Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/060301

Establishment of Computed Tomography Diagnostic Reference Levels on Paediatric Patients in Uganda

G. Ayugi [1,*], *B. Oruru* [1], *F. Kiragga* [2], *H. Kisembo* [3] *and H. Kyagulanyi* [1].

[1] Department of Physics, College of Natural Sciences, Makerere University, P. O. Box 7062, Kampala, Uganda.
[2] Department of Physics, Faculty of Science, Gulu University, P. O. Box 166, Laroo Division, Gulu Municipality, Uganda.

[3]Department of Radiology, Ministry of Health, Mulago National Referral and Teaching Hospital, P. O. Box 7051, Kampala, Uganda.

Received: 15 Jun .2021, Revised: 18 Jul .2021, Accepted: 14 Aug. 2021.
Published online: 1 Sep. 2021.

Abstract: Paediatric dosimetry in radiation protection when compared with adults is based on radiation sensitivity of children to radiation. Children are known to be at a higher risk of developing radiation-induced cancer. The aim of this study was to determine the radiation doses to paediatric patients during computed tomography procedures (CT) so that a diagnostic reference levels (DRLs) could be proposed. DRLs are useful in high dose examinations such as CT to achieve collective dose reduction. Information about patients, protocol and CT system for 684 patients were recorded during 2019 and 2020 from five CT scanners. The dose was determined in four age groups: 0-1 year, 1-5 years, 5-10 years, and 10-15 years for the head, chest and abdomen protocols. The 75th percentile of $CTDI_{vol}$ and DLP were considered as DRLs and compared with IAEC and Japan DRLs. CT dosimetry software Impact CT patient dosimetry calculator, version 1.0.4 with National Radiation Protection Board SR250 data set, was used to validate and compare scanner generated dose values. DRLs are proposed using $CTDI_{vol}$ (mGy) and DLP (mGy cm). The mean DRL of 43.6 and 922 for the head, 3.0 and 258 for the Chest and 3.1 and 292.5 for the abdomen were established during the study. There was high deviation in head CT doses compared to the reported DRLs in IAEC and Japan. The established DRLs for head were higher than those available in other countries. This study showed the need for harmonization of radiation dose optimization of this protocol.
Keywords: Computed tomography, Diagnostic reference levels, Peadiatric, Kampala.

1 Introduction

The use of computed tomography in medicine is now firmly established as an essential tool for diagnosis, and in many cases, it is a lifesaving resource used when rapid decisions are needed in case of emergency [1]. Normally, a patient undergoing CT examination would expect that the radiation dose impacted in different hospitals would be within a narrow range but a large number of surveys indicate that this is not the case [2]. It is increasingly being documented that patient doses are higher than necessary and the image quality in CT scans often exceed the level needed for confident diagnosis compared to other modalities such as Magnetic Resonance Imaging which uses non-ionising radiations [3]. Dose estimates in paediatric computed tomography (CT) have been an area of interest in recent years because of the increased awareness of the radiation risk associated with exposure from CT procedures in childhood [3,4,5]. The CT dose optimization for pediatric patients in most cases is more challenging than for adult because children are more radiosensitive to radiation [7], and they have longer lifetimes which allows potential radiation effects to manifest [8]. There are also large variations of body size and composition in terms of percentages of fat, muscle, and bone within each age group and across different groups [9,10,11]. Some clinical centers have applied age- and child-size–specific CT scan protocols, and their effect on dose reduction has been recognized [9,12,13].

In 1996, the International Commission on Radiological Protection [2] introduced Diagnostic Reference Levels (DRL) standardized at the 75th percentile of imaging examination doses. In 2001, it promoted the use of local DRL to achieve best practice and obtain optimum range of values for the specific medical imaging protocols so that the radiation doses to patients are as low as compatible with the clinical purpose and the ALARA (as low as reasonably achievable) principle.

The purpose of this study was to propose DRLs and estimate the effective doses to paediatric patients during head, chest, and abdominal CT scans for different age

*Corresponding author e-mail: gertrude.ayugi@mak.ac.ug

groups.

2 Methods and Materials

2.1 Data Collection

This study was performed during 2019-2020 at five hospitals in Uganda. These hospitals included Mulago National Referral Hospital (Kawempe), Mengo Hospital, Nile International Hospital, Uganda Cancer Institute, International Hospital Kampala, and International Medical Centre (Wandegeya). Data for 684 patients (410 were males while 274 were females) from five CT scanners were collected using the IAEA CT data collection tool form. The form requested for data that included the patient information: gender, age, height and weight; examination data: date, number of phases and scanning mode (axial or helical); exposure parameters: tube voltage, tube current, current – time product, rotation time and beam width; dose indexes recorded from the scanner console: weighted $CTDI_{weight}$ or volume $CTDI_{vol}$ for each sequence, and DLP for the whole examination.

Since paediatric patients do not differ much in weight but rather on age, the data was clustered in the age groups: 0-l years, 1-5 years, 5-10 years and 10-15 years, respectively. Three body parts were studied; head, chest and abdomen. Clinical indications were not specified in the study.

2.2 Selection of CT Scanners

Five scanners were used in this study, and all were multi slice with slices ranging from 16 to 64. They were all in position to display $CTDI_{vol}$ and the total DLP for a complete scan on the CT console. Table 1 shows the manufacturer, model and installation year. The scanners had undergone quality assurance in the last 12 months and all tested using free in air phantom measurements, and their output was still satisfactory.

Table 1: Percentages of solutions for sample preparation.

Center	Manufacturer	Model	Year of installation	Number of slices
A	Phillips	Brilliance 40	2011	16
B	Phillips	BigBore	2016	16
C	GE	Brightspeed	2013	16
D	Siemens	Somatom go.Now	2019	16
E	Siemens	Somatom	2019	64

Table 2: Patient dose during paediatric head CT. D_m is mean effective dose in mSv (**), DPL is in units of mGy cm (*).

Age	$CTDI_{vol}$ (mGy)	DLP (*)	D_m (**)	IAEA, 2010		IAEA, 2015		Japan, 2015	
				$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
0-l	40.9	829	7.93	25.1	486	25.8	439	38	500
1-5	43.1	908	5.40	38.3	584	36.1	536	47	660
5-10	42.7	953	3.07	55.6	738	43.3	692	60	850
10-15	47.5	997	2.69	59.7	987	53.0	835	-	-

Table 3: Patient dose during paediatric chest CT. D_m is mean effective dose in mSv (**), DPL is in units of mGy cm (*).

Age	$CTDI_{vol}$ (mGy)	DLP (*)	D_m (**)	IAEA, 2010		IAEA, 2015		Japan, 2015	
				$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
0-l	2.3	104	4.41	3.0	52	5.2	129	5.5	105
1-5	2.3	171	6.79	4.2	106	6.0	142	7.0	150
5-10	3.1	276	4.48	5.5	250	6.8	171	7.5	205
10-15	64.1	480	4.17	59.7	987	53.0	835	-	-

Table 4: Patient dose during paediatric abdominal CT. D_m is mean effective dose in mSv (**), DPL is in units of mGy cm (*).

Age	$CTDI_{vol}$ (mGy)	DLP (*)	D_m (**)	IAEA, 2010		IAEA, 2015		Japan, 2015	
				$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
0-l	2.8	243	6.95	3.4	130	5.2	129	5.5	220
1-5	2.3	171	10.67	4.3	190	7.0	245	8.0	200
5-10	3.1	276	8.89	7.3	315	7.8	308	8.5	265
10-15	4.1	480	6.29	7.1	402	9.8	456	-	-

The peadiatric head CT DRLs established in this study (Table 2) in terms of CTDI $_{vol}$ for head CT are similar to reference values from available reports, which vary between 25.1 and 40.9 mGy for the age group 0-1 year, between 36.1 and 47 mGy for 1-5 years, between 42.7 and 60 mGy for 5-10 years and between 42.7 and 53.0 mGy for 10-15 years [14, 15]. The established DLP values in this study almost doubled the values published. This could be attributed to the longer scan length, number of phases used and the use of non-optimized protocols.

The chest CT $CTDI_{vol}$ obtained in this study (Table 3) were greatly lower than those published in the studies by Vassileva *et al* and Galanski *et al* [16,17]. However, all the proposed DRLs for DLP in this study are higher than those in referred studies by [16,17]. This can be attributed to the use of longer scan ranges and the use adult protocols on peadriatrics, as well as the fact that some scans exceeded one sequence.

The $CTDI_{vol}$ obtained for the abdominal CT scan in this study (Table 4) had no much difference with those published in the studies by Vassileva *et al* and Galanski *et al* [16,17]. However, the DLP values nearly multiplied by a factor of 2. This can still be attributed to the longer scan ranges and more than one scan sequences in some of the abdomen examinations.

The mean effective dose value estimates from this study are slightly higher than the values reported in literatures [18] for all the different protocols. The reported average effective dose values for the head, chest and abdomen are 2, 7 and 8 mSv, respectively. The abdomen had the highest effective dose, because longer scan lengths is required to cover its volume.

4 Conclusions

The DRLs for CT examinations have been established for paediatric patients in Uganda. The DLP values per procedure for head CT were higher than those for chest and abdominal CT scans. The reasons for higher DRLs were due to longer scan lengths, higher mA and lower pitch values used. This shows a huge optimization potential among almost all the centers and standardization of practice is also lacking.

Acknowledgement

This project was supported by the Government of Uganda under the Makerere University Research and Innovation Fund (RIF).

References

[1]. W.E. Muhogora, N. A. Ahmed, A. Almosabihi, J. S. Alsuwaidi, A. Beganovic, O. Ciraj-Bjelac, F.K. Kabuya, A. Krisanachinda, M. Milakovic, G. Mukwada, and M. J. Ramanandraibe, Patient doses in radiographic examinations in 12 countries in Asia, Africa, and Eastern Europe: initial results from IAEA projects. Am. J. Roentgenol., **190(6)**, 1453-1461, 2008.

[2]. International Commission on Radiological Protection (ICRP). Radiological protection and safety in medicine: ICRP publication 73. Ann ICRP., **26**, 23-24, 1996.

[3]. G. I. Ogbole Radiation dose in paediatric computed tomography: risks and benefits, Ann. Ib. Postgrad. Med., **8(2)**, 118-126, 2010.

[4]. M. S Pearce, J. A. Salotti, M. P. Little, K. McHugh, C. Lee, K. P. Kim, Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. The Lancet., **380(9840)**, 499-505, 2012.

[5]. J. D. Mathews, A. V. Forsythe, Z. Brady, M. W. Butler, S. K. Goergen, G. B. Byrnes, et al, Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. Bmj., **346**, 2360, 2013.

[6]. D. L. Miglioretti, E. Johnson, A.Williams, R. T Greenlee, S. Weinmann, L. I. Solberg, et al, The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. JAMA pediatrics., **167(8)**, 700-707, 2013.

[7]. S. T. Feng, M. W. Law, & B. Huang, et al, Radiation dose and cancer risk from pediatric CT examinations on 64-slice CT: a phantom study, Eur. J. Radiol., **76(2)**, 19-23, 2010.

[8]. J. D. Mathews, A. V. Forsythe, & Z. Brady, et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. Bmj., **346**, 1-8, 2013.

[9]. K. L. Hopkins, D. R. Pettersson, & C. W. Koudelka, et al, Size-appropriate radiation doses in pediatric body CT: a study

of regional community adoption in the United States, Pediatr. Radiol., **43(9)**, 1128–1135, 2013.
[10]. J. Reid, J. Gamberoni, F. Dong, and W. Davros, Optimization of kVp and mAs for pediatric low-dose simulated abdominal CT: is it best to base parameter selection on object circumference? Am. J. Roentgenol., **195(4)**, 1015-1020, 2010.
[11]. F. Dong, W. Davros, J. Pozzuto, & J. Reid, Optimization of kilo voltage and tube current-exposure time product based on abdominal circumference: an oval phantom study for pediatric abdominal CT. Am. J. Roentgenol., **199(3)**, 670-676, 2012.
[12]. D. J. Watson, and K. S. Coakley, Paediatric CT reference doses based on weight and CT dosimetry phantom size: local experience using a 64-slice CT scanner. Pediat. Radiol., **40(5)**, 693-703, 2010.
[13]. S. Singh, M. K. Kalra, and M. A. Moore, et al, Dose reduction and compliance with pediatric CT protocols adapted to patient size, clinical indication, and number of prior studies. Radiology., **252(1)**, 200-208, 2009.
[14]. Y. Yonekura, Diagnostic reference levels based on latest surveys in Japan–Japan DRLs 2015, Japanese network for research and information on medical exposure. Medical exposure research information network, 2019.
[15]. J. Vassileva, M. M. Rehani, K. Applegate, N. A. Ahmed, H. Al-Dhuhli, and H. M. Al-Naemi, IAEA survey of paediatric computed tomography practice in 40 countries in Asia, Europe, Latin America and Africa: procedures and protocols. Eur. Radiol., **23(3)**, 623-631, 2013.
[16]. J. Vassileva, M. Rehani, D. Kostova-Lefterova, H. M. Al-Naemi, J. S. Al Suwaidi, D. Arandjic, E. H. O. Bashier, S. Kodlulovich Renha, L. El-Nachef, J. Aguilar, et al., A study to establish international diagnostic reference levels for paediatric computed tomography, Radiat. Prot. Dosimetry., **165(1-4)**, 70-80, 2015.
[17]. M. Galanski, H. Nagel, and G. Stamm, Paediatric CT exposure practice in the federal republic of Germany. Results of a nation-wide survey in 2005, 2006.
[18]. F.A. Mettler, W. Huda, T. Yoshizumi, M. Mahesh Effective doses in Radiology and Diagnostic Nuclear Medicine: A catalog. Radiologic Society of North America (RSNA), Radiology., **248(1)**, 254-263, 2008.