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Radiation Dose from CT-Scan of Childhood's Head: Results of the First Ivorian Survey in a Single Study Site

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Abstract

Objectives: This study aims to evaluate the level of X-ray doses used in childhood's head as Local Diagnostic Reference Levels (LDRLs) in computed tomography (CT) at a university hospital in Côte d'Ivoire. The Diagnostic Reference Level (DRL) have been set up and used to prevent unusually high radiation doses used in radiology departments and is therefore an optimization tool for practices and procedures in medical X-ray imaging for the radiation protection of patients. **Methods**: A prospective study of volume CT dose index ($CTDI_{vol}$) and dose length product (DLP) was performed on images of childhood's head obtained from a CT-scanner of 64 bars equipped with the tube current modulation capability and manufactured by Hitachi Medical System. 122 CT-scan data from 55 childhood's head were analyzed. The scan data were stratified in four age groups: <1.5 years, 1.5 - 5.5 years, 5.5 - 10.5 years, and 10.5 - 16 years. **Results**: The 75th percentile of $CTDI_{vol}$ and DLP (set as LDRL) obtained with respect to the stratified age groups are: 22.5 mGy and 452.5 mGy·cm, 27.7 mGy and 690.6 mGy·cm, 28 mGy and 722.4 mGy·cm, 33.6 mGy and 736.8 mGy·cm respectively. These outcome values increase with respect to the age of pediatric patients and are comparable to DRLs values obtained internationally. **Conclusions**: Obtaining good image quality while using low dose in children's head computed tomography for radiation protection require to setup more surveys in Côte d'Ivoire for regional and national DRL. We proposed through this survey LDRLs in terms of $CTDI_{vol}$ and DLP, comparable to international DRLs values. This survey will be strengthened by additional surveys in order to obtain national DRLs for the radiation protection of the child patient in Côte d'Ivoire.

Keywords

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

1. Introduction

The management of radiation doses in radiology is an indispensable patient safety procedure, particularly in CT which is the most irradiating medical imaging device [1]. This situation led the International Commission on Radiological Protection (ICRP) to make recommendations to all countries around the world to determine DRLs for the most widely used medical ionizing radiations devices [2] in order to optimize practices and procedures for a better radiation protection of patients. The main purpose of the DRLs is to identify a radiology department where radiation protection is not optimized. In this framework the first study in conventional radiology was initiated in Côte d'Ivoire through a technical cooperation untitled "Strengthening radiological protection of patients and control of medical exposure (AIEA/RAF/9/059)" with the International Atomic Energy Agency (IAEA) [3].

The radiation dose administered to patients could affect their health due to harmful effects of ionizing radiations and particularly concerning children with growing tissues who have higher tissue sensitivity than adults and are therefore exposed to greater risk [4]. This situation justifies to carry out a first survey in pediatric CT imaging for evaluating the level of doses administered in childhood radiology and proposing optimization procedures by quality control of CT devices and improvement of clinical procedure in CT imaging. This study aims also to compare the results of doses assessment to a similar study on adult's skull carried out in Côte d'Ivoire [5] and to pediatric DRLs internationally published. The potential implications of the study findings are the extension of the study to regional and national DRLs and their periodic reassessment accordingly, in addition to the sensibilization and the training of imaging technicians and radiologists on the risks from radiations used in CT imaging and the radiation protection procedures in CT imaging. Knowing that LDRL values, which are tools to keep doses as low as reasonably achievable, were established for a routine procedure and for typical patient groups such as children and not for individual exposures, regular exceedance of this level will lead to inform clinical decision-making to control imaging protocols and facilities in order to take corrective action for the optimization of procedures.

2. Materials and Methods

This prospective study was carried out at the University Hospital of Angré (UHA) located in Abidjan in Côte d'Ivoire from November 2023 to February 2024. 122 brain CT scans of 55 children from 0 up to 16 years old were performed using a Scenaria 64 bars scanner commissioned in 2018 and equipped with the tube current modulation capability and manufactured by the company Hitachi Medical System. Good clinical images were obtained with this CT system combining automatic exposure control and iterative reconstruction algorithm. The kilovoltage (kV) used range from 80 kV to 120 kV and the displayed charge range from 75 mAs to 191 mAs. Our study begins after checking the calibration of our CT-scan with the manufacturer biomedical engineer.

DRL is an arbitrary notional value set at 75th percentile of the distribution of dose quantities such as CTDIvol and DLP [2]. Determining CTDIvol or DLP as LDRLs for childhood head CT scans is not a calculation of average values, but a choice of values below which 75% of all CTDIvol or DLP measurements are located. This means that the 25% corresponding to the highest doses were achieved under non-optimized conditions. This implies that there are control and correction actions to be made to the equipment after identifying the reasons for this dose increase. In accordance with recommendation of ICRP 2017 [2], LDRLs were defined as the 75th of the dose ($CTDI_{vol}$ or DLP) distribution for pediatric CT imaging. They were compared to international DRLs using age bands [6] [7].

The grouping and analysis of radiation dose data were based on children's age classification in order to show the variation of the 75th percentile of $CTDI_{vol}$ or DLP with respect to age groups in pediatric computed tomography and for comparison with practices in other countries. Moreover, head exams were grouped by age because of uncertainty in the size estimation due to the inconsistent presence of shoulders in the field of view. So, we decided to use age groups based on Wagner *et al.* [6] study for comparison purpose to the DRL obtained internationally. There were challenge to obtain very large data for each age group because pediatrics patients in CT imaging are rare. The sample size is important to take into account the variation of doses into each age band and will ensure that the sample is representative of the study findings at our radiology facility for a given age group.

So as Wagner *et al.*, we classified pediatric patients into four age groups: <1.5 years, 1.5 - 5.5 years, 5.5 - 10.5 years, and 10.5 - 16 years [6].

Radiation doses data such as Volumetric Computed Tomography Index ($CTDI_{vol}$) and Dose Length Product (DLP) used for each child's scan were obtained by displaying on the Scenaria CT console after the examination of each patient in our cohort. All the child CT scan were performed based on indication explicitly given by physicians and the quality of images were obtained with respect to clinical indication.

$CTDI_{vol}$ and DLP data were analyzed and stratified with respect to age group. As Wagner *et al.*, we evaluated each CT-scan separately, even if more than one CT scan had to be acquired for a patient due to a problem of image quality or if the exam required two or more follow-up CT scans [6]. The assessment of each CT-scan is justified by the fact that a displayed $CTDI_{vol}$ is different from one scan sequence to another one because the $CTDI_{vol}$ in an individual scan is not constant when tube current modulation is used [2]. DRLs are defined as the 75th percentile of the dose distribution in accordance with the recommendation of ICRP [2].

3. Results

We analyzed 122 patient scan data from 55 patients (56.4% are boys and 43.6% are girls) where ages vary from less than 1 year old up to 16 years old in a unique medical center (UHA). The data were classified in the following groups: <1.5 years, 1.5 - 5.5 years, 5.5 - 10.5 years, and 10.5 - 16 years.

As a first observation, comparing to other parts of the body like thorax or abdomen, the examination of the children's head through CT scan is the most performed CT exam act in the hospital (UHA) of our study. We presented in **Table 1** the medical indications with and without contrast material for which we recorded pediatric patient's data of our study.

The number of CT-scan without contrast material was very low, so we pooled CT-scan data with and without contrast materials [6] for the evaluation of $CTDI_{vol}$ and DLP for each CT-scan with respect to age groups. We also observed that $CTDI_{vol}$ and DLP values increase with patient age. The minimum values of these parameters were recorded for patient with age less than 1.5 years old (9.3 mGy for $CTDI_{vol}$ and 155.2 mGy·cm for DLP). The maximum ones are 42.7 mGy and 1573.5 mGy·cm for patients with age from 10.5 up to 16 years old. The 75th of our study (33.6 mGy, 736.8 mGy·cm), for the oldest patient of our cohort, are naturally lower than the DRLs for adults (50.9 mGy, 982.9 mGy·cm) obtained by Monnehan *et al.* in 2016 [5]. The statistics of our study are described in the **Table 2**.

The main result of our study (75th percentile of $CTDI_{vol}$ and DLP for UHA) are compared to the results of international DRL studies [8] [9] [10] [11] with respect to the different age groups and summarized in **Table 3**. The obtained 75th percentile of $CTDI_{vol}$ and DLP are respectively: 22.5 mGy and 452.5 mGy·cm, 27.7 mGy and 690.6 mGy·cm, 28 mGy and 722.4 mGy·cm, 33.6 mGy and 736.8 mGy·cm. As shown in **Figure 1**, our results for $CTDI_{vol}$ values are lower than the international values for the children with age range from 5.5 years old to 16 years old. As shown in **Figure 2**, our DLP data are almost higher than those of other countries except Cameroon for the children with age range from 1.5 years old to 10.5 years old [8].

Table 1. Clinical indications for head CT imaging in paediatrics with and without contrast materials.

Childhood's head CT imaging	Medical indications
Brain without contrast material injection	Cranial trauma
Brain with contrast material injection	hemiplegia
	Conscience disorder
	coma
	Feverish hydrocephalus

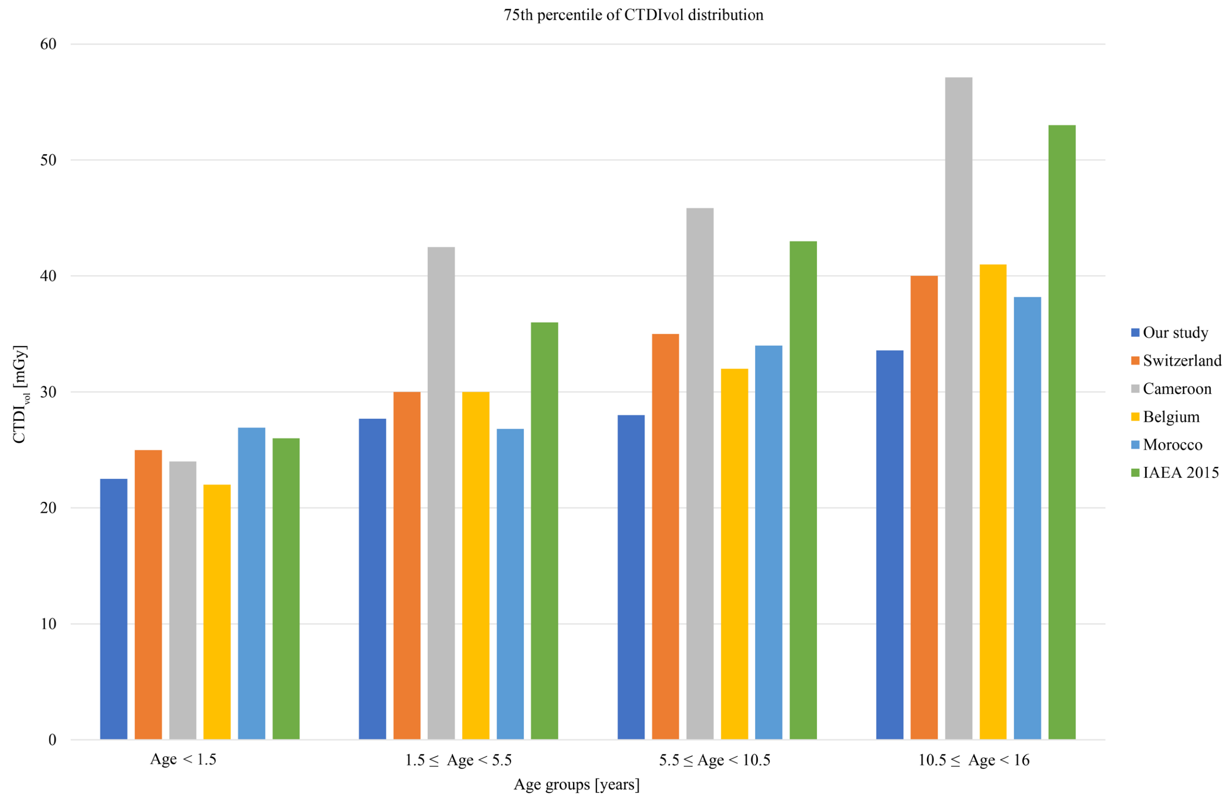

Figure 1. Distribution of $CTDI_{vol}$ per country with respect to age groups.

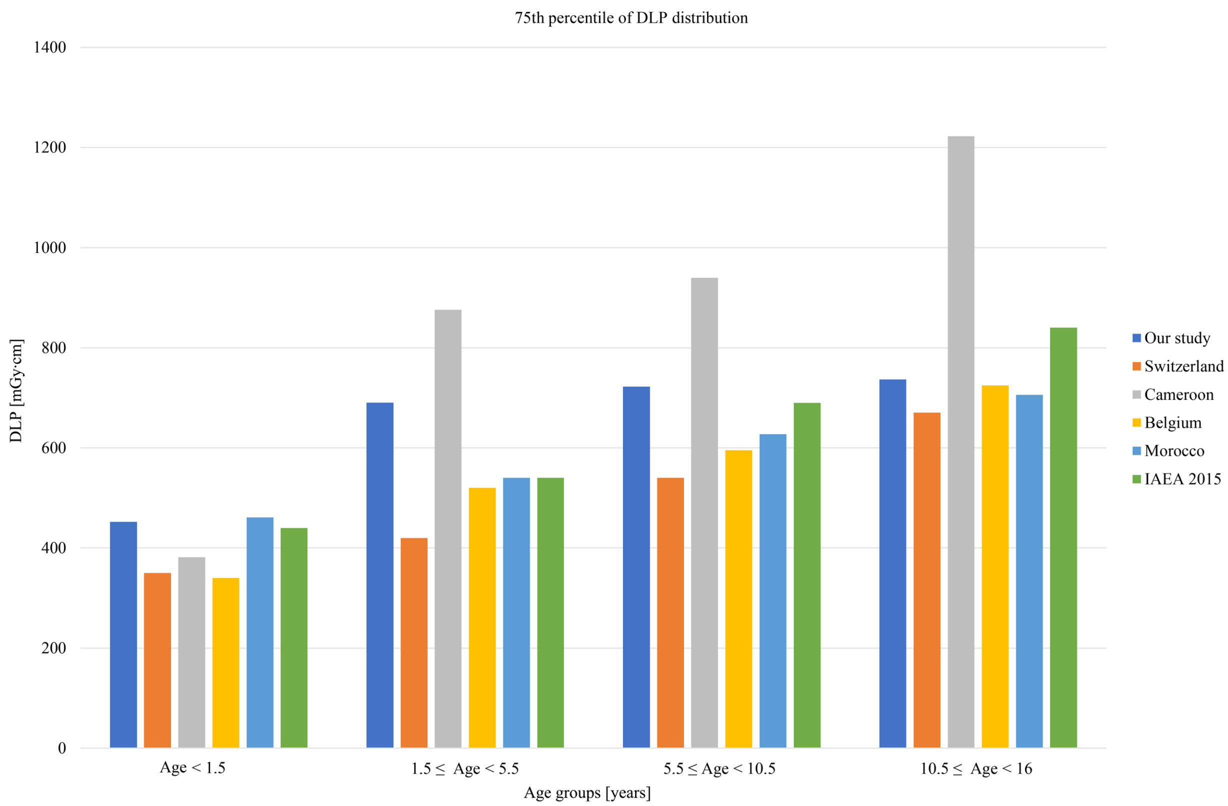

Figure 2. Distribution of DLP per country with respect to age groups.

Table 2. Statistics of childhood CT head data and the outcome DRLs.

Age [years]	Dose quantity	Min	Mean ± SD	Median	Max	75^{th} percentile
<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

Table 3. Comparison of our study results to international DRLs values.

Age (years)	Dose quantity	Our Study	IAEA	Switzerland	Cameroon	Belgium	Morocco
<1.5	$CTDI_{vol}$ (mGy)	22.5	26	25	24	22	26.9
	DLP (mGy·cm)	452.5	440	350	381.3	340	461.6
1.5 - 5.5	$CTDI_{vol}$ (mGy)	27.7	36	30	42.5	30	28.8
	DLP (mGy·cm)	690.6	540	420	875.6	520	540
5.5 - 10.5	$CTDI_{vol}$ (mGy)	28.0	43	35	45.9	32	34
	DLP (mGy·cm)	722.4	690	540	939.6	595	627.2
>10.5	$CTDI_{vol}$ (mGy)	33.6	53	40	57.1	41	38.2
	DLP (mGy·cm)	736.8	840	670	1222.3	725	705.9

4. Discussion

Our study aimed to assess $CTDI_{vol}$ and DLP values and then to yield LDRL for head's CT procedures using data related to patients in childhood. We introduce LDRL for pediatric CT brain scans at a medical center (UHA) of Abidjan in Cote d'Ivoire where there are no studies currently on the radiation protection of children during CT scans. So, the strength of our study is the fact that we are the first to propose a LDRL study in childhood CT examinations in Côte d'Ivoire. As shown in **Figure 1** and **Figure 2**, our results from this study indicated that 75th percentile of $CTDI_{vol}$ and DLP values are comparable to values of these parameters obtained internationally [8] [9] [10] [11]. The performance of our CT scanner (equipped with automatic exposure control system including current modulation capability and iterative reconstruction algorithm) could justify these results. However, the slightly high values of our DLP results compared to those of other countries except those of Cameroon could be improved if imaging technicians rigorously use optimized protocols including the pediatric protocol activated on our CT system. In case of lack of grouping information, it will be difficult to compare DRLs reported in different studies. So, the age is a grouping information. The process of comparison of LDRLs is based on the age bands. The fact that LDRLs values are close to international standards on the basis of stratification by age groups makes it possible to validate the values of LDRLs. The results will contribute to the optimization of radiation doses in pediatric CT imaging by identifying facilities and exams where levels of patient doses are unusually high and by reviewing procedures and equipment.

One of the limitations for this study is that it is one hospital site study. It's not representative of the whole Ivorian situation but it deserves to have been realized and will be the starting point for the establishment of pediatric CT DRLs in Côte d'Ivoire. Another limitation is that the optimized protocols with standardized value of kV with respect to the age of the patient and clinical indications are often not used during CT examination by radiology technicians and there is no medical physicist in the hospital to perform periodically the quality control of radiology equipment.

The study findings align with current best practices and guidelines for pediatric imaging as the LDRLs from our study are sensibly close to the DRLs of the countries like Switzerland [6], Belgium [9], Morocco [10] and that of the IAEA [11]. These findings imply that our future research should be extent to regional and national DRLs to survey clinical practices in pediatric CT imaging and to get more robust DRLs values in order to improve clinical guidelines in Cote d'Ivoire. Moreover, the implication will integrate a regularly reassessment of the radiological practices based on DRLs as optimization tool

Ultimately, these findings suggest to harmonize CT-scan protocols in all radiology departments of Ivorian hospitals and to set-up Local, Regional and National DRLs, whatever CT-scan medical indications, for pediatric and also adults' patients for their safety and security against hazardous effects of medical ionization radiations in Côte d'Ivoire.

5. Conclusion

In the present work, we dealt with a survey on the level of doses delivered in computed tomography, particularly in childhood examinations with the aim to establish the national DRLs which are good optimization tools in diagnostic radiology. Preserving the image quality in computed tomography for the diagnose of their pathology while using low dose to patients, especially to children for their radiation protection, require more surveys in Abidjan and in the other regions of Côte d'Ivoire in order to setup regional and national DRL. In addition to collaborations between radiologists, imaging technicians and medical physicist in the organization of work in the imaging department taking into account radiation protection issues, the present study is the starting point of these surveys that will ensure compliance and optimization for CT imaging protocols.

Conflicts of Interest

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

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