Radiation Doses of Children, Undergoing Computed, Tomography of the Head at Moi Teaching and Referral Hospital

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Abstract:

***Objective*: To determine the Volumetric Computed Tomography Dose Index, Dose Length Product and the effective dose of radiation delivered during routine head Computed tomography examination in children less than 15 years at Moi Teaching and Referral hospital and their association with Body Mass Index and age.**

***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 effective radiation dose decreased as age increased (4.31 to 3.25 mSv, with a P= 0.025 and R=0. 511. There was no association between Body Mass Index and the effective dose (R=0.076).

***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

Computed Tomography refers to a computerized x-ray imaging procedure in which a narrow beam of x-rays is aimed at a patient and quickly rotated around the body, producing signals that are processed by the machine's computer to generate cross-sectional images or slices of the body. The slices also known as tomographic images contain more detailed information than conventional x-rays. Once several slices are obtained by the machine's computer, they can be digitally stacked together to form a three-dimensional image of the patient that allows for easier identification and location of basic structures and pathologies [1].

CT scans uses X-ray beams and all X-rays produces ionizing radiation. According to WHO Ionizing radiation has been described as radiation with enough energy so that during interaction with an atom it can remove tightly bound electrons from an orbit of an atom causing an atom to become charged or ionized. Ionizing radiation has potential to cause biological effects in living tissue. This is a risk that increases with number of exposures added up over an individual's lifetime[2].

Children are especially at risk due to ionizing radiation exposure mainly due to their longer life expectancy, and have a greater chance of living long enough to develop radiation induced neoplasm[3]. Furthermore, they have growing tissues with high cell turnover and high radio sensitivity. Their cells also have a high water content which augments damage from ionizing radiation[4]. A study done in Japan on risk following radiation exposures showed that children were found to be more sensitive to ionizing radiation than adults for development of about 25% of tumor types[5].

As a result of the increasing radiation risk among young children as compared to adults, radiation exposure in children undergoing radiographic imaging is increasingly becoming a public health concern[6]. When using radiation in medical diagnostics the risk on one hand and the benefit on the other are considered [7]. The principles of radiation protection in medicine apply wherever ionizing radiation is used for diagnosis or therapy. This is particularly important in the case of pediatric patients, who have a significant risk from ionizing radiation following X-ray examinations(chest, abdomen and skeletal), Computed Tomography (CT) and Positron Emission tomography (PET) imaging[8].

As low as reasonably Achievable (ALARA) is a principle of radioprotection stating that whenever ionizing radiation has to be applied to humans, animals or materials, exposures should be as low as reasonably achievable. It is rudimentary to the principles of radiation protection[9]. The principle states that to reduce radiation exposure risks, any medical radiation exposure must be justified and any examination which uses ionizing radiation must be optimized. Justification is the process of weighing potential benefit of exposure against risks. The role of justification involves referring physicians, radiographers and radiologists. Optimization means that imaging is performed using dosages as low as reasonably achievable, consistent with diagnostic duty[10].

The International Commission on radiological Protection (ICRP) recently issued specific radiation protection recommendations for the diagnostic and interventional radiology in paediatric population which are justification and optimization [7]. The main purpose of the report was to provide referring physicians and staff performing diagnostic and interventional procedures, as well as equipment vendors with common paediatric radiation protection guidelines. Studies have shown that the level of knowledge among clinicians on radiating medical procedures and justification of requests for the procedures is inadequate [11].

A worldwide movement has arisen with the efforts to ensure optimization of pediatric ionizing radiation doses with CT examinations, optimization efforts generated by Image gently alliance for children who are socially and medically vulnerable population[12]. Recently, Africa Wide campaign on radiation safety (AFROSAFE) was launched. AFROSAFE is a campaign made by radiation health workers in Africa for Africa. Its main goal is to ensure radiation-based procedures are appropriate, justified and optimized for maximum benefit of patients [13].

There are three ways to measure the radiation dose these are the CTDI (Computed Tomography Dose Index), DLP (Dose Length Product) and Effective Dose [1].

Effective dose is the tissue weighted sum of equivalent doses in all specified tissues. Different body parts have different sensitivities to radiation. For example, the head is less sensitive than the chest. Effective dose relates to the overall long-term risk to a person from a procedure and is useful for comparing risks from different procedures.

CTDI is measured in milliGray (mGy) and the Dose length product (DLP) is measured in milliGray.Centimeter (mGy.cm), which are the major radiation dose indicators. These are usually displayed in the CT planning console and give an estimate of the absorbed dose. The European Guidelines on Quality Criteria for Computed Tomography have described region-specific normalized effective dose that can be multiplied with DLP to obtain the broad estimate of the effective dose in milli-Sievert. An alternative way of estimating effective dose is by use of mathematical anthropomorphic phantom using the Monte Carlo techniques[14].

The CTDI is the integral along a line parallel to the axis of rotation (z) of the dose profile (D (z)) for a single slice, divided by the nominal slice thickness T

$$C = (1/T)\int_{-\infty}^{\infty} D_1(z)\,dz,$$

Where

Where:

D (z) = the radiation dose profile along the z-axis,

N = the number of tomographic sections imaged in a single axial scan. This is equal to the number of data channels used in a particular scan. The value of N may be less than or equal to the maximum number of data channels available on the system, and

T = the width of the tomographic section along the z-axis imaged by one data channel. In multiple-detector-row (multi-slice) CT scanners, several detector elements may begrouped together to form one data channel. In single-detector-row (single-slice) CT, the z-axis collimation (T) is the nominal scan width.

CTDIvol represents the average absorbed radiation dose over the x, y, and z directions. It represents the dose for a specific scan protocol, which usually involves a series of scans, and take into account any gaps or overlaps between the x-ray beams from consecutive rotations of the x-ray source.

$$\mathrm{CTDI}_{\mathrm{vol}} = \frac{1}{\mathrm{Pitch}} \times \mathrm{CTDI}_{\mathrm{w}}$$

I = the table increment per axial scan (mm). Since pitch is the ratio of the table travel per rotation (I) to the total nominal beam width (Pitch).

Pitch was defined as the ratio of the table travel per x-ray tube rotation to the slice width (which was typically, but not always, equal to the beam collimation). A pitch of 1.0 indicates contiguous radiation beams, a pitch less than 1.0 indicates overlap of radiation beams, and a pitch greater than 1.0 indicates gaps between the radiation beams

Pitch=1/N x T

To better represent the overall energy delivered by a given scan protocol, the absorbed dose can be integrated along the scan length to compute the Dose-Length Product (DLP)

DLP (mGy.cm) = CTDIvol (mGy) x scan length (cm)

The DLP reflects the total energy absorbed (and thus the potential biological effect) attributable to the complete scan acquisition.

The effective dose, E, is defined in ICRP 60 and ICRU 51. It is the sum over all the organs and tissues of the body of the product of the equivalent dose, HT, to the organ or tissue and a tissue weighting factor, WT, for that organ or tissue, thus:

$$\mathbf{E=\sum_T W_T H_T}$$

The tissue weighting factor, WT, for organ or tissue T represents the relative contribution of that organ or tissue to the total detriment arising from stochastic effects for uniform irradiation of the whole body.

Unit: J/kg. The special name for the unit of effective dose is sievert (Sv). The sum over all the organs and tissues of the body of the tissue weighting factors, WT, is unity.

The effective dose is currently deemed to be the best available dose descriptor for quantifying stochastic risks in diagnostic radiology. The effective dose takes into account the dose and the relative radio sensitivity of all irradiated organs and may be converted into a corresponding estimate of detriment (i.e., carcinogenesis and genetic effects) if proper account is taken of the age and gender of an exposed individual. Patients undergoing CT examinations can range from neonates to oversized adults.

In 1996 the ICRP recommended the use of diagnostic reference levels for the patients as a quality assurance tool for radiation dose optimization. The diagnostic reference levels are not suggested or the best dose for a particular procedure or an absolute upper limit for dose.

The Dose reference should be used as the gold standard when administering CT Scan to patients.

The reference levels act as “trigger levels” to initiate quality improvement and identify dose levels that may be too high and reduce the dosage without compromising on image quality. National diagnostic reference levels (NDRLs) can be established for specific examinations and patients, based on dose distributions in national surveys. The third quartile is the dose most commonly adopted as dose reference level[15]. Local DRLs (LDRLs) can also be determined for a hospital or an imaging practice representing the mean dosage for a specific examination allowing greater control and opportunity for optimization of doses. LDRLs are usually calculated from the mean rather than from the third quartile because of the smaller sample in the survey [16].

This study aims to assess the local doses for paediatric head CT examinations for the purpose of optimization. This will be achieved by sampling dose parameters across several age groups for paediatric head CT examinations performed at Moi teaching and referral hospital. The LDRLs will be derived and mean values of dose indicators ($\mathrm{CTDI_{vol,}}$ DLP and effective dose) compared to National and International DRLs to facilitate benchmarking.

Problem Statement

The use of Computed tomography (CT) for diagnostic evaluation has increased significantly over the past two decades[17]. 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[6]. 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. Exposure to moderate to high doses of radiation increases the risk of cancer in most organs. For all solid cancers combined, cancers of the thyroid, breast and lung, and leukemia, risk estimates are fairly precise, and associations have been found at relatively low doses (<0.2 Gy), Recent publications have discussed the risk of cancer that can result from lower radiation exposures from CT examinations [18]. There is a wide underestimation of CT radiation dosages and associated risks among clinicians[19]. 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 [13]. There is paucity of 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[20]. This shows the need to scale up DRLs initiatives in children in LMICs.

Study Objective

To determine the CT radiation doses delivered during head CT examination for children under 15 years and their association with BMI and age.

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. The subsequent participants were selected systematically at an interval of $k = N/n = 459/127 \approx 3$. Where the participant who fell in the 3 interval did not consent, consent was obtained from the next patient that is the 4th and thereafter recruitment continued at every 3rd interval.

The department has a record book where all patients undergoing CT examinations are recorded therefore every third patient who met the inclusion criteria was identified from the records. This approach was repeated until the desired sample size was achieved. 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. Patients booked for CT were identified and sampled from the CT record book in the CT console room which showed patients booked for CT for the particular day. Patients were recruited into the study systematically in the sequence of which they arrived with regards to the sampling technique. For patients who met the inclusion criteria consent was taken from parent or guardian accompanying the patient. Weight and height measurements were taken before scanning. A weighing scale (Contrex MS-150) with a height meter was obtained by the principal investigator and kept in the CT room where data was being collected. The weighing scale was set at zero before weighing patients. Patients recruited for the study were asked to remove all heavy clothing and shoes before getting on the weighing scale and were asked to remain still as the patient's weight is recorded. For infants and toddlers who could not stand on the weighing scale, the parent was asked to remove shoes and stand on the weighing scale first alone after undressing and covering the infant in a blanket. With the parent still on the scale and her weight displayed the undressed infant was handed to the parent and the difference in the two weights was taken as the infant's weight. While on the weighing scale the height meter was pulled up to obtain the height. For infants and toddlers, a tape measure was used to measure their height/length.

All scans were performed using the standard institution Paediatric head CT protocol in the CT console and the parameters were based on a 16-diameter plastic phantom. Patients were placed supine, headfirst into the gantry, with head in the head holder. The table height was set such that the external auditory meatus is at the center of the gantry. The scan angle was set to be parallel to the supraorbital meatus line, this was achieved by tilting the patient's chin toward the chest ('tucked' position) or by tilting the gantry. The patient was then immobilized by using straps.

The dose parameters and dosed measurements that were displayed in the console were recorded onto the data collection sheets.

The validation of displayed dose measurements was calculated using the following equations (1-4). The CT air kerma index ($CTDI_{100}$) in $mGymAs^{-1}$ for the head phantom was estimated using Equation 1:

$$CTDI_{100} = \frac{1}{NT}\int_{-50\ mm}^{50\ mm} D(z)dz$$

Where,

D(z) = the radiation dose profile along the z-axis,

N = the number of tomographic sections imaged in a single axial scan.

T = the width of the tomographic section along the z-axis imaged by one data channel.

CTDI represents the averaged absorbed dose along the z-axis, from a series of contiguous irradiations. The weighted CT dose index ($CTDI_W$) in mGy mAs^{-1} was obtained using Equation 2. The values of 1/3 and 2/3 approximate the relative areas represented by the center and edge values of a phantom for a particular tube current -exposure time product (mAs):

$$CTDI_W = \frac{1}{3}CTDI_{100,C} + \frac{2}{3}CTDI_{100,P}$$

The volume CT dose index ($CTDI_{vol}$) was obtained using Equation 3 in mGy per volume scanned:

$$CTDI_{vol} = CTDI_w \frac{N \times T}{I}$$

Where I = the table increment per axial scan (mm).

The CT dose length product (DLP) for axial and spiral scanning for complete CT examination was estimated using Equation 4:

$$DLP = CTDI_{vol} \times scan\ length$$

Where scan length is the product of the total number of serial or helical scans and slice width.

Effective dose was estimated using Equation 5:

$$E = E_{DLP} \times DLP$$

Where DLP values calculated in Equation 4 were obtained from questionnaire records, while appropriate region-specific normalized effective dose coefficients (k) values in mSv mGy^{-1} cm^{-1} were obtained from age specific and sex specific conversion factors in ICRP 103. Effective dose coefficients of k-factors are used to convert DLP displayed on the CT console per examination to derive patient-effective doses. The effective dose conversion factors were obtained from data averages over many models of scanners therefore it's non-specific to a CT scanner. The collective effective dose was determined for each age group as a mean effective dose. As a guideline for good practice, the median patient dose values for each age group Head CT examination procedure were determined and proposed as the local dose reference level for the head CT examination. In the study, the effective dose according to age and gender categories were reported.

Data was captured using the questionnaires and those abstracted from the files were entered into an electronic database created using Microsoft Access. The data was de-identified of any personal identifying information before entry into the electronic database and each participant record were assigned a unique identifier to help maintain the anonymity of the data collected during the study. The database with the patient data entered was encrypted with a password to ensure that confidentiality of the patient data is maintained. The computer log-in was also restricted by assigning a user name and a password. The user name and the passwords were available to the research assistant doing the data entry and to the principal investigator. Data verification and cleaning continued as data is collected and entered. Upon completion of data entry and data cleaning the data was backed up using external drives that were encrypted and kept in separate locations to cushion against data loss.

Hard copy questionnaires and data collection forms were stored in a cabinet under lock and key accessible only to the principal investigator. Data collected was shared with the supervisors upon request during study consultation and with the data analyst for analysis.

Statistical analysis was carried out using STATA version 13.1 SE (College Station, Texas 77845 USA). 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, Dose 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 ($\text{CTDI}_{\text{vol,}}$ 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 $\text{CTDI}_{\text{vol,}}$ 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). The approval letter from IREC was presented to the management of the MTRH where a written approval from the CEO, MTRH to allow me to carry out the study was given.

The data collection questionnaires did not have any personal details that could be linked to the subjects. A brief description of the study process and its aims was given to the study population. The study population was not coerced in any way to take part in the study. Those who agreed to take part in the study signed a consent form. Informed consent was obtained from the caregiver or the guardian of the child. The cost of the CT scan was solely met by the participant.

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%).

Clinical Indications for CT

The most common indication for CT was hydrocephalus followed by head injury at 24% and 23.3% respectively. The least clinically diagnosed indication was intracranial bleed at 3.1%.

Table 3: Clinical Indications for CT

Variable	N	Frequency (n)	Percent (%)
Hydrocephalus	**127**	31	24.1
Head injury		29	23
Others-extracranial mass		23	18.6
Seizures/convulsions		13	10.1
Space occupying lesion		10	7.8
Others-congenital anomaly		9	7.0
Intracranial infection		8	6.2
Intracranial bleed		4	3.1

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 4: 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 5 below shows the mean values and standard deviation of the patients distributed among the different age groups

Table 5 Average parameters and effective dose per age group (Mean and SD)

Variable	0-1Y N=46	>1-5Y N=32	>5-10Y N=27	>10-15Y N=22
Average tube voltage (kV)	108.9 SD(SD (9.14)	110.6 SD (13.6)	119.6 SD (10.1)	120.4 SD (7.05)
mA's	246.2 SD (81.4)	257.5 SD (66.9)	240.7 SD (34.7)	263.1 SD (74.1)
Acquisition slice setting (mm)	3.17 SD (1.41)	3.70 SD (1.17)	3.90 SD (1.70)	4.41 SD (2.13)
Pitch	3.99 SD (1.63)	4.22 SD (1.17)	4.53 SD (0.88)	4.16 SD (1.28)
Rotation time (Seconds)	2.06 SD (1.69)	2.58 SD (2.14)	2.29 SD (1.23)	2.74 SD (2.35)
CTDI (Vol) (mGy)	28.5 SD (10.3)	33.8 SD (8.54)	35.6 SD (8.15)	37.1 SD (4.41)
DLP (mGy cm)	646.5 SD(SD (345.5)	1161.9 SD (802.4)	1293.7 SD (455.5)	1186.2 SD (646.6)
Estimated Effective Dose(mSv)	4.31 SD (2.06)	4.33 SD (2.87)	3.77 SD (1.33)	3.25 SD (1.71)

Table 6 Dependent variables compared against Age for Head CT Scans

		Mean Values			
Variable	**0-1Y (N=47)**	**>1-5Y**	**>5-10Y**	**>10-15Y (Reference)**	**P value**
CTDI (Vol) (mGy)	28.5	33.8	35.6	37.1	**0.000**
DLP (mGy cm)	646.5	1161.9	1293.7	1186.2	**0.002**
Estimated Effective Dose(mSv)	4.31	4.33	3.77	3.25	**0.001**

The findings from our study showed that CTDI dose values increased as the age of the patient increased. These results were statistically significant with p values of P=0.000 The DLP dose increased from age 0-10 but decreased after 10 years the results were however statistically significant at P=0.002.

Our results also showed, the effective radiation dose decreased as age increased from year 5 to 15 for patients receiving head CT (4.33 to 3.25 mSv, these results were statistically significant with a p value of $p < 0.001$. The minor discrepancies in the flow could be attributed to the unequal distribution of numbers amongst the different age groups.

Table 7 Dependent variables compared against BMI for Head CT Scans

		Mean Values		
Variable	**Underweight**	**Normal**	**Overweight**	**P value**
CTDI (Vol) (mGy)	32.3	32.6	34.7	0.072
DLP (mGy cm)	1110.7	878.7	780.6	0.387
Estimated Effective Dose(mSv)	4.11	3.90	3.68	**0.018**

The findings from our study showed that CTDI_{VOL} dose values increased as the BMI of the patient increased. These results were however not statistically significant with a p-value of P=0.060.

DLP dose values decreased as the BMI of the patients increased these results were also not statistically significant with a P-value of 0.410.

Our results also showed, the effective radiation dose decreased as BMI increased for patients receiving head CT (4.11 to 3.97 mSv, these results were statistically significant with a p-value of $p < 0.021$.

It was decided to triangulate further our results using median values as shown in the box plots below. The median and IQR ranges of CTDI_{vol} and DLP levels increased with age whereas the effective dose decreased with age this mirrored the results with our mean analysis.

Pearson Correlation between Head CT effective radiation doses. Age and BMI

There was a statistically significant relationship between age and effective CT radiation dose P=0.018, the correlation between the two variables was also strong r= 0. 511. There was however no relationship with BMI P= 0.077(*r* = 0.081).

Table 8 Pearson Correlation between Head CT effective radiation dose vs. Age and BMI

Variable	R	P Value
Age	0.511	0.018
BMI	0.081	0.077

IV. DISCUSSION

The findings from our study showed that $CTDI_{vol,}$ DLP dose values increased as the age of the patient increased. The doses had a wide range in values primarily because of a wider range of x-ray technique factors selected and secondarily due to the variation in children head size.

These findings agree with the principles of radiation protection in paediatric patients which entails the use of less radiation doses in very young children[21]. Our results are also supported by a systematic review which over 10 studies on children aged between 1-10 which also found out that the $CTDI_{vol,}$ DLP dose values increased with age [22]. Similarly, another multicenter study done in Uganda University also mirrored the same findings with the current study [23].

Kharbanda et al in their study also found similar results with the current study where with regards to CTDIvol, DLP dose values, the values increased as the age of the patients increased. Similar to our study also the effective radiation dose decreased as age increased for patients receiving head CT [24].

In our study, the average CTDIvol dose values compared well with the values of other studies which included Thailand, Australia, and South Africa. The findings in our study showed that the $CTDI_{VOL}$ dose values are within the same parameters as a study done in South Africa which showed the dose levels to be 32 [25]. Hayton et al in a study done in Australia found the mean $CTDI_{VOL}$ dose level to be 35 which was within the same parameters with our study [26].

Another multicenter survey in Thailand also found the average values to be 32 which mirrors our findings [27].

Our mean dose values were however different to the ones in UK and IAEA. A study in UK showed the mean average to be 60 which differs with our findings [15].

With regards to DLP and effective dose, our mean values were at par with the average of NDRL Kenya. There was a huge difference between our averages as compared to others like Thailand, Australia, UK and South Africa which had mean values of almost half when compared to our findings.

The results of this study found a strong correlation between the effective dose and the age of patients where the effective dose decreased with increasing age (R= 0.587). The results compared well with a study done in Khartoum Sudan R=0.17 [28]. However, it contrasted another study done in Sudan By Alzimami et al who found no significant difference in effective dose between age groups (p=0.57) [29]. The difference in findings could be explained by the methodology used by Alzimami et al where a retrospective study was done in patients aged 0-10 years only.

The results of this study also found no correlation between BMI and effective CT radiation dose, these findings were similar to a study done by Lodwick et al which also found no significant relationship between BMI and effective CT dose[30]. This was however not the case in another study where a significant association was found between body mass and effective CT dose with a determination r^2= 0.35. [31]. The discrepancies between the two studies could be that the BMI distribution in our study was not equal at all categories whereas the other study had equal distribution among all the BMI categories. It could also be explained by the fact that Huda et al had a small sample size of 23 and collected data on infants aged 0-2years only.

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

V. CONCLUSIONS

1. The mean $CTDI_{VOL}$, DLP and Effective dose for patients undergoing head CT at MTRH was 32.84mGy, 1006.1mGy.cm and 4.01mSv respectively.
2. There was a strong correlation between Effective dose and the age of patients where effective dose reduced with increasing age. However, there was no correlation between BMI and effective dose.

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 Tertiary 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.

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