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Research Article

A Pilot Study to Establish National Diagnostic Reference Levels for Paediatric Computed Tomography in Cameroon

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ABSTRACT

This study reports results from the largest national dose survey in pediatric computed tomography (CT) in Cameroon. The main purpose of this pilot study was to etablish the national diagnostic reference level (NDRL) of computed tomography (CT) examinations to optimise medical exposure in pediatric medical imaging centers in Cameroon. This work was performed for 15 CT scanners installed in various parts of the Cameroon region. Data were collected for 1269 pediatric patients.For each patient, Volume CT Dose Indexes (CTDIvol) and Dose Length Product (DLP) in each group were recorded and their third quartile was calculated and set as NDRL. Pediatrics were divided into four age groups andyears. Then, the third quartile values for head were, respectively, calculated for each group in terms of CTDIvol: 34.2, 36.6, 39.5 and 49.6 mGy; and in terms of DLP: 710.1, 838.4, 964 and 1177.2 mGy.cm. The collected data for CT examinations for chest and abdomen for this study were low. Finally, NDRLs were compared with other countries and international studies. As a result, DLP values were superior than other national and international studies. Variation of scan parameters (tube voltage (kVp), tube current (mAs) and scan length)), CTDIvol and DLP of different procedures among different age groups were statistically significant (P-value). The variations in dose between CT departments as well as between identical CT scanners suggest a large potential for optimization of examinations. DRLs reported in this article can be used in this country with sufficient medical physics support to identify non-optimised practice. This study provides helpful data for optimization pediatric CT scan.

Keywords: Diagnostic Reference Levels, Volume CT Dose Index, Dose Length Product, 75th percentile.

INTRODUCTION

Computed tomography (CT) is a widely used modality in diagnostic radiology. CT-scan is the most irradiating tool in diagnostic radiology. It has found its way into emergency medicine where it represents an indispensable diagnostic tool. The main disadvantage of CT is the high radiation dose delivered to patients, which is why a lot of emphases is given to the development of optimised scanning protocols. Radiation protection of patients in diagnostic radiology requires the use of examination protocols appropriate for the patient's age, size or body mass, region of imaging and clinical indication. There is currently no Pediatric Regulatory Diagnostic Reference Level (DRL) in Cameroon to standardize protocols in hospitals but a

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pilot study to establish a DRL of adults in five radiology departement have been published in Cameroon [1].

The term "diagnostic reference level (DRL)" was introduced in 1996 by the International Commission on Radiation Protection (ICRP) (ICRP, 1996). A guideline for establishing DRLs was therfore introduced in medical imaging to provide optimisation of procedures (ICRP, 2017 ; ICRP, 2001). As a result, paediatric guidelines were proposed by three authorities, the ICRP, the European Commission (EC) and the International Atomic Energy Agency (IAEA). This concept was subsequently developed by the IAEA (IAEA, 2013), the ICRP (ICRP, 2017) and the EC.

Each state must develop and use DRLs. In Cameroon, despite the increasing number of CT-machines, the pediatric Diagnostic Reference Levels have not yet been established. Differences were found in the methods used to establish paediatric CT DRLs across the world, including apatient's age, size or body mass, region of imaging, clinical indication, modes of data collection and statistical analysis. The majority of the studies were based on retrospective patient surveys. The head, chest and abdomen were the common regions. The volume computed tomography dose index (CTDIvol) and dose–length product (DLP) were the dosimetric quantities chosen in the majority of publications. Moreover, these DRL variations suggest the importance of establish a national DRL for each country considering advanced techniques and dose reduction methodologies. Diagnostic Reference Levels (DRL) are procedures involving ionizing radiation are important tools to optimizing radiation doses delivered to patients and in identifying cases where the levels of doses are unusually high. They not only can be used as quality measures locally, but also to compare the performance of the local medical imaging institutions. Many countries have already taken action to establish and assess DRLs for paediatric radiological procedures. This has become a growing trend in the field of radiological protection during the past decade.

The frequency of use the computed tomography (CT) scans in African countries increased in the last decade. However, a published study had reported that the frequency of CT examinations performed on children in Africa (20%) was higher than in Asia (16%) and Eastern Europe (5%) continents. Currently, there are not national DRLs established in Cameroon for any imaging procedure The purpose of the pilot study was to establish the National diagnostic reference levels for paediatric head computed tomography in Cameroon. These DRLs we be the tool to evaluate and improve the performance of our CT service by improved compliance and a reduction in radiation dose to our paediatric patients. We have also been able to benchmark our performance with similar national and international institutions [2].

MATERIALS AND METHODS

CT technique and dose analysis

Patient cohort was divided into four age groups: <1 y, >1–5 y, >5–10 y and >10–15 y. After a literature review, it was decided to allow comparison with existing DRLs and dose data from other surveys. Patient weight in the age groups was not included as an additional parameter. One body part was studied: head. Clinical indications were not specified in all facilities. Data were collected in standard Excel forms, containing for each patient: 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 (average values if tube current modulation utilised), rotation time and beam width; dose indexes recorded from the scanner console: weighted CTDIw or volume CTDIvol for each sequence/phase, and DLP for the whole exam. Participants were asked to extract from the scanner archive, data for at least 10 patients of each examination and each age group (retrospective part), and for at least 10 patients of each group in the prospective data collection. The purpose was to compare patient doses after implementation of corrective actions. Patient data were collected manually by us and the local staff, put together in an Excel sheet and returned electronically to us by whatsap software. Close contact was kept with the participants during the whole period of data collection (2018-21), in order to provide support and clarification when needed and feedback when potential for optimisation was seen [3].

Statistical analysis

All data were summarised in an Excel database, with a separate worksheet for each age group. For multi-sequence or multiple phase scans, the average value of DLP and CTDIvol were calculated. Data were reviewed and processed by an experienced medical physicist, and independent quality assurance check of the processed data was performed. Only data for CTDIvol were analysed because of the low number of data from facilities with CTDIw display. For each facility, minimum, maximum, median of CTDIvol and DLP values were calculated. For each data set, facility's mean values were grouped together and descriptive statistical analysis was performed, calculating minimum, maximum, mean and 75th percentile (3rd quartile) values. Additionally, individual patient data from all facilities for each data set were pooled together and descriptive statistics performed. For statistical analysis, Microsoft Excel with the Analysis ToolPak was used. Or, comparison of samples heteroscedastic Student's t-test to the 75th percentile values was used, with $p < 0.05$ considered as significant. [4].

Ethical considerations

Ethical approval was obtained from the Ethical Review Board of University of Dschang and some facilities of this study.

RESULTS

Database

Data from 15 CT facilities in 15 hospitals from this country are included in this article. The distribution by region was 2 CT scanners in West, 1 in South-West, 10 in Center and 2 in Littoral. A variety of models of CT equipment of different vendors was represented. All systems were multi-detector CT. The total number of patient data used for the analysis is 1269.

The distribution by geographical region was 219 patient data entries from West, 53 from South-West, 922 from Center and 72 from Littoral. Because of the different number of facilities participating and patient data provided, no difference in patient doses between geographical regions was investigated and data from all hospitals were analysed individualy and then together. The highest number of patient data, 1269, was collected for head examination, 30 for chest and 60 for abdomen. Similarly, with respect to age, the highest number of patient data, 421, was collected for the age group >5–10 y, 378 for the age group >10–15 y, 272 for the age group >1–5 y and the lowest number, 198, for the age group <1 y. In total, 15 Excel worksheets were created and analysed, separate for each hospitals. Scan parameters for the same examination were different to some extent between centers. The tube voltage were the same in all hospitals (120kvp). The mAs were differents. Possible dose reduction strategies suggested in this study are adjusting kV (80-120), increasing the slice thickness (5mm), and reduction in mAs [5].

DRL

Comparison between DRL of CTDIvol showed that the difference is significance; hence variations between the CT scanner demonstrate that dose differences are not just attributed to the CT scanner design, but can be due to differences in protocols used, CT scanner used and scanning parameters as kvp, mAs, slice tickhness, medical imiging technicians, scan length used, knowledge in radiological protection and risk from ionizing radiation while looking at Figure 1 established by this study. Figure 1 and 2 summarises 75th percentiles of distributions of CTDIvol and DLP values for all age groups in all hospitals.

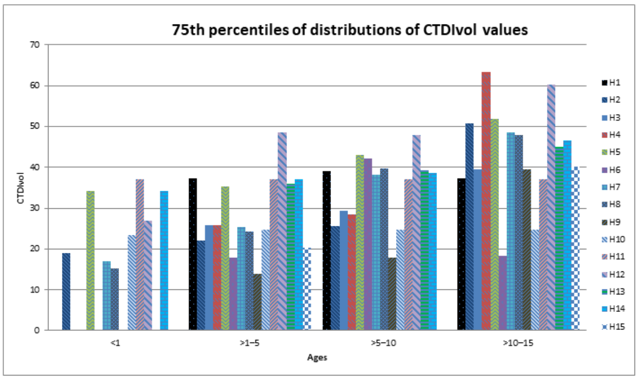

Figure1: Comparison of the 75th percentile of CTDIvol values of all hospitals in this study.

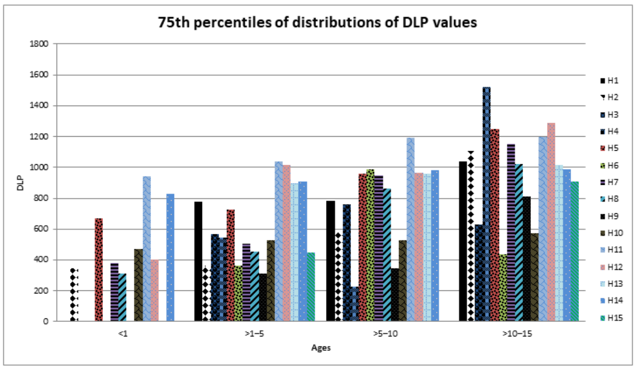

Figure2: Comparison of the 75th percentile of DLP values of all hospitals in this study.

For each examination, 3rd quartile of CTDIvol and DLP were calculated and considered
as diagnostic reference levels. The results are shown in Table 1.

Table1: DRLs from this study compared to international DRLs for CTDIvol and DLP for head CT, and for all age groups.

	CTDI vol				DLP			
	<1	>1–5	>5–10	>10–15	<1	>1–5	>5–10	>10–15
Our study DRLs	34,2	36,6	39,5	49,6	710,1	838,4	964	1177,2
VASSILEVA 2015	26,0	36,0	43,0	53,0	440	440	690	840
IRAN 2020	21,3	24,4	24,2	36,3	322,2	390,1	424,9	694,1
TAMIL NADU 2017	20	38			352	505		
SWITZERLAND 2018	25	30	35	40	350	420	540	670
SOUTH AFRICA 2013	30	31	32		488	508	563	
MOROCCO 2020 (Local survey)	26,9	28,8	34	38,2	461,6	540	627,2	705,9
IAEA 2015	26	36	43	53	-	-	-	-
MOROCCO 2020	27,1	28,7	35,7	39,8	-	-	-	-
(National								

survey)								
THAILAND 2012	25	30	40	45	-	-	-	-
PORTUGESE 2013	48	50	70	72	630	770	1100	1120

The national DRLs of CTDIvol and DLP established in this survey for the head and for the four age groups are presented in Table 1 with international published data. For the head, DRLs are given for standard head phantom with a diameter of 16 cm. Findings from our study show that the CTDIvol reported in our work is higher than all internationally reported value except Portugese, IAEA (>10–15y), Vasseliva (>5y) and Thailand (>5–10y). The DLP for this study were considerably higher. The main problem would be scan length because DLP is proportional to scan length. Portugese 2013 have DLP higher than this study for children aged to >5–10y.

Results obtained from studies conducted in other places revealed that DRLs are not the same for the similar body region because DRL is a quantity that can be influence by several parameters such as operators and interpreter radiologists knowledge and expertise, scanner type, filter, scan time, patient body thickness, exposure factors, including kVP and mAs as well as selected protocol.

DISCUSSION

There has been confusion in literature on whether paediatric patients should be grouped according to age, weight or other parameters when dealing with dose surveys. The present work aims to suggest a pragmatic approach to achieve reasonable accuracy for performing patient dose surveys in countries with limited resources. Therefore, an internationally accepted protocol should be followed when establishing DRL. Moreover, these DRL variations suggest the importance to establish a country's own NDRL considering advanced techniques and dose reduction methodologies. The variations in dose between CT departments as well as between identical scanners suggest a large potential for optimization of examinations relative to which this study provides helpful data. Therefore, the ICRP has recommended DRLs to be established taking these factors into consideration and that a LDRL or regional DRL should equal the national benchmark.

Analysis of dose indices and establishment of DRLs

Diagnostic Reference Levels (DRL) of procedures involving ionizing radiation are important tools to optimizing radiation doses delivered to patients and in identifying cases where the levels of doses are unusually high. This is particularly important for paediatric patients undergoing computed tomography (CT) examinations as these examinations are associated with relatively high-dose. Our initiative via the determination of the first cameroonian diagnostic reference levels for paediatric head CT must be a starting point to spread this investigation towards other examinations and imaging modalities. The current study highlights the role of DRLs in establishing institutional dosimetry baselines, in refining local imaging practice, and in enhancing patient safety. Standard age stratification for DRL and LDRL reporting is recommended.

National DRLs for paediatric CT and comparison with published data

Findings from our study show that there were apparent significant differences between Cameroon and other countries with the CTDIvol and DLPs in Cameroon being relatively high, because DLP is proportional to scan length. In the all age category, the DLP was higher than the 75th percentile for the DRLs reported elsewhere. However, for CTDIvol, the values in Cameroon were close to those of other countries. This study confirmed variations in the CTDIvol and DLP values of paediatric CT scans in Cameroon. These variations were attributed to the different protocols, CT scanner and equipment used. There is a need to optimise paediatric CT examinations doses in Cameroon. Findings from our study suggest that technical factors like scan length, exposure factors may be significant contributor for high CT dose value in the study centre. Reason for higher dose in our study may be our scan length for head CT examination is longer than the respective centres. This is due to the significant discrepancy observed globally in some parameters among the radiology departments. The variation in mAs could be because of the variances in CT scanner geometry whereas the significant difference in scanned length might be due to the routine head could be interpreted differently through the CT clinics worldwide. All radiology departments used the same tube voltage (120 kvp) except one center (130 kvp).

Our DRls exceeded the internationals DRLs by a statistically significant amount and therefore further investigation is required. Variations between the CT scanner demonstrate that dose differences are not just attributed to the CT scanner design, but can be due to differences in protocols used, CT scanner used and scanning parameters. Moreover, the higher DLP can be probably attributed to variation in data collected, because the nature of this examination may vary significantly depending on the clinical indication. A process of continuous audit is recommended to ensure that all data collected are for the same clinical indication.

The DRL can be reduced by coordinating effort between radiologists, technologists and medical physicist. There is always a trade-off between dose reduction and diagnostic image quality. However, especially for head examinations, optimization is still feasible. The concept of DRL provides a valuable means for practitioners and manufacturers in optimizing CT protocols. Application of DRLs which resulted from this study can help to optimize radiation dose to the patients while maintaining acceptable diagnostic images quality. Periodic national updates of DRLs, following international comparisons, are essential.

The findings of this work justify further research in the optimisation of CT protocols with the overall aim of reducing DRLs and individual patient dose levels.

Limitation of the survey

There are several limitations of this survey influencing the accuracy of estimated DRL values. First, the size of the sample, limited to 15 services due to a lack of resources to cover the whole country, some non functional machines during the data collection and the opposition of some health facilities. The second limitation is the manual recording of data, which increases the risk of associated human errors, influenced by the attention, knowledge and expertise of the staff collecting data. The third lilitation is the lack of international uniformity in age stratification for DRL data. We advocate standardised age stratification to facilitate interpretation and comparison of data. A source of limitation is also insufficient information about clinical indications for CT, which can lead to high individual variations in patient doses in the same data set due to differences in technical settings, phases, etc., associated with different image quality requirements. Furthermore, it is envisaged that the data reported here will form the basis of further collaborative work in Cameroon with a view to establishing examination specific national DRLs for both children and adults [6,7].

CONCLUSION

This article reports results from the largest national dose survey in paediatric CT in 15 hospitals in Cameroon. 1269 individual patient data were recorded, and statistical analysis demonstrated potential for optimisation of CT practice for children. National DRLs were established for CTDIvol and DLP for patients in four age groups and for routine head CTexaminations. DRLs can be used by clinical staff in Cameroon without sufficient medical physics support to identify unoptimised practice. The establishment of DRL will give us the tool to evaluate and improve the performance of our CT service by improved compliance and a reduction in radiation dose to our paediatric patients. DRL are important tools in the management of radiation doses delivered to patients. They not only can be used as quality measures locally, but also to compare the performance of the local medical imaging institutions with other published national and international DRL data. There is always a trade-off between dose reduction and diagnostic image quality. However, especially for head examinations, optimization is still feasible. The concept of DRL provides a valuable means for practitioners and manufacturers in optimizing CT protocols [8-10].

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