DOSIMETRIC ASSESSMENT OF PEDIATRIC BRAIN CT-SCAN PERFORMED IN TOGO

K. ADAMBOUNOU[*,**#], *K. AMOUSSOU*[**], *K. KATASSOU*[**], *A.M.Y. ADIGO*[**,***], *K.D. BAKPATINA-BATAKO*[*], *L. SONHAYE*[**], *K. ADJENOU*[**]

[*]Biophysic and Medical Imaging Departments, Campus Teaching Hospital, University of Lome, Togo, [#]e-mail: kadambounou@yahoo.fr
[**]Radiology Department, Campus Teaching Hospital, University of Lome, Togo
[***]Radiology Department, North Ardennes Intercommunal Hospital, Charleville-Mezieres, France

Abstract. The computed tomography (CT) is a fast, non-invasive, accessible, but highly radiating, sectional medical imaging modality. The purpose of this study is to assess the dosimetric values of the pediatric brain CT-scans to establish pediatric CT-scan diagnostic reference level (*DRL*) in Togo. It was a cross-sectional study carried out from 6 March to 30 July 2016 in all health facilities with a functional computed tomography unit in Togo. The mean age of the 157 children included was 5.3 years with extremes of one day and 14 years. The sex ratio was 1.5. The devices were 6 and 16 detector rows, and more than 9/10 of the pediatric exams were performed in helical mode with a number of scans varying from 1 to 3 depending on the centers. The kilovoltages used in children were almost identical to those used in adults. The average scan length increased with the age of the children from 16.13 to 18.38 cm. For scans without contrast agent, the pediatric cerebral *DRL* was 626.03 mGy·cm (less than one year), 898.53 mGy·cm (1–4 years), 933 mGy·cm (5–9 years) and 999 mGy·cm (10–14 years). For scans without and with contrast agent, it was 1589.27 mGy·cm (less than one year), 1834 mGy·cm (1–4 years), 1866 mGy·cm (5–9 years) and 1922 mGy·cm (10–14 years). The average effective doses associated with the different types of exams ranged from 1 to 3.28 mSv. There is a high dispersion of dose delivered during pediatric brain CT-scans in Togo requiring a process of homogenization of procedures and dose optimization strategies from thus established *DRL*.

Key words: Dosimetry, diagnostic reference level, CT-scan, child, Togo.

INTRODUCTION

The scanner or computed tomography (CT) is a fast, non-invasive, accessible, but highly radiating, sectional medical imaging modality [9]. Despite a relatively low demand frequency compared to radiography, CT-scan takes a large proportion of the total collective dose that issues from radiological examinations. Indeed, CT-scan was

Received: July 2021;
in final form September 2021

ROMANIAN J. BIOPHYS., Vol. 32, No. 1, P. 33–44, BUCHAREST, 2022

responsible for about 68 % of the total collective dose in the United Kingdom [10] and accounted for about 50 % of diagnostic medical irradiations in the general population in Canada [15]. The brain CT-scan is most often performed as a first line in the exploration of cranio-encephalic pathologies of both adults and children [1, 9], and in Togo, it is the most performed pediatric CT-scan. The undeniable diagnostic contribution of computed tomography, however, should not make us forget the risks of deleterious biological effects that its realization entails children in particular. Due to the high activity of the growing cells, a child is a very radiosensitive being. Hence, it is needed to respect the fundamental principles of radiation protection, in particular those of justification and optimization, in order to limit or reduce the risk of possible deterministic and stochastic pathological effects of ionizing radiation emitted during CT-scans [8]. For a better implementation of the principle of optimization, the learned societies recommend the establishment, updating and regular consultation of the Diagnostic Reference Levels in order to carry out examinations providing less dose. These diagnostic reference levels are dosimetric indicators below which examinations are considered to be performed in radiation protection standards [5]. Unfortunately, no dosimetric study of pediatric CT-scans at the national level to allow the establishment of diagnostic CT diagnostic reference levels, especially pediatric, is yet carried out in our country Togo. We have therefore undertaken this work, which general objective was to assess the dosimetric quantities of pediatric brain CT-scans performed in all CT units in Togo.

MATERIALS AND METHODS

The present work is a descriptive cross-sectional study carried out over a period of five months, from 6th of March to 30th of July 2016, in four health facilities with a functional CT unit during the study period.

This study included the subjects under 15 years of age who received a brain scan in that period.

For the sake of confidentiality, the data collected, the centers included (2 private and 2 public) will be called from C1 to C4. The survey sheet, developed according to the literature, was structured around the following parameters: the age of the children, the brand and characteristics of the CT machines, voltage, charge, number and the height of acquisition, dose report, volume computed tomography dose index (*CTDI*), dose-length product (*DLP*) by acquisition and by complete exam. A minimum of 30 examinations were required in each center included in this study.

The data were analyzed and processed with Epi Info version 7.1.3.3 and SPSS. Figures and tables were generated by Microsoft Excel 2010.

Data collections were made with the informed consent of the parents, guardians and accompanying persons of the children.

RESULTS

The sample consisted of 157 children, of whom 95 were male (60.5 %) and 62 were female (39.5 %), for a sex ratio of 1.5. Their ages ranged from one day to 14 years with an average of 5.1 years. The 5–9 years age group was the most represented (Table 1).

Table 1

Distribution of children in each center by age group

	C1		C2		C3		C4		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
< 1 year	12	30.0	10	25.6	12	30.0	5	13.2	39	24.8
1–4 years	13	32.5	8	20.5	11	27.5	6	15.8	38	24.2
5–9 years	8	20.0	13	33.3	12	30.0	10	26.3	43	27.4
10–14 years	7	17.5	8	20.5	5	12.5	17	44.7	37	23.6
Total	**40**	**100**	**39**	**100**	**40**	**100**	**38**	**100**	**157**	**100**

The examinations were performed in sequential mode on 12 children, or 7.6 %, and in helical mode in the remaining 92.4 %.

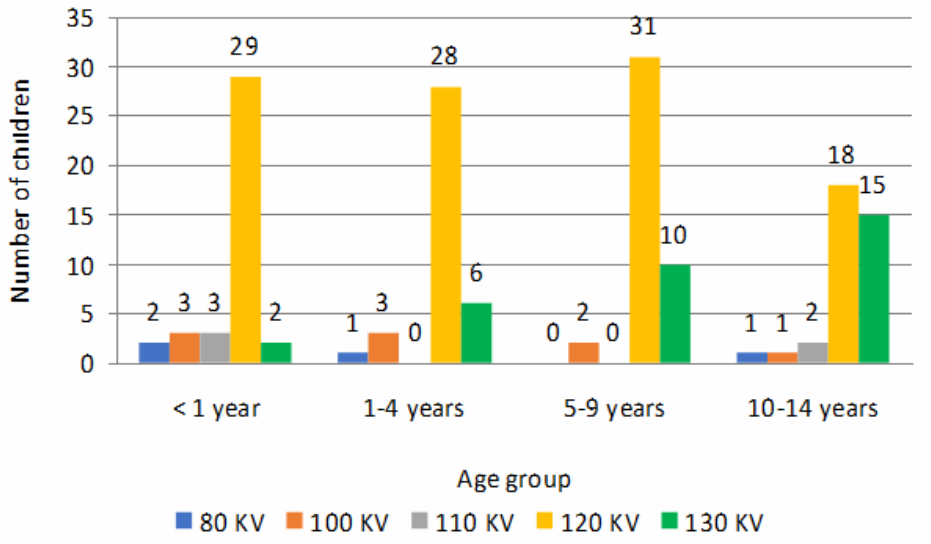

Fig. 1. Distribution of the voltage value (kV) used according to the age group of the children.

The technical parameters used during the examination varied with the age of the children, but the majority of the voltages (kilo-voltages) were almost identical to those of the adults [1] (Figure 1). Charges (mAs) were in modulation mode in 75 % of the centers (Table 2).

Table 2

Distribution of other acquisition parameters by center

	Tension (kV)	Charge (mAs)	Section thickness (mm)	Rotation time (s)	Pitch
C1	80–120	Mod	2.5–5	0.8–2	0.938
C2	120	Mod	1.25	0.8	1.375
C3	120	Mod	1.25	0.8	0.562
C4	110–130	120–165	1.25	1	0.65

The number of acquisitions varied from 1 to 3 according to the different centers (Table 3).

Table 3

Distribution of the number of acquisitions by children age group

	Number of acquisitions						Total	
	1		2		3			
	n	%	*n*	%	*n*	%	*n*	%
< 1 year	29	74.4	9	23.1	1	2.6	39	100
1–4 years	27	71.1	10	26.3	1	2.6	38	100
5–9 years	26	60.5	17	39.5	0	0.0	43	100
10–14 years	23	62.2	14	37.8	0	0.0	37	100
Total	**105**	**66.9**	**50**	**31.8**	**2**	**1.3**	**157**	**100**

The average length of acquisition increased with the age of the children with a maximum of 26 cm and a minimum of 11.5 cm (Table 4).

Table 4

Distribution of CT-scan acquisitions length (cm) by children age group

	Minimum	Maximum	Average	Standard deviation
< 1 year	11.50	20.63	16.13	2.61
1–4 years	13.50	24.37	17.67	3.04
5–9 years	14.25	25.38	18.08	3.12
10–14 years	15.50	26.00	18.38	3.58

The volume computed tomography dose index (*CTDI*) was increasing with age, and the 75th percentile *CTDI* at C1 was low in those under one year of age compared to other centers (Table 5).

The values of the mean and 75th percentile *DLP* per acquisition increased with the age of the children for both non-injected series (Figs 2, 3, 4, and 5) and injected series (Figs. 6, 7, 8, and 9).

Table 5

Distribution of the *CTDI* (mGy) by children age group

	C1		C2		C3		C4		Total	
	Average	75th centile	Average	75th centile	Average	75th centile	Average	75th centile	Average	75th centile
<1 year	21.36	24.58	22.88	27.04	34.85	37.43	33.27	45.53	27.43	33.35
1–4 years	30.25	30.97	25.59	30.44	37.18	39.65	45.53	45.53	33.69	39.82
5–9 years	34.90	37.84	31.20	35.20	44.81	50.41	45.53	45.53	39.02	45.53
10–14 years	40.39	48.86	34.09	35.36	47.96	52.18	42.86	45.53	41.18	45.53

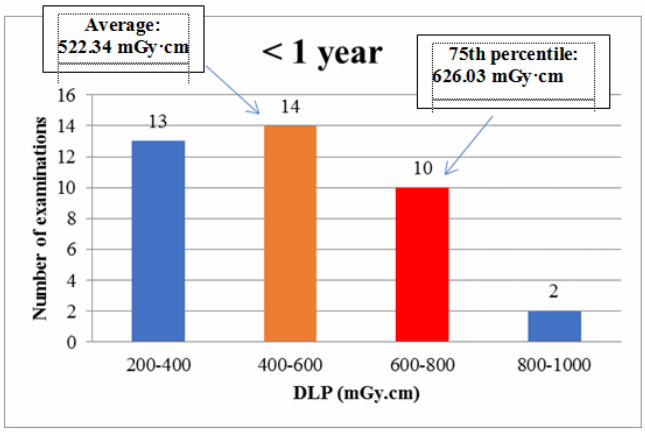

Fig. 2. *DLP* variation of CT without injection in children of less than 1 year of age.

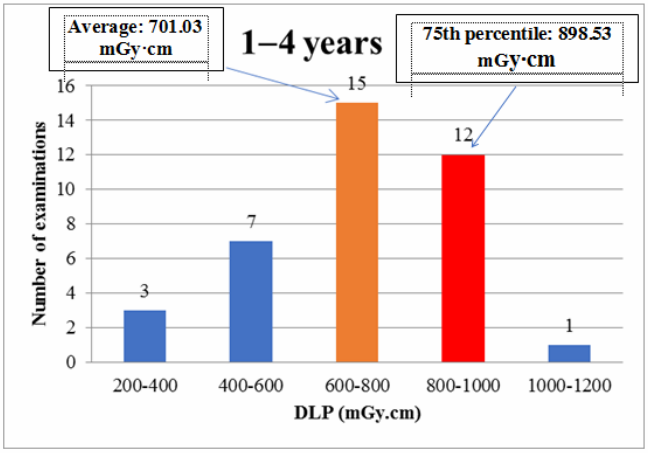

Fig. 3. *DLP* variation of CT without injection in children of 1–4 years of age.

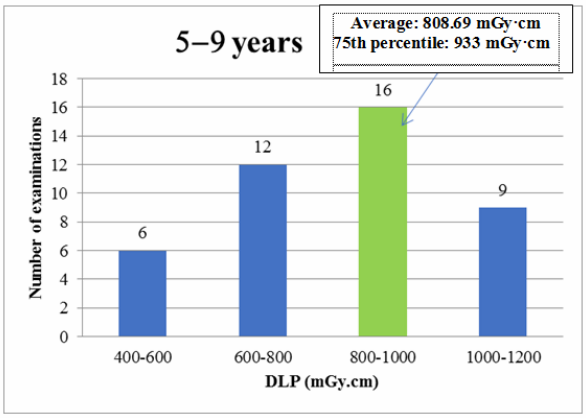

Fig. 4. *DLP* variation of CT without injection in children of 5–9 years of age.

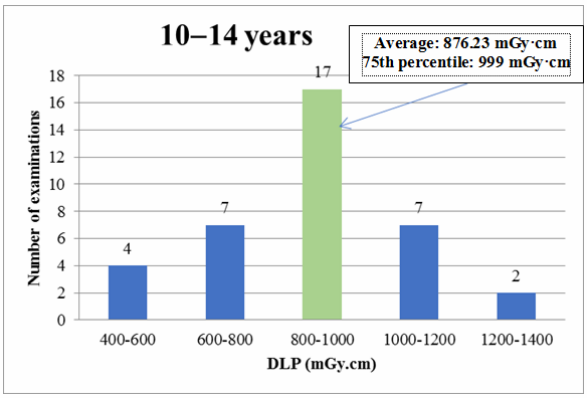

Fig. 5. *DLP* variation of CT without injection in children of 10–14 years of age.

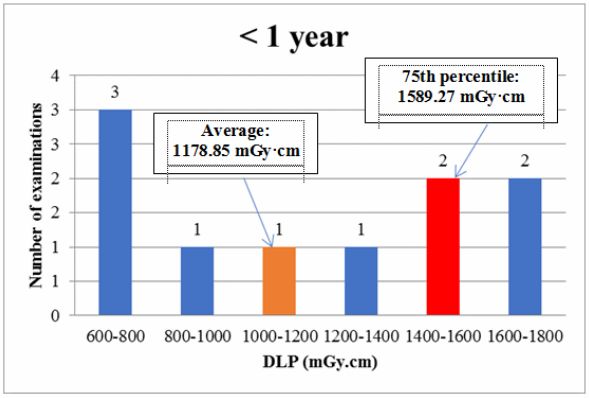

Fig. 6. *DLP* variation in CT injected series in children of less than one year of age.

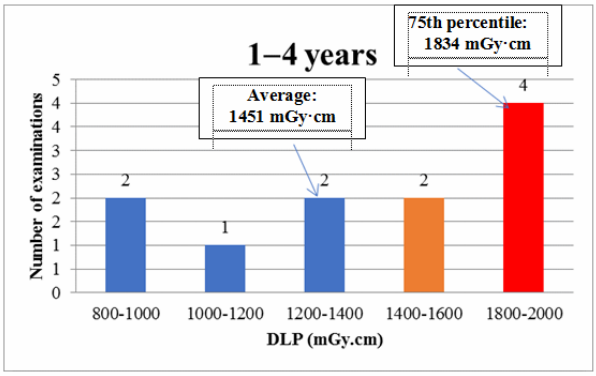

Fig. 7. *DLP* variation in CT injected series in children of 1–4 years of age.

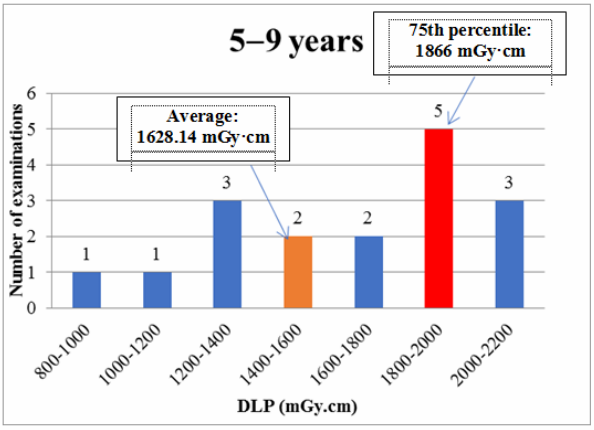

Fig. 8. *DLP* variation in CT injected series in children of 5–9 years of age.

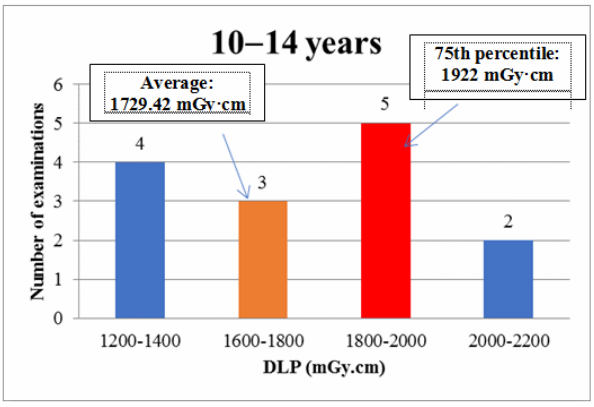

Fig. 9. *DLP* variation in CT injected series in children of 10–14 years of age.

The *DRL* for pediatric brain CT-scan without injection were therefore 626.03 mGy·cm (less than one year), 898.53 mGy·cm (1–4) years, 933 mGy·cm (5–9) years and 999 mGy·cm (10–14) years. For acquisitions without and with contrast agent, the *DRL* were 1589.27 mGy·cm (less than one year), 1834 mGy·cm (1–4) years, 1866 mGy·cm (5–9) years and 1922 mGy·cm (10–14) years.

The average effective dose changed significantly based on the average *DRL* value and the number of acquisitions with values between 1 mSv and 3.28 mSv (Table 6).

Table 6

Variation in average effective doses for different *DLP* by children age groups

	Average *DLP* (mGy·cm)	Effective dose (mSv) according to CIPR 103
< 1 year	522.34	0.99
<1 year	1178.85	2.23
1–4 year	701.03	1.33
1–4 years*	1451	2.75
5–9 years	808.69	1.53
5–9 years*	1628.14	3.09
10–14 years	876.23	1.66
10–14 years*	1729.42	3.28

*Examination with 2 acquisitions according to the age.

DISCUSSION

The analyzed data were collected in 4 health facilities with a minimum of 30 examinations per center. Moifo *et al*. [13], in a dose quantification study to establish the diagnostic reference level in Cameroon had selected 15 to 30 examinations per health facility. The minimum number of examinations per center of our work is in line with the recommendations of the Institut de Radioprotection de Sureté Nucléaire (IRSN) of the Société Française de Radiologie (SFR) according to whom a valid statistical study of dosimetric data must include at least 30 studies per type of examinations and per hospital [11].

The sex ratio of children in this study, marked by a high proportion of boys, was already reported in a previous study we carried out on the profile of pediatric CT-scans performed in Togo in 2012 [2]. The 5–9 age group was the most represented while it was less represented in Canada [3]. This can be explained by the fact that in Canada, in younger children, MRI (a non-irradiant technique) more accessible compared to Togo, is privileged as far as possible to the CT-scan which is the most irradiant medical imaging technique [7].

The exposure parameters including voltage used in this study were insufficiently reduced and therefore almost identical to those of adults. Thus, more

than 80 % of the brain CT-scans in our sample were performed with a voltage greater than 120 kV whereas in France, nearly 97 % of pediatric CT were performed at less than 120 kV. This situation that is likely related to the lack of integration of pediatric protocol in CT practices in Togo, calls for an upgrade of radiological practices in Togo through regular continuous training in radiation protection for CT test performers in Togo.

Sequential mode was only performed in 7.6 % of the children in this study, while Ongolo-Zongo had 21 % of scanners with sequential mode in 2012 in Cameroon [14]. The quantification of dose delivered to patients during CT-scans generally requires the measurement of two specific dosimetric quantities: *CTDI* and *DLP*. *CTDI*, which represents the dose delivered to the patient during an acquisition, was increasing in our study with the age of the children. This increase of *CTDI* is partly related to the attenuation profile of the cranio-encephalic structures of the growing child.

The 75th percentile *CTDI* values in C4 were almost constant no matter the age group and were higher than the other centers for the first two age groups. This was due to the exclusive use of the adult brain protocol in children in this center where the voltage and tube charge were fixed (130 kV and 165 mAs). The relative low value of the *CTDI* of the other centers was therefore the consequence of the modulation of the tube charge (mAs) according to the thickness of the anatomical area to be explored despite that sometimes a high voltage (120 kV) is used.

Comparing the 75th percentile *CTDI* values with those of other countries (Table 7), showed that the values of the first two age groups in Togo were identical to those of Switzerland and significantly higher than those of Kenya and Australia. *CTDI* at the 75th percentile of the 10–14 years age range in our series was lower than in France and Switzerland.

Table 7

Comparison of the 75th percentile of the pediatric brain CT-scan *CTDI* (mGy) of different countries

	Our study	France [17]	Australia [4]	Switzerland [12]	Kenya [16]
< 1 year	33.35	–	30	33	30
1–4 years	39.82	30	30	40	31
5–9 years	45.53	40	35	50	32
10–14 years	45.53	50	35	50	–

The *DLP* is calculated based on the *CTDI* and acquisition length. For the same anatomical scanned area, the *DLP* value depended on the length or number of acquisitions.

We adopt as *DRL* the value of the 75th percentile of doses measured for a given procedure, on a large number of patients distributed in a large number of centers, representative of the radiological practice of a country. The *DRL* is therefore not an average but, for each practice, a value below which are 75 % of the examinations performed with low doses. This means that the 25 % of exams corresponding to the highest doses are not optimized.

The *DRL* of this work, based on *DLP*, were compared with those of other countries and it was found that the pediatric brain *DRL* of Togo in the different age groups was higher than those of the other countries (Table 8). This situation is the consequence of a high length of acquisition in some children. It is also the consequence of the application of the adult brain protocol to pediatric cases, and especially the lack of a dose optimization program in the different centers. It is important to remember that for this type of examination, acquisition length has a very strong influence on young children. The average acquisition length of our series was higher than those found in the works of Brisse *et al*., in France [6] and Vawda *et al*. [16] (Table 9). The manipulators should therefore reduce the acquisition fields of brain CT scans in the radiology departments of Togo.

Table 8

Confrontation of *DRL* (75th percentile of *DLP*) of Togo with other countries

	Our study	Canada [3]	France [6]	Switzerland [12]	Kenya [16]
< 1 year	626.03	632	–	390	488
1–4 years	898.53	632	420	520	508
5–9 years	933.00	817	600	710	563
10–14 years	999.00	1053	900	920	–

Table 9

Confrontation of the acquisition average length of our serry with others

	Our study	H. Brisse [6]	Z. Vawda [16]
< 1 year	16.13	–	–
1–4 years	17.67	14	16.6
5–9 years	18.08	15	17.8
10–14 years	18.38	18	–

The effective dose, expressed in millisieverts (mSv), is an indicator of the risk of health harm from individual exposure to ionizing radiation. The average effective dose of brain CT-scan in this study was age-dependent. It was approximately 1 mSv in those under one year of age and reached 1.66 mSv in 10–14 years of age for head exposure in examinations with only one acquisition.

For exams with at least 2 acquisitions, this dose reached 3.28 mSv in older children. The effective dose of our series increased significantly with the *DLP*

value by age and number of acquisitions. However, these relatively high effective dose values are not as alarming as they are below the 200 mSv threshold for deterministic effects. But the risk of stochastic effects in children irradiated during brain CT-scans in this study must lead the Togolese health authorities and the medical irradiating examinations performers to make efforts to ensure that doses delivered not only during CT scans but also in all irradiant examinations in Togo are as low as reasonably possible.

In this perspective, the *DRL*s established at the end of this pilot study must therefore be evaluated periodically in Togo and the CT-scans devices must also be subject to regular quality control for continuous optimization of the doses delivered to patients in the country.

CONCLUSIONS

The doses of X-rays delivered to children during brain CT-scans in Togo were variable according to the health facilities and according to the age of the children. The *DRL* of pediatric brain CT-scans established at the end of this study were high in Togo compared to several countries, particularly western countries. However, the calculated average effective doses were well below the threshold for deterministic effects. A process of homogenization of pediatric CT-scan delivery protocols, regular quality control of CT-scans devices and a dose optimization strategy are required in the pediatric CT-scan delivery units in Togo to minimize the risk of stochastic effects related to CT-scans.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: K.A. put the idea and the design of the study. K.A., K.K., A.M.Y.A. data collection and have contributed to the conception and design of the manuscript. L.S., K.D.B., K.A. had contributed to the conception and design of the manuscript. All authors have been involved in drafting and revising the manuscript. All authors read and approved the final manuscript.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. ADAMBOUNOU, K., K. KATASSOU, A.M.Y. ADIGO, L. SONHAYE, K. ADJENOU, Dosimetric evaluation of adult CT scans in Togo, *Romanian J. Biophys*, 2021, **31**(4), 199–213.
2. ADAMBOUNOU, K., K. LAWSON-EVI, N. GNAKADJA, R. ASSOUMA, P. GBANDE, A.M.Y. ADIGO, Imagerie tomodensitométrique dans la prise en charge médicale des enfants au Togo: Profils et conditions techniques de réalisation, *J. Rech. Sci. Univ. Lomé* (Togo), 2015, **17**(1), 251–258.

3. APIBQ, Etude des doses en tomodensitométrie (CT Scan), https://www.otimroepmq.ca/wp-content/uploads/2015/05/etude-des-doses-en-tomodensitometrie_consignes_2008.pdf, 2008, accessed 25 October 2016.
4. ARPANSA, National Diagnostic Reference Level Fact Sheet, https://www.arpansa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service, accessed 10 October 2019.
5. BEAUVAIS-MARCH, H., M. VALERO, A. BIAU, M. BOURGUIGNON, Niveaux de référence diagnostiques : spécificités de la démarche française en radiologie, *Radioprotection*, 2003, **38**(2), 187–200.
6. BRISSE, H., S. NEUENSCHWANDER, *Optimisation de la dose au CT-scanner pédiatrique*, Institut Curie, Paris, 2002.
7. CHAUMOITRE, K., C. BOYER, Radiopédiatrie, *J. Rad*., 2002, **88**(7–8), 930–932.
8. CORDOLIANI, Y.S., H. FOEHRENBACH, *Radioprotection en milieu médical, principe et mise en pratique*, 2nd edition, Masson, Paris, 2008.
9. DILLENSEGER, J.P., E. MOERSCHEL, *Guide des technologies de l'imagerie médicale et de la radiothérapie*, Elsevier Masson, 2009.
10. HART, D, B.F. WALL, M.C. HILLIER, P.C. SHRIMPTON, Frequency and collective dose for medical and dental X-ray examinations in the UK, 2008, *Report HPA-CRCE-012*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/340154/HPA-CRCE-012_for_website.pdf, accessed 25 October 2016.
11. LECLET, H., M. MADOU, *Guide pratique de radioprotection en radiologie médicale*, Sauramps médical, 2012.
12. MARCONATO, M., Niveau de référence diagnostic (NRD) en Suisse, 2009, https://www.irsn.fr/FR/professionnels_sante/documentation/Documents/niveaux_reference_diagnostic_en_Suisse.pdf, accessed 23 Fevrier 2018.
13. MOIFO, B., J.R.M. TAPOUH, M.N. GUENA, T.N. NDAH, R.N. SAMBA, A. SIMO, Diagnostic reference levels of adults CT-scan imaging in Cameroon: A pilot study of four commonest CT-protocols in five radiology departments, *Open J. Med. Imaging*, 2017, **7**(1), 1–8.
14. ONGOLO-ZOGO, P., C. MPEKE MOKUBANGELE, B. MOIFO, F. GONSU, Evaluating pediatric patient dose during computed tomography in two university teaching hospitals in Yaoundé – Cameroun, *Radioprotection*, 2012, **47**(4), 533–542.
15. SOTO, J.A., *Emergency Radiology. An Issue of Radiologic Clinics of North America*, E-Book. Elsevier Health Sciences, 2012.
16. VAWDA, Z., R. PITCHER, J. AKUDUGU, W. GROENEWALD, Diagnostic reference levels for paediatric computed tomography, *S. Afr. J. Rad*., 2015, **19**(2), a846, https://doi.org/10.4102/sajr.v19i2.846.
17. ***Arreté du 24 0ctobre 2011 relatif aux niveaux de référence diagnostiques en radiologie et en médecine nucléaire, *IRSN,* 2011, www.nrd.irsnfr/présentations/Documents/arreté_NRD_2011-pdf, accessed 10 October 2016.