pediatric chest CT examinations are presented in **Table 1** and **Figure 1**.

Figure 2 has a scattered plot of the DLP as a function of the effective diameter as surrogate of the patient size, since we did not have the patients weights information available to us in this study.

Our results indicates slightly higher dose reference levels than the internationally reported ones as in [5] [6] [7] [8]. Our patients ED was found to be smaller than the values tabulated in AAPM (TG-204).

Table 1. Pediatric chest CT examinations results grouped by age, the results are in average values for the parameters: ED, $CTDI_{(vol)}$, DLP and SSDE.

Age group	Male	Female	Effective diameter (ED) [cm]	$CTDI_{(vol)}$ [mGy]	DLP [mGy·cm]	SSDE [mGy]
Less than 1 year	7	6	11.0	1.5	25.7	4.5
1 < Age < 5 years	25	18	14.2	2.2	46.1	4.9
5 < Age < 10 years	15	13	16.6	3.7	87.5	6.3
10 < Age < 13 years	5	4	20.1	4.2	110.0	6.7

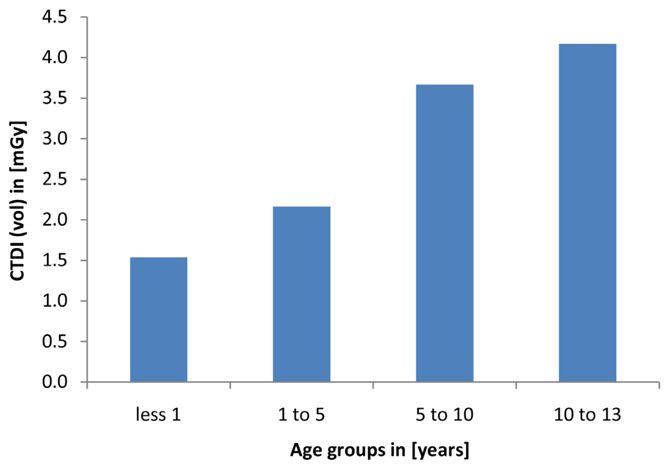

Figure 1. Histogram of the CTDI$_{(vol)}$ as function of the age groups used in this study.

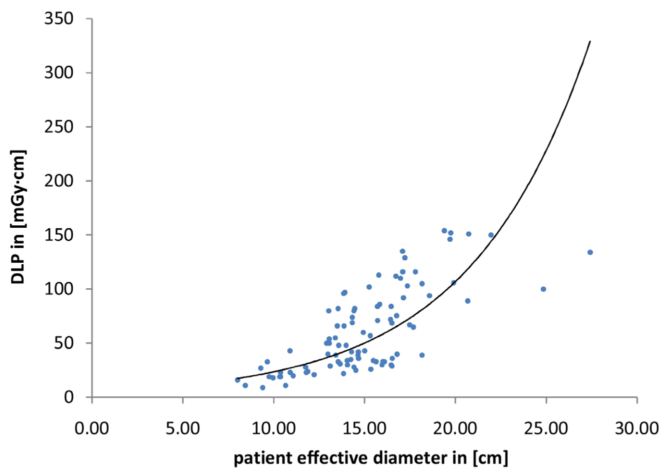

Figure 2. Showing the DLP in [mGy·cm] as a function of the patient effective diameter in [cm].

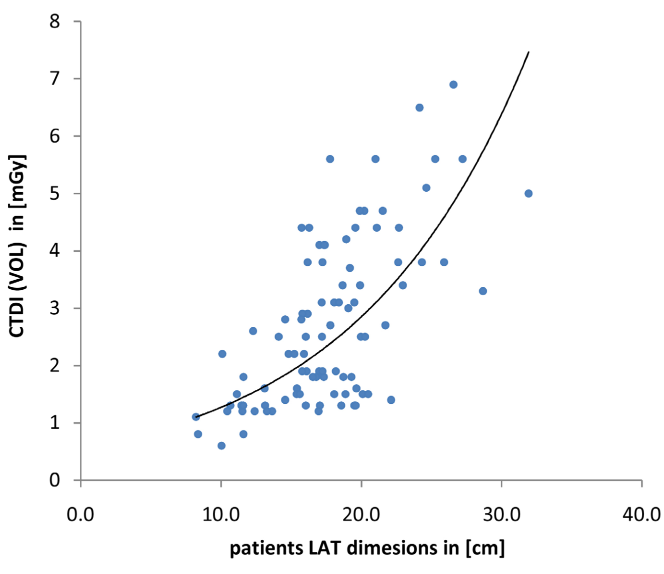

Figure 3. Scatter plot of the CTDI$_{(vol)}$ as function of the patients LAT dimension in [cm].

4. Discussion

Only a few countries have established their DRLs for pediatric examinations. The European guidelines on reference dose levels published in 2018 contain basic recommendations on how to establish and use DRLs for pediatric X-ray examinations and procedures, which include defining local, national, and European DRLs, the examinations for which DRLs should be established, using weight and age groups, and providing a dose reference for each group and type of image [9].

The ICRP recommendation is that DRLs for the pediatric population should be adjusted for weight or size and that this adjustment, in turn, should help in optimizing the use of radiation without interfering with the quality of diagnostic information; EC radiation protection report 185 recommends the use of patient weight as grouping variable to report and analyze DRLs for pediatric patients [10].

The age and weight must be taken into account when establishing DRL for pediatric patients, owing to large variations in the children's body size. The association between dose and patient size may be used to adjust CT protocols for a specific patient [11].

High performance CT scanners on the international market today with many radiation dose optimization features have contributed to lowering the radiation dose delivered to the patient during CT scanning, this trend is very beneficial to the pediatric patient community worldwide.

DLP data permit facilities to compare the amounts of radiation used to perform similar examinations to perform such comparison there is a need to specify the patient size because most CT scanners use automatic exposure control to adjust the amount of radiation and this latter feature is based on patient size and shape [12].

The difference in radiation doses are mainly due to the differences in patient's size (weight and height), the exposure parameters, the scan length, the number of acquisition series and the scanner model.

Scanners have evolved over time and automatic exposure control techniques play a major role in todays' scanners in order to reduce the radiation dose received by the patients while maintaining acceptable image quality.

Using the world largest database of CT dose information from actual patient examinations in the world; multivariate regression analysis showed that water equivalent diameter and lateral thickness were significant predictors of dose indexes [13]. Therefore, taking patients' size into account is important factor to consider in future studies related to developing DRLs in CT, size based DRLs is the future direction in CT DRLs.

Our data analyzed in the results section and in **Figure 3**, we can see that there is an exponential fit to the reported data. The same applies to **Figure 2** in same section of this paper.

The current trend in the use and application of DRls in CT are based on clinical indication (DRL_{ci}), since more than one indication maybe present for one anatomical area. The chest for example, different scan protocols can be applied depending on the purpose of the requested CT scan. Therefore DRLs should be classified based on clinical indication and not on anatomical area [14].

The lack of focus on actual scanning protocols has produced estimates that do not reflect the range and complexity of modern CT practice. To allow clinicians, patients and policy makers to make informed risk versus benefit decisions the individual and population level risks associated with modern CT practices are essential [15].

Large variation in the delivered radiation doses from CT imaging in children can be explained by the fact that there is significant body weight variation among the children inside each of the age groups. Another factor is the use of different imaging protocols among medical centers in every country, clinical indications and the used CT scanners type and technology are all factors responsible for the large variations observed among different reported studies. Therefore clear trends in radiation doses from CT scanning in children will be better understood after collecting large numbers of data from different institutions and countries worldwide.

One major shortcoming of this study was the absence of patient weights data, it is highly recommended to keep track of patients weights and heights along with the radiation doses in pediatric CT examination as recommended by many standards.

5. Conclusion

DRLs are a good optimization tool in diagnostic radiology, a continuous evaluation of the DRL in CT applications are very important since there is room for optimization in that area. The use of DRL based on clinical indications is required in order to reduce patient's radiation dose. Standardizing CT acquisition protocols is warranted at the local, national and international levels. Clinicians should be aware of this current optimization strategy undertaken by a number of countries around the world.

Conflicts of Interest

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

References

[1] Brady, Z., Ramanauskas, F., Cain, T.M. and Johnston, P.N. (2012) Assessment of Paediatric CT Dose Indicators for the Purpose of Optimisation. *Br J Radiol*, **85**, 1488-1498. https://doi.org/10.1259/bjr/28015185

[2] European Society of Radiology. European Guidelines on DRLs for Paediatric Imaging; PiDRL; European.

[3] Boone, J., Strauss, K., Cody, D., *et al.* (2011) AAPM Report No. 204: Size-Specific Dose Estimates (SSDE) in Paediatric and Adult Body CT Examinations. American

Association of Physicists in Medicine, College Park. https://doi.org/10.37206/143

[4] Habib Geryes, B., Hornbeck, A., Jarrige, V., Pierrat, N., Ducou Le Pointe, H. and Dreuil, S. (2019) Patient Dose Evaluation in Computed Tomography: A French National Study Based on Clinical Indications. *Phys Medica*, **61**, 18-27. https://doi.org/10.1016/j.ejmp.2019.04.004

[5] Shrimpton, P.C., Hillier, M.C., Meeson, S. and Golding, S.J. (2014) Doses from Computed Tomography (CT) Examinations in the UK-2011 Review. Public Health England, London.

[6] Muhammad, N.A., Karim, M.K.A., Hassan, H.A., Kamarudin, M.A., Wong, J.H.D. and Ibahim, M.J. (2019) Estimation of Effective Dose and Organ Cancer Risk from Paediatric Computed Tomography Thorax-Abdomen-Pelvi Examinations. *Radiat. Phys. Chem.*, **165**, 108438. https://doi.org/10.1016/j.radphyschem.2019.108438

[7] Hwang, J.Y., Do, K.H., Yang, D.H., Cho, Y.A., Yoon, H.K., Lee, J.S., *et al.* (2015) A Survey of Pediatric CT Protocols and Radiation Doses in South Korean Hospitals to Optimize the Radiation Dose for Pediatric CT Scanning. *Medicine*, **94**, e2146. https://doi.org/10.1097/MD.0000000000002146

[8] Hayton, A. and Wallace, A. (2016) Derivation of Australian Diagnostic Reference Levels for Paediatric Multi Detector Computed Tomography. *Australas Phys Eng Sci Med*, **39**, 615-626. https://doi.org/10.1007/s13246-016-0431-4

[9] (2018) European Commission European Guidelines on Diagnostic Reference Levels for Paediatric Imaging. *Radiation Protection*, **185**. http://www.eurosafeimaging.org/wp/wp-content/uploads/2018/09/rp_185.pdf

[10] Vañó, E., Miller, D.L., Martin, C.J., Rehani, M.M., Kang, K., Rosenstein, M., *et al.* (2017) ICRP Publication 135: Diagnostic Reference Levels in Medical Imaging. *Ann ICRP*, **46**, 1-144. https://doi.org/10.1177/0146645317717209

[11] Smith-Bindman, R., Wang, Y., Chu, P., *et al.* (2019) International Variation in Radiation Dose for Computed Tomography Examinations: Prospective Cohort Study. *BMJ*, **364**, k4931. https://doi.org/10.1136/bmj.k4931

[12] Wagner, F., Bize, J., Racine, D., Le Coultre, R., Verdun, F., Trueb, P.R. and Treier, R. (2018) Derivation of New Diagnostic Reference Levels for Neuro-Paediatric Computed Tomography Examinations in Switzerland. *J Radiol Prot*, **38**, 1013-1036. https://doi.org/10.1088/1361-6498/aac69c

[13] Roch, P., Célier, D., Dessaud, C., Etard, C. and Rehani, M.M. (2019) Long-Term Experience and Analysis of Data on Diagnostic Reference Levels: The Good, the Bad, and the Ugly. *Eur Radiol*, **30**, 1127-1136. https://doi.org/10.1007/s00330-019-06422-2

[14] Paulo, G., Damilakis, J., Tspaki, V., Schegerer, A.A., Repussard, J., Jaschke, W. and Frija, G. (2020) Diagnostic Reference Levels Based on Clinical Indications in Computed Tomography: A Literature Review. *Insights into Imaging*, **11**, 96. https://doi.org/10.1186/s13244-020-00899-y

[15] Jarvinen, H., Seuri, R., Kortesniemi, M., Lajunen, A., Hallinen, E., Savikurki-Heikkila, P., *et al.* (2015) Indication-Based National Diagnostic Reference Levels for Paediatric CT: A New Approach with Proposed Values. *Radiat Prot Dosimetry*, **165**, 86-90. https://doi.org/10.1093/rpd/ncv044