Scientific Research Publishing

World Journal of Nuclear Science and Technology, 2025, 15(1), 45-52
https://www.scirp.org/journal/wjnst
ISSN Online: 2161-6809
ISSN Print: 2161-6795

Establishment of Diagnostic Reference Levels for Childhood Head CT in the District of Abidjan in Côte d'Ivoire

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How to cite this paper: Anouan, K.J., Kabas, R.-M., Kouao, J.-P. and Diabaté, A.S. (2025) Establishment of Diagnostic Reference Levels for Childhood Head CT in the District of Abidjan in Côte d'Ivoire. *World Journal of Nuclear Science and Technology*, **15**, 45-52.
https://doi.org/10.4236/wjnst.2025.151004

Received: December 31, 2024
Accepted: January 7, 2025
Published: January 10, 2025

Abstract

Computed tomography is an indispensable X-ray imaging modality used to diagnose numerous pathologies, but it can also involve the delivery of high ionizing radiation doses harmful to the health of patients. This study aims to survey the level of radiation doses delivered to child patients during head exams in CT imaging to set up the Dosimetric Reference Levels (DRLs), a routine dose optimization tool, based on data acquired at the University Hospital of Angré (UHA), the University Hospital of Treichville (UHT) and the Polyclinic Hospital Farah (Farah) for optimizing procedures in Ivorian hospitals. Prospectively performed on 334 CT images of 186 child patients, this study was carried out on CT systems such as Hitachi Scenaria, Sinovision Insitum, and Philips Incisive used respectively at UHA, UHT and Farah. Children's scan data were classified into four age bands: <1.5 years, 1.5 - 5.5 years, 5.5 - 10.5 years, and 10.5 - 16 years. Each yielded dose index (volume CT dose index as $CTDI_{vol}$ or dose-length product as DLP) value, whatever the hospital, increases with respect to the age of child patients. Based on the 75th percentile of the whole dose distributions, the DRLs of the $CTDI_{vol}$ is 54.37 mGy whatever the age groups and those of the DLP with respect to age bands are 1224.55 mGy·cm, 1414.06 mGy·cm, 1632.24 mGy.cm and 1544.57 mGy·cm, respectively. The averaged values of $CTDI_{vol}$ and DLP smaller than the corresponding DRLs values suggest that practices in our three facilities are optimized. However, comparing our results with those from different international studies, we see that the $CTDI_{vol}$ and DLP values obtained in the present work are higher. These results suggest additional surveys to ensure our DRLs values and efforts from radiologists, imaging technicians and medical physicists to strengthen clinical procedures for the radiation protection of children undergoing CT scans in Côte d'Ivoire.

Keywords

Computed Tomography, Childhood Head Imaging, Radiation Protection, Diagnostic Reference Levels

1. Introduction

Patients, children or adults need to be protected from the harmful effects of ionizing radiations, particularly those due to X-ray from computed tomography (CT), the imaging device which contributes the most to patient irradiation in medical X-ray imaging [1]. The Diagnostic Reference Levels (DRLs) concept is internationally recognized as an important tool for optimizing patient doses in radiology, particularly for child patients exposed to greater risk due to their body tissues growing so that they are highly sensitive to ionizing radiations [2]. DRLs are tools for checking unoptimized radiation protection procedures in a country's radiology departments. In this context, various studies on DRLs have been led in Côte d'Ivoire since 2009, mainly in conventional radiology based on technical cooperation with the International Atomic Energy Agency (IAEA) for controlling medical exposure and strengthening the radiological protection of patients [3]. The first study on DRLs for adult head CT procedures was performed by Monnehan *et al.* [4], followed by a survey on local DRLs for children's head CT procedures led by Anouan *et al.* on a single hospital site [5]. To aim for the improvement of clinical guidelines on radiation protection in Côte d'Ivoire, we did the present work, which is the extension of the previous study performed on radiation dose from a CT scan of a childhood's head [5]. So, we surveyed, in the same context, two supplement hospitals in the district of Abidjan in order to get local DRLs set as LDRLs for volume CT dose index ($CTDI_{vol}$) and the Dose Length Product (DLP). LDRLs are values to keep radiation doses as low as reasonably achievable in radiodiagnosis and medical imaging departments, where the exceedance of these values will involve optimization actions such as X-ray imaging devices, including CT, quality control, and revision of linked clinical protocols.

2. Materials and Methods

This study was performed prospectively from November 2023 to November 2024, including three hospitals in the District of Abidjan: the University Hospital of Angré (UHA), the Université Hospital of Treichville (UHT) and the Polyclinic Hospital Farah (Farah). A total of 186 child patients aged under 16 underwent head CT-scan in each of these hospitals for an amount of 334 CT acquisitions. The CT systems used in this study are Hitachi Scenaria 64 bars, Sinovision Insitum 64 bars and Philips Incisive 128 bars respectively for UHA, UHT and Farah. For each CT scanner, the kilovoltage (kV) used ranged from 80 kV to 120 kV and the screened charge (mAs) varied from 75 mAs to 400 mAs. For the purpose of reproducibility and comparability, some details regarding CT imaging parameters that may influence radiation dose are given in **Table 1**. After having checked for the calibration of each system in collaboration with the biomedical engineers from these CT-systems manufacturing companies or with those from private companies providing subcontracting for external maintenance, we began our survey.

Table 1. Parameters of CT devices used in this study that may influence radiation dose.

Parameters	CT Hitachi Scenaria (UHA)	CT Sinovision Insitum (UHT)	CT Philips Incisive (Farah)
Slice thickness	5 mm	5 mm	2 mm
Pitch	0.6	0.5	0.4
Reconstruction algorithm	Iterative Reconstruction algorithm	Iterative Reconstruction algorithm	Iterative Reconstruction algorithm

Set as the 75th percentile of dosimetric quantities distribution such as $CTDI_{vol}$ or DLP, the DRLs is an arbitrary concept [6]. It involves that 25% of the remaining highest dose corresponds to unoptimized conditions for obtaining CT images. In this context, quality control of the CT equipment and revision of the clinical protocols are required in order to find the reason for this unoptimized situation. LDRLs are also defined in childhood CT imaging based on age intervals [7] [8].

To identify how the 75th percentile of dose distribution varies with age bands in pediatric CT imaging, as Wagner *et al.* [7], we grouped and analyzed $CTDI_{vol}$ or DLP data with respect to children's age classification for the aim of comparison with other studies internationally published. Child patients in CT imaging are rare, and it was therefore challenging to get large data in each age interval for this study. To ensure our sample is representative of our findings from our diagnosis and medical imaging departments, we used in this study sample sizes able to take into account dose variation through an age band. The age groups such as: <1.5 years, 1.5 - 5.5 years, 5.5 - 10.5 years, and 10.5 - 16 years were used for stratification of dose data [7]. To obtain $CTDI_{vol}$, DLP and other CT parameters such as kVp and mAs, we displayed the values of these parameters on each CT-scanner console of our three facilities, for the scan acquisition of each patient who underwent this imaging examen after an explicit prescription from a medical doctor. Each CT-scan was evaluated separately even if a patient underwent more than one CT-scan because the $CTDI_{vol}$ is a parameter different from one scan to another and a scan sequence varies with the current modulation capability which equipped each CT-scanner of our three imaging facilities [6].

3. Results

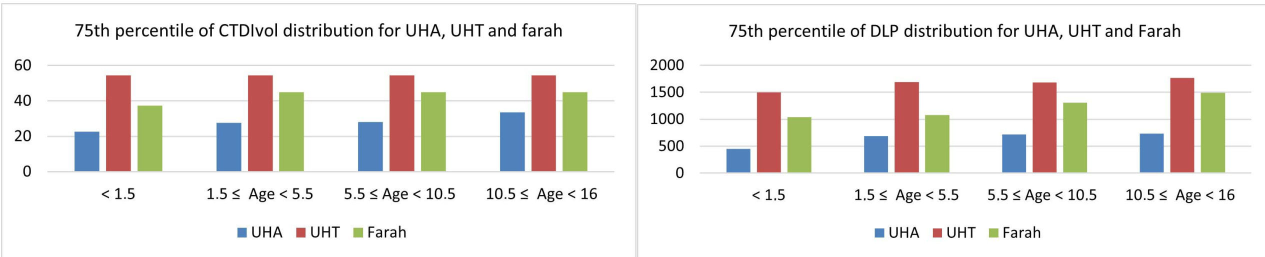
A total of 334 CT-scans from 186 child patients with ages varying from 0 up to 16 and including 61.3% of males and 38.7% of females were analyzed. The main medical indications for which these patients underwent CT examinations are as follows: cranial trauma without contrast materials, and conscience disorder, hemiplegia, feverish hydrocephalus, macrocrania, chronic headaches with contrast materials. So as Wagner *et al.*, we pooled CT scans with and without contrast materials because the number of CT acquisitions without contrast materials was very low for a good determination of the 75th percentile for the distribution of dosimetric index such as $CTDI_{vol}$ or DLP varying with age bands [7]. As expected, $CTDI_{vol}$ and DLP values increase with age. The numeric values of DRLs for children with age < 1.5 years are 9.3 mGy, 54.37 mGy and 19.69 mGy respectively for diagnosis and medical imaging departments of UHA, UHT and Farah. The same trend is observed for the corresponding DLP values for these three medical centers. Considering children with age > 10.5 years, the DRLs as DLP are 736.8 mGy·cm, 1768.3 mGy·cm and 1488.6 mGy·cm respectively for UHA, UHT and Farah. This is also the same trend for the corresponding values of DRLs, regardless of the age band. All these data are summarized in Table 2.

Table 2. Statistics of child patient data with the corresponding DRLs.

	Age [years]	Dose quantity	Min	Mean ± SD	Median	Max	75th percentile
UHA	<1.5	$CTDI_{vol}$ (mGy)	9.3	18.4 ± 6.0	22.0	24.8	22.5
		DLP (mGy·cm)	155.2	376.0 ± 146.0	409.3	589.3	452.5
	1.5 - 5.5	$CTDI_{vol}$ (mGy)	17.4	23.7 ± 5.3	23.1	38.4	27.7
		DLP (mGy·cm)	373.3	588.3 ± 160.4	466.8	833.7	690.6
	5.5 - 10.5	$CTDI_{vol}$ (mGy)	18.3	26.4 ± 3.6	25.9	34.3	28.0
		DLP (mGy·cm)	330.7	591.0 ± 165.7	523.2	895.0	722.4
	>10.5	$CTDI_{vol}$ (mGy)	23.4	30.7 ± 4.7	30.7	42.7	33.6
		DLP (mGy·cm)	444.9	708.7 ± 219.6	667.0	1573.5	736.8
UHT	<1.5	$CTDI_{vol}$ (mGy)	54.37	54.37	54.37	54.37	54.37
		DLP (mGy·cm)	632.95	1367.61	1401.26	1795.46	1496.41
	1.5 - 5.5	$CTDI_{vol}$ (mGy)	20.91	53.03	54.37	62.41	54.37
		DLP (mGy·cm)	611.75	1450.48	1496.41	1849.83	1692.49
	5.5 - 10.5	$CTDI_{vol}$ (mGy)	13.94	53.75	54.37	60.41	54.37
		DLP (mGy·cm)	449.66	1601.66	1632.34	1877.97	1686.71
	>10.5	$CTDI_{vol}$ (mGy)	36.25	54.35	54.37	60.41	54.37
		DLP (mGy·cm)	1097.4	1627.3	1659.5	2115.7	1768.27
Farah	<1.5	$CTDI_{vol}$ (mGy)	19.69	32.94	35.17	45.02	37.45
		DLP (mGy·cm)	667.5	834.07	854.09	1326.34	1039.7
	1.5 - 5.5	$CTDI_{vol}$ (mGy)	25.14	38.86	39.39	46.06	45.02
		DLP (mGy·cm)	535.77	982.33	1046.18	1256.93	1081.97

Continued

	5.5 - 10.5	$CTDI_{vol}$ (mGy)	21.1	42.27	42.21	68.76	45.02
		DLP (mGy·cm)	339.74	1217.01	1222.56	2182.21	1308.34
	>10.5	$CTDI_{vol}$ (mGy)	17.27	44.06	44.49	57.5	45.02
		DLP (mGy·cm)	461.25	1287.69	1237.95	1681.48	1488.62



(a) (b)

Figure 1. Comparison of the values of $CTDI_{vol}$ and DLP as DRLs obtained for UHA, UHT and Farah.

As shown in **Figure 1**, the results of DRLs obtained in UHA have low values compared to those of UHT and Farah which is in the second position as the relatively low values of dosimetric indexes.

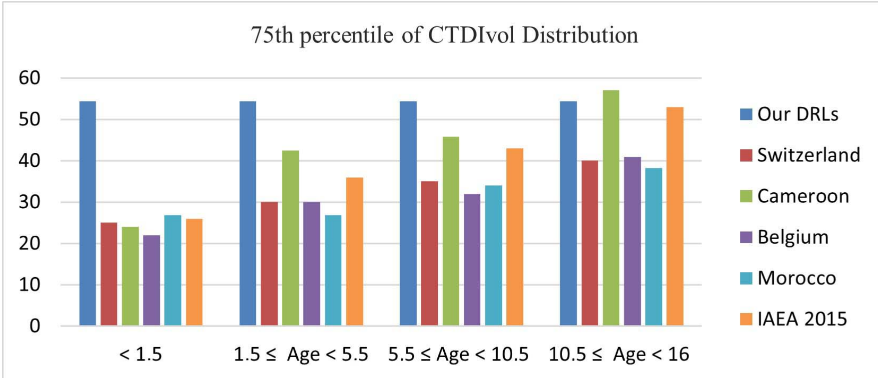
We also calculated the DRLs of this study based on the grouping per age bands of data from the three diagnosis and medical imaging departments as the DRLs for a type of examination (including the associated indication) and for an age group is established directly by taking the 75-percentile of a dose distribution [6] [9].

As shown in **Table 3**, for each age group, the average value of each dosimetric quantity considered ($CTDI_{vol}$ or DLP) is lower than the corresponding 75th percentile, suggesting that clinical practices in our three facilities are optimized [10].

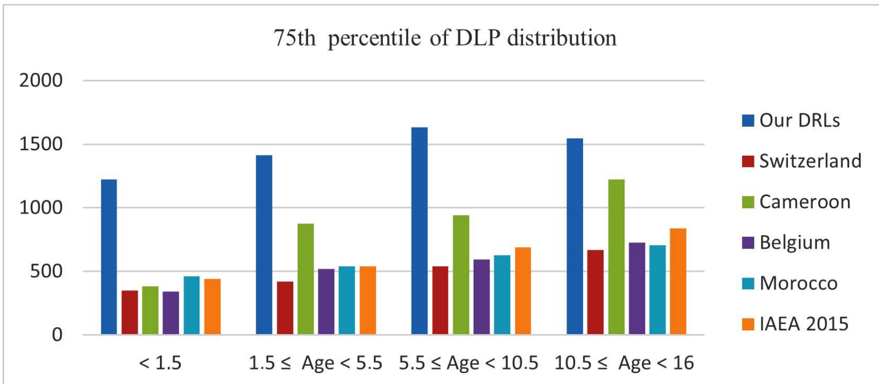
Table 3. Diagnostic reference level resulting from our survey.

	Age [years]	Dose quantity	Mean ± SD	75th percentile
Yielded DRLs of our	<1.5	$CTDI_{vol}$ (mGy)	35.2 ± 15.9	54.37
		DLP (mGy·cm)	869.2 ± 466.8	1224.55
	1.5 - 5.5	$CTDI_{vol}$ (mGy)	40.0 ± 14.3	54.37
		DLP (mGy·cm)	1041.6 ± 445.1	1414.06
	5.5 - 10.5	$CTDI_{vol}$ (mGy)	39.7 ± 14.2	54.37
		DLP (mGy·cm)	1090.1 ± 534.6	1632.24
	>10.5	$CTDI_{vol}$ (mGy)	42.0 ± 11.4	54.37
		DLP (mGy·cm)	1036.4 ± 447.5	1544.57

Moreover, the summarized results in **Table 3** were compared to those obtained from international studies [7] [11]-[14] as shown in the work of Anouan *et al.* [5]. **Figure 2(a)** and **Figure 2(b)** highlight this comparison and show trends. We can notice that our DRLs ($CTDI_{vol}$ or DLP) values are higher than those of other countries except Cameroon, for which our values are comparable.



(a)



(b)

Figure 2. (a) Distribution of $CTDI_{vol}$ with respect to age bands; (b) Distribution of DLP with respect to age bands.

4. Discussion

This survey was carried out to investigate the DRLs, such as $CTDI_{vol}$ and DLP, of three imaging facilities using data from child patients. It is in this context of a study that the first result concerning UHA were published [5]. The strength of this study is that it is the first to include three large hospitals in Côte d'Ivoire. It is important to highlight that pediatric CT imaging is a rare medical diagnosis act where there are not numerous patients, so this can affect the statistics of our data. As shown in Table 2, UHA has lower radiation dose values, whatever the dose index, which could be explained by the high performance of the X-ray tube current modulation capability for the CT-system of this facility compared to the two other hospitals. As shown in Table 1, for the purpose of reproducibility and comparability, the CT acquisition parameters such as slice thickness, pitch, and reconstruction algorithms, are almost similar. So, in addition to the absence of harmonized clinical procedures, variations in CT models and manufacturers across the three hospitals could justify the radiation dose differences obtained from these three facilities. At Farah, good clinical protocols have been established, and they are even noticeable in the displayed data of patients. However, these protocols are not always efficiently used when CT images are acquired by imaging technicians.

DRLs in the District of Abidjan were set in this study for the children's head CT examinations after grouping the data from the three medical imaging facilities per age band followed by the determination of the 75th percentile of dose distribution per each age class based on studies from Vano *et al.* [6] and Francis Verdun *et al.* [9].

In **Table 3**, the averaged values of $CTDI_{vol}$ or DLP per age class are systematically lower than the 75th percentile whatever the facility, suggesting that our procedures in the three facilities are optimized [10], but as shown in **Figure 2(a)** and **Figure 2(b)**, our values are high compared to those of international studies, excepted those of Cameroon [10]. This situation suggests that efforts should be made to improve clinical practices in medical X-ray imaging, particularly in childhood disease diagnosis through CT imaging. This situation suggests extending our study to other cities in Côte d'Ivoire in order to have a real trend of DRLs in CT throughout the whole country. Besides, Periodic quality control of CT facilities and harmonization of clinical protocols through Côte d'Ivoire should be carried out.

5. Conclusion

This survey, on levels of the radiation dose used in CT of childhood heads carried out in Côte d'Ivoire, was relative for the first time in three large medical facilities. Special attention should be paid to the CT imaging clinical procedures of patients in this age class for radiation protection as they grow. As our averaged values of $CTDI_{vol}$ and DLP per age bands are systematically lower than the corresponding 75th percentile, the clinical practices are optimized. However, compared to international studies, our values are high. These results show the importance of regular reassessment of DRLs and the limitation of the study performed in a few numbers of facilities. So, additional studies in other towns and even in the whole country of Côte d'Ivoire should be carried out to get more robust values for DRLs. Efforts are necessary from radiologists, imaging technicians and medical physicists to improve the quality control of CT imaging devices and the harmonization of clinical procedures to ensure the radiation protection of patients undergoing medical X-ray imaging in Côte d'Ivoire.

Conflicts of Interest

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

References

[1] Report of the United Nations Scientific Committee for the Study of Ionizing Radiation; Sixty-Seventh and Sixty-Eighth Sessions (2-6 November 2020 and 21-25 June 2021).

[2] Alzen, G. and Benz-Bohm, G. (2011) Radiation Protection in Pediatric Radiology.

Deutsches Ärzteblatt International, **108**, 407-414. https://doi.org/10.3238/arztebl.2011.0407

[3] Monnehan, G.A., Anouan, K.J., Onoma, D.P., Yao, K.B., Kouadio, L.D., Koua, A.A., and Dali, P.A.T. (2009) Determination of Diagnostic Reference Levels in Cote d'Ivoire: The Cases of the Chest X-Ray Standard Front and Abdomen Adult in the District of Abidjan and in the Region of Sud Comoé. *Revue Ivoirienne des Sciences et Technologie*, **14**, 45-53.

[4] Monnehan, G.A., Silue, K.A., Djagouri, K., Koua, A.A., Gogon, B.D.L.H., Dali, T.P., Kezo, P.C. and Konate, I. (207) Determination of Diagnostic Reference Levels in Côte d'Ivoire: Case of the Adult Skull Computed Tomography in the District of Abidjan. *International Journal of Science and Research*, **6**, 422-425.

[5] Anouan, K.J., Dje, A.S., Garba, I. and Soro, Y.E. (2024) Radiation Dose from CT-Scan of Childhood's Head: Results of the First Ivorian Survey in a Single Study Site. *Journal of Applied Mathematics and Physics*, **12**, 1725-1732. https://doi.org/10.4236/jamp.2024.125107

[6] 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. *Annals of the ICRP*, **46**, 1-144. https://doi.org/10.1177/0146645317717209

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

[8] Kanal, K.M., Butler, P.F., Chatfield, M.B., Wells, J., Samei, E., Simanowith, M., *et al.* (2022) U.S. Diagnostic Reference Levels and Achievable Doses for 10 Pediatric CT Examinations. *Radiology*, **302**, 164-174. https://doi.org/10.1148/radiol.2021211241

[9] Verdun, F.R., Gutierrez, D., Vader, J.P., Aroua, A., Alamo-Maestre, L.T., Bochud, F., *et al.* (2008) CT Radiation Dose in Children: A Survey to Establish Age-Based Diagnostic Reference Levels in Switzerland. *European Radiology*, **18**, 1980-1986. https://doi.org/10.1007/s00330-008-0963-4

[10] Office fédérale de santé publique: Directive R-06-06; Niveaux de référence diagnostiques en tomodensitométrie.

[11] The Federal Agency for Nuclear Control (FANC) (2020) CT Scanners. https://afcn.fgov.be/fr/professionnels/professions-medicales/applications-radiologiques/nrd/CTscanners

[12] Kamdem, E.F., Samba, O.N., Manemo, C.T., Kouam, B.B.F., Abogo, S., Tambe, J., *et al.* (2022) Establishment of Local Diagnostic Reference Level for Routine Paediatric Computed Tomography Examinations in Bafoussam West Cameroon. *Radiation Protection Dosimetry*, **198**, 815-820. https://doi.org/10.1093/rpd/ncac143

[13] Benmessaoud, M., Dadouch, A., Talbi, M., Tahiri, M. and El-Ouardi, Y. (2020) Diagnostic Reference Levels for Paediatric Head Computed Tomography in Morocco: A Nationwide Survey. *Radiation Protection Dosimetry*, **191**, 400-408. https://doi.org/10.1093/raddos/ncaa170

[14] Vassileva, J., *et al.* (2015) A Study to Establish International Diagnostic Reference Levels for Paediatric Computed Tomography. *Radiation Protection Dosimetry*, **165**, 70-80.