Facility dose reference levels for radiation doses for paediatric head CT examination at Moi teaching and referral hospital

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Abstract:

***Objective*: To establish facility dose reference levels for radiation doses for paediatric head CT examination at Moi teaching and referral hospital.**

***Methods*: This was a descriptive cross sectional study done at Moi Teaching and Referral Hospital. A total number of 127 patients aged between 0 to 15years were recruited into the study using systematic sampling technique. Data was collected from the Computed tomography console and estimated effective dose calculated. Categorical variables were summarized as frequencies and percentages. Bivariate analysis was done using T-test to test for association between the dependent and independent variables between the groups. Pearson correlation coefficient and scatter plots were used to describe the relationship between the radiation doses, age and Body Mass Index. A P value of <0.05 was considered to be statistically significant.**

***Results*: The mean age for the participants studied was 5.21years. The most common indication for Computed tomography was hydrocephalus (24%). The average Computed Tomography Dose Index, Dose Length Product and effective dose was 32.84 mGy, 1006.1 mGy.cm and 4.01mSv respectively.**

The Facility reference level was set as the median value for $CTDI_{VOL}$, DLP and effective dose at 36.5mGy, 850.6mGy.cm and 3.75mSv respectively.

***Conclusion*: Computed Tomography Dose Index of the patients are within normal parameters with other places in the world. The Dose Length Product and effective dose are within range with the ones of National Diagnostic Reference Level for Kenya but higher than others countries such as Turkey. There was statistically significant correlation between age and effective dose.**

***Keywords*: Computed Tomography Dose Index, Dose Length Product, Effective dose**

I. BACKGROUND

Globally, most DRL data available are estimated for adults. There is little literature especially in LMICs on DRL for children. An analysis on the comprehensiveness of available data on DRL's from 1996-2015 found only 53 articles were on CT examination with paediatric DRLs representing 14 (26%) of these articles(Meyer et al., n.d.). The trend in establishing DRLs for LMICs however was shown to be improving with 29 (54%) of articles having been published between 2011 and 2015 [1]. Most DRLS data available is from high-income countries.

In 2010 the IAEA coordinated a project consisting of 3 phases where dose indices based on standard protocols in paediatric CT and technical factors were surveyed. Patient cohorts were divided into four age groups <1year, >1-5years, >5-10years and >10-15years. Data from 82 CT facilities in 72 hospitals from 32 countries were included in the survey. The distribution was 42 CTs in Asia, 30 in Europe, 7 in Africa and 3 in Latin America. The total number of patients used for analysis was 6115. DRLs were set at the 75^{th} percentile of the distribution of mean values. The established DRL for CTDI and DLP for head CT for age groups <1year, >1-5years, >5-10years and >10-15years were 26mGy, 36mGy, 43mGy and 53mGy respectively and 440mGy.cm,540mGy.cm, 690mGy.cm and 840mGy.cm respectively[2].

The UK NDRLs are based on the body region examined. The doses for Paediatric CT examinations were based on 16cm standard CT dosimetry phantom. The set NDRLs for paediatric head CT in the UK are given in age groups where whose $CTDI_{vol}$ per sequence is 25mGy and DLP per complete examination for 0-1year is 25mGY and 350mGycm, for >1-5 years 40mGy and 650mGYcm and >5year 60mGy and 860mGycm respectively[3].

In Australia MDCT (Multidetector Computed Tomography) paediatric DRLs were set using data from a survey done by the Royal Australian and New Zealand College of Radiologists (RANZCR). Dosimetry information was collected from twelve facilities.

The paediatric MDCT DRLs were determined by determining the 75^{th} percentile of the spread of individual doses submitted. The set NDRL for baby/infants (0-4years) for head CT were DLP 470mGy.cm and $CTDI_{vol}$ 30 and for children 5-14years a DLP of 600mGy.cm and a $CTDI_{vol}$ of 35mGy [4].

Among the few published is a retrospective study that was done in a tertiary level hospital in South Africa where scan parameters were based on a 16cm diameter phantom. The $CTDI_{vol}$ and DLP values for each study were recorded in a data collection sheet. An analysis of volume-based CT dose index and DLP data from non-contrast head CT scans showed a mean $CTDI_{vol}$ and DLP values of 30mGy and 488mGy.cm for 0-2years age group;31mGy and 508mGycm for >2-5years and 32mGy and 563mGy.cm for >5-10years respectively. The mean $CTDI_{vol}$ compared favourably with those published for Australia, Switzerland, Germany and the UK. The study highlighted the role of LDRL in establishing institutional dosimetry baselines and changing the local imaging practice to improve patient safety[5].

In 2012, 30 facilities operating in Kenya were requested to participate on a voluntary basis in a study aimed to estimate the NDRLs. Survey data was received from 15 of the facilities representing 50% coverage of all facilities in the country. The CT facilities that provided patient dose survey data had clinical protocols dose measurements based on phantoms using CT head (16cm diameter) and body (32cm diameter) with a calibrated CT external detector instrument. The established paediatric NDRLs (National Dose Reference Levels) for head CT which are higher than those described in above-reviewed studies were for 0-1-year age group was $CTDI_{vol}$ of 38mGY. DLP of1005mGy.cm and Effective dose of 6mSv, for 2-5years age group $CTDI_{vol}$ of 50, DLP of 1395 and effective dose of 5mSv, and for 11-15 years age group $CTDI_{vol}$ of 55mGy, DLP of 1608 and effective dose of 4mSv. The study concluded that there was need to establish customized CT facility optimization strategies, justification and LDRLs specific to facility performing procedure [6].

Problem Statement

The use of Computed tomography (CT) for diagnostic evaluation has increased significantly over the past two decades[7]. This is because CT examination is quick and does not require sedation for children undergoing examination. CT examinations deliver larger radiation doses compared to more common conventional X-ray imaging procedures[8]. A major concern in paediatric imaging is the dose delivered from CT scanning and the risk associated with ionizing radiation. Ionizing radiation has been demonstrated to increase the risk of cancer in individuals who are exposed to high doses. Recent publications have discussed the risk of cancer that can result from lower radiation exposures from CT examinations[9]. There is a wide underestimation of CT radiation dosages and associated risks among clinicians[10]. The concept of “As Low as Reasonably Achievable” is now well accepted among physicians. However exact amount of radiation dose delivered during routine CT examinations has not been well described[11]. There is no published data on local DRLs. A review on published data on DRLs in low and middle-income countries (LMICs) showed only one-quarter of 135 low and middle-income countries had any form of published DRL data of which Kenya and India had leading outputs, most being adult reference levels[1]. This shows the need to scale up DRLs initiatives in children in LMICs.

Study Objective

To establish facility dose reference levels for radiation doses for paediatric head CT examination at Moi teaching and referral hospital.

II. METHODOLOGY

This was a cross-sectional study. The study included patients younger than 15 years of age undergoing head CT examinations as part of their evaluation at Moi Teaching and Referral Hospital. Children under 15 years of age undergoing head CT examinations whose parents /guardians gave consent to participate in study. Systematic sampling was used to select the participants to be included in this study. The first participant was the first patient who met the inclusion criteria on the first day of the data collection. A radiographer with experience in CT imaging was trained to assist with data collection in the absence of the principal investigator. A structured questionnaire was used to record both the patient information and CT scanner radiation exposure parameters.

Descriptive statistics such as frequencies and the corresponding percentages were used to summarize categorical variables such as age groups (0 – 1 year, >1 – 5 years, >5 – 10 years, >10 – 15 years) gender and indication for examination. While the mean and the corresponding standard deviation (SD) were used to summarize continuous variables that assume the Gaussian distribution otherwise the median and the corresponding interquartile range (IQR) were used. Such variables include child age, child weight, CT dose index, CT length product, effective dose, among others.

Students T-test was used to test the significant differences of the independent and dependent variables between different groups. It was used to test if the statistical differences measured in means could have happened by chance. A P value of 0.05 was considered to be statistically significant.

Pearson correlation coefficient and box plots were used to describe the relationship between the radiation doses ($CTDI_{vol,}$ DLP and effective dose) and age, and BMI. Pearson correlation coefficient was used to assess the relationship between the independent variables and the dependent variables including $CTDI_{vol,}$ DLP and effective dose.

The independent variables were categorized as follows; gender (male, female), age (0 – 1 years, 1 – 5 years, 5 – 10 years, and 10 – 15 years), BMI Underweight, Normal, Overweight and Obese. The correlation together with their corresponding P values was reported. All statistical tests were considered to be statistically significant if the p-value was <0.05. Results were presented using tables and graphs.

Ethical approval was sought and granted from the Moi Teaching and referral hospital/ Moi University College of Health Sciences Institutional Research and Ethics Committee (IREC).

III. RESULTS

Table 1: Socio-demographic characteristics

Variable	N	Frequency (n)	Percent (%)
Gender	**127**		
Male		69	54.3
Female		58	45.7
Age in Years	**127**		
Mean 5.10			
SD 4.59			
Height in Centimeters	127		
Mean 97.2			
SD 38.2	127		
Weight in Kilograms			
Mean 18.9	127		
SD 14.6			

Distribution of Head CT scans per age group.

Table 2 shows the distribution of head scans with age groups.

Majority of the patients who underwent head CT scan during the study period were aged between 0-1 at 46 (36.4%) with the least examined age group being >10-15 at 23 (17.8%).

Table 2 Distribution of Head CT scans among the age groups

Exam Type	**0-1Y**	**>1-5Y**	**>5-10Y**	**>10-15Y**	**Total**
Head CT	46	32	27	22	127

Majority of the patients studied were underweight 74 (57.4%) followed by normal BMI 41(33.3%) and least were overweight 12(9.3%).

CTDI vol and DLP

The average CTDI vol value for the head was 32.67 mGy and the average DLP was 1006.1 mGycm. The minimum and maximum values for the DLP were 89.1mGycm and 4720mGycm respectively. The minimum and the maximum values for the CTDI vol were 8.1mGy and 55.9mGy respectively.

The minimum and the maximum pitch values were 0.3 and 10 respectively with a mean pitch value of 4.19.

For scans of the head, the effective dose varied from 0.24 mSv to 16.52 mSv with the mean effective dose being 4.01 mSv.

The average tube voltage used for the head scans was estimated to be 113.6 kV. The mean Slice thickness of acquired head scans was 3.67 mm.

Table 3: Average parameters and effective dose

MEAN and SD VALUES							
Average tube voltage (kV)	**mA's**	**Acquisition slice setting (mm)**	**Pitch**	**Rotation time (seconds)**	**CTDI (Vol) (mGy)**	**DLP (mGy cm)**	**Estimated Effective Dose(mSv)**
113.6	250.9	3.67	4.19	2.36	32.67	1006.1	4.01
SD(11.4)	SD(68.9)	SD(1.62)	SD(1.33)	SD(1.36)	SD(9.23)	SD(624.2)	SD(2.14)

Table 4.: Facility dose reference levels for radiation doses for paediatric head CT examination at Moi Teaching and Referral Hospital.

	Median (IQR)		
	CTDI (Vol) (mGy)	**DLP (mGy cm)**	**Estimated Effective Dose(mSv)**
Median (IQR)	36.5 (8.55)	850.6 (750.65)	3.75 (2.43)
Min-Max	8.10-55.97	89.10-4720	0.24-16.52

The facility dose reference level for head CT at MTRH for $CTDI_{VOL}$, DLP and estimated dose were set at the median values as presented above.

Table: 5 Facility dose reference levels for radiation doses for paediatric head CT examination at Moi Teaching and Referral Hospital according to age.

Median (IQR)				
Variable	**0-1 (N=46)**	**>1-5 (N=32)**	**>5-10(N=27)**	**>10-15 (N=22)**
CTDI (Vol) (mGy)	32.2 (23.3)	37.02 (5.12)	37.5 (6.20)	38.7 (2.96)
Min-Max	13.4-41.76	8.10-43.67	15.8-55.9	23.9-46.6
DLP (mGy cm)	605 (508)	933.3 (662.15)	1391 (654)	1014 (797)
Min-Max	161.2-1712	181.1-4720	352.3-2515	89.1-2657.5
EstimatedEffective Dose(mSv)	4.18 (3.65)	3.87 (2.35)	3.75 (1.37)	2.94 (2.14)
Min-Max	1.42-9.07	0.63-16.52	0.95-6.75	0.24-7.18

A further analysis was done to assess the facility dose reference level for head CT at MTRH with regards to age for

$CTDI_{VOL}$, DLP and estimated dose for ages 0-1,1-5,5-10 and 10 -15 the results as presented above.

Table 6 Comparison between our findings and other studies

	CTDI $_{vol}$		DLP		Effective dose	
CURRENT STUDY	0-1	32.2	0-1	605	0-1	4.183
	1-5	37.02	1-5	933.3	1-5	3.87
	5-10	37.5	5-10	1391	5-10	3.75
	10-15	38.7	10-15	1014	10-15	2.94
NDRL KENYA (Korir et al., 2016).	0-1	38	0-1	1005	0-1	6
	1-5	50	1-5	1395	1-5	5
	5-10		5-10		5-10	
	10-15	55	10-15	1608	10-15	4
NDRL TURKEY (Gokce et al., 2015)	0-1	31	0-1	288	0-1	1.9
	1-5	33.4	1-5	368	1-5	1.5
	5-10	40.3	5-10	267	5-10	1.5
	10-15	51.3	10-15	625	10-15	1.3
DRL SOUTH AFRICA (Vawda et al., 2015).	0-1	30	0-1	488	0-1	
	1-5	31	1-5	508	1-5	
	5-10	32	5-10	563	5-10	
	10-15	32	10-15	563	10-15	
DRL AUSTRALIA (Hayton et al., 2013).	0-1	30	0-1	470	0-1	
	1-5	30	1-5	470	1-5	
	5-10	35	5-10	600	5-10	
	10-15	35	10-15	600	10-15	
NDRL UK (Shrimpton et al., 2006)	0-1	25	0-1	350	0-1	
	1-5	40	1-5	650	1-5	
	5-10	60	5-10	860	5-10	
	10-15	60	10-15	860	10-15	
IAEA (Vassilera et al., 2020)	0-1	26	0-1	440	0-1	
	1-5	36	1-5	540	1-5	
	5-10	43	5-10	690	5-10	
	10-15	53	10-15	840	10-15	
NDRL THAILAND (Kritsaneepaiboon et al., 2012).	0-1	25	0-1	400	0-1	
	1-5	30	1-5	570	1-5	
	5-10	40	5-10	610	5-10	
	10-15	45	10-15	800	10-15	
NDRL SWITZERLAND (Verdun et al., 2008)	0-1	20	0-1	270	0-1	
	1-5	30	1-5	420	1-5	
	5-10	40	5-10	560	5-10	
	10-15	60	10-15	1000	10-15	

We did a comparison of DRL between the current study and several other studies from different parts of the world. With regards to CTDI $_{vol}$ our results corresponded with results from other parts of the world and they were in agreement with another study done at Kenyatta National Hospital.

The DLP comparison with other studies differed with the results of other studies done internationally in that our DLP values in our study and that done in Kenyatta National Hospital differed with other studies done internationally, our findings were higher than the DLP values of theirs. The explanation could be DLP is proportional to scan length. High DLP and effective dose in current study may be associated with human factors such as scanning longer body size attainable due to fast CT scanning technique. It is also difficult to discern fine anatomical detail at the craniocervical junction and upper cervical spine on lateral scout projections in children. High DLP and effective dose could also be attributed to several other factors which include the age of the equipment, limited experience in justifying CT procedures among clinicians and the type of machine used during the scans.

IV. DISCUSSION

It can be concluded that the estimated effective doses received by paediatric patients undergoing head CT procedures at MTRH were within the acceptable values (1 to 10 mSv).

Both developed and developing countries have established dose survey data as a guideline to develop their own DRL in medical imaging procedures. A DRL could serve as a good tool in optimizing the radiation doses of CT examinations in pediatric patients and ensuring good image quality.

These values are compliant with a study done in Malaysia which had the same DRL as our study. The reason for the similarity could be because both studies were conducted in a hospital setting [12]. Another study done in Egypt also mirrored our results with their findings showing results that were within the accepted parameters and in line with the International Radiology Safety Standards the study was also conducted in a tertiary hospital [13]. Another study conducted in South African academic hospitals found out that most of the calculated DRLs are acceptable and internationally comparable [14].

A study conducted at a health center in Sudan had DRL that were not in tandem with the international standards. Their results total contradicted our results and those of the above mentioned studies, the reason for the difference in the DRL could be assumed to have been contributed by the different levels of the facilities [15]. The health worker level at the two levels of health facilities is different and could be the main contributor to the different results [15].

Despite that, multiple studies had stated that it was challenging to balance radiation exposure and image quality due to variances in the patients' body adjustments of CT scanning parameters should be made in the optimization processes, particularly when pediatric patients are involved. The noise reference level and range should be included when determining the DRL values. Therefore, it could be considered an expanded concept of DRL as suggested by IAEA in 2018 and acts as a guide in balancing the radiation exposure [16].

We did a comparison of DRL between the current study and several other studies from different parts of the world. With regards to CTDI $_{vol}$ our results corresponded with results from NDRL Kenya and other parts of the world such as Turkey, South Africa and the United Kingdom .

The DLP comparison with other studies differed with the results of other studies done internationally in that our DLP values in our study and that done in Kenyatta National Hospital differed with other studies done internationally, our findings were higher than the DLP values of countries like Australia, Thailand and the values found by IAEA [17]. The explanation could be DLP is proportional to scan length. The DLP comparison with other studies differed with the results of other studies done internationally in that our DLP values in our study and that done in Kenyatta National Hospital differed with other studies done internationally, our findings were higher than the DLP values. The explanation could be DLP is proportional to scan length. High DLP and effective dose in the current study may be associated with human factors such as scanning longer body size attainable due to fast CT scanning technique. It is also difficult to discern fine anatomical detail at the craniocervical junction and upper cervical spine on lateral scout projections in children. High DLP and effective dose could also be attributed to several other factors which include the age of the equipment, limited experience in justifying CT procedures among clinicians and the type of machine used during the scans.

V. CONCLUSIONS

1. The Facility dose reference level for Radiation dose for paediatric Head in terms of $CTDI_{VOL}$, DLP and Effective dose were within the National DRL.

VI. RECOMMENDATIONS

1. More careful attention should be given when planning CT head examination in children in MTRH to reduce scan length hence the DLP and effective dose in order to maintain the recommended DRL.
2. CT in young children should be used only when other imaging modalities like Magnetic Resonance Imaging (MRI) are not feasible or will not be effective.

Study limitation

Several limitations of this study should be noted. This study was conducted in an urban level 6 hospital and the results may not be generalizable to other organizations where practices may vary.

Despite our methodology of directly obtaining the radiation dose from CT machines, the values were corrected for organ sensitivity to determine the effective dose. This number is an estimate, not a direct measure, of the amount of radiation delivered to body tissues. However, this methodology has been used in prior studies and is accepted as an appropriate method by which compare effective dose across institution and scan types. There was also lack of international uniformity in age stratification for DRL data therefore the comparative component of the present study was limited.

ACKNOWLEDGEMENTS

I would like to acknowledge my research assistants for data entry and questionnaire administration and the patients who participated in this study.

Conflict of Interest: The authors declare no conflict of interest in this study

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