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Research Article

Determination of Safe Paediatric Computed Tomography (CT) Scan Ranges for Head Scan in Selected Medical Facilities in Rivers State, Nigeria

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ABSTRACT

The field of radiology is still evolving and Computed Tomography (CT) is a specialized modality in medical Radiography. Computed Tomography (CT) scan of tissues, organs, bones, and vessels of the body provides doctors with a much clearer picture of what is happening inside the body than conventional X-rays. This paper is organized around determining the safe paediatric Computed Tomography (CT) Reference Range for head scans in Rivers State, Nigeria, where no previous research has been conducted. It analyzes six paediatric CT scanning centers in Port Harcourt, Rivers State for children aged 0 to 18 years using a retrospective and prospective research design. Using the z-scores for unlimited population, a sample size of 100 was determined at random from National Population Commission data on Rivers State paediatric residents. The children were grouped according to their ages into four viz Group 1 (<1-<5 yrs); Group 2 (5-<10 yrs); Group 3 (10-<15 yrs) and Group 4 (15-<19 yrs). The Kruskal-Wallis statistical rank test and the Kolmogorov-Smirnov test of normality were used to calculate results of the Computed Tomography dose index $CTDI_{vol}$ (mGy) and dose length product DLP (mGy. cm) on head scans at the 75th percentile. This study determined that $CTDI_{Vol}$ is 45.84 -54.08 (mGy) while DLP is 44.95 - 54.81 (mGy.cm). A maximum of 1 millisievert (mSv) per scan and cumulative dose not exceeding 5 mSv per year is a reasonably achievable radiation dose stipulated by U.S. Department of Health and Human Services. The study's findings suggest that if the CT machines were of higher slices (64slices and above) the radiation dose could be reduced further. Using a scaling factor of 0.623 and a conversion factor of 0.017 to convert the CTDIw value to the effective dose, we concluded that a patient will be exposed to a total dose of 2mGy for a CT scan length of 200mm. The study supports the use of a CT scanner with higher slices (64slices and above) in order to advance research on the reference dose for pediatric CT scans.

Keywords: Radiation, Computed Tomography (CT), Paediatrics, Head Scan, CT Dose Index, Dose Length Product.

Introduction

Computed tomography (CT) has grown in popularity as a diagnostic tool over the past 20 years. The fact that radiation doses from frequently performed diagnostic CT exams are higher and more varied than typically indicated (Smith-Bindman *et al.*, 2009) emphasizes the need for improved institutional consistency. Installation and usage of the medical imaging technology are growing in Nigeria despite the potential risks connected to CT procedures (Ekpo *et al.*, 2019).

However, there hasn't been much focus on the monitoring and reporting of computed tomography dose (Thomas *et al.*, 2018). Furthermore, given that paediatric head CT doses in Nigeria are higher than those reported internationally, a dose optimization intervention is required. Computed tomography is a common imaging modality for the diagnosis of trauma, renal calculi, appendicitis, paediatric cancer, and heart issues (Ekpo *et al.*, 2019). Children are more susceptible to developing cancer from ionizing radiation exposure than adults.

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Due to their developing life expectancy after exposure, in the wake of nuclear accidents, and when radiation is used for diagnosis or therapy, children require special care (Donnelly *et al*., 2001). Computed Tomography (CT), a specialized modality in medical radiography, is a branch of radiology that is still developing. The art and science of using radiation to produce images of the body's tissues, organs, bones, and blood vessels is known as computed tomography. Compared to traditional X-rays, a CT scan gives doctors a much clearer picture of what is happening inside the body.

Notably, while developing examination protocols for adult patients, children's needs are occasionally overlooked, despite the rise in the use of CT in pediatric conditions. Consequently, the dose produced is two to six times greater than what is necessary to produce images with a satisfactory level of quality (Donnelly *et al*., 2001). CT scans have two drawbacks: the dangers of ionizing radiation and possible side effects from the intravenous contrast agent, or dye that may be used to improve visibility. Ionizing radiation exposure may slightly increase a person's lifetime risk of developing cancer (US FDA, 2022). Ionizing radiation exposure is particularly dangerous for pediatric patients because younger patients have a higher cancer risk per unit dose of radiation than adults do and the effects of radiation exposure manifest as cancer progress slowly in younger patients. However, in both children and adults, the risk associated with a medically necessary imaging examination is relatively low when compared to the benefit of an accurate diagnosis or intervention. When performing CT scans on children, it is essential to use the right exposure factors because using exposure settings meant for adults could result in a higher radiation dose than is required to produce a useful image for a child. If your doctor recommends a CT scan for you or your child, the US Food and Drug Administration (FDA) advises you to discuss the benefits and risks of the procedure as well as any prior X-ray procedures you or your child may have undergone with them (US FDA, 2022). If a CT scan or other exam involving little radiation exposure is deemed medically necessary, it should always be done. Thus, for pediatric CT scanning, the Computed Tomography Dose Index (CTDI) and Dose Length Product (DLP) for head scans were developed (Ekpo *et al*., 2019). The majority of Nigerians, according to Idowu and Okedere (2020), are covered by the country's public healthcare system, which is insufficient because of a lack of funding, personnel, and resources. In order to close this gap, private healthcare facilities which account for 70% of the country's health services play a crucial role. The main barriers to radiology practice in Nigeria are also a lack of reliable electricity and problems with equipment availability and maintenance. The aim of this study is to determine safe Paediatric Computed Tomography (CT) scan ranges for head scan in selected medical facilities Port Harcourt, Rivers State, Nigeria as the available literature indicates that no research has been done on paediatric CT scan in in the study area. The study's specific goals are to calculate the dose length product (DLP) and computed tomography dose index (CTDI) for pediatrics.

Materials and Methods

Study Area

The study areas are six (6) selected medical facilities all located within the Port Harcourt metropolis of Rivers State, Nigeria. Port Harcourt metropolis is located between Latitude $5'11''$and $5^{o}15'45''$ North of the equator and Longitude $6^{o}22'25''$and $8^{o}5'12''$ East of the Greenwich meridian. The selected medical facilities are, Rivers State University Teaching Hospital (RSUTH) - located at 84 Forces Ave, Orogbum, Old GRA, Port Harcourt; University of Port Harcourt Teaching Hospital (UPTH) –located along East-West Road, Chioba, Port Harcourt; Orange Diagnostics Limited, –located at 32 Orieku Street, off Ogbunabali Road, Nkpogu, Port Harcourt; Image Diagnostics, –located at Omaduma Street, off Elegbam Road, Port Harcourt; Intercontinental Diagnostics Port Harcourt –located at No 5 Ezimbgu link road / MummyB road, GRA Phase 4, Port Harcourt; and Georges Diagnostics Centre –located at Ezimgbu Road, Rumuola, Port Harcourt. These selected medical facilities are designated Centre 1, Centre 2, Centre 3, Centre 4, Centre 5, and Centre 6 respectively.

Principal equipment used in this study

The equipment used in this study are 6 Multi-Slice CT scanners with the following characteristics as obtained from the study centres: **Centre 1, 2, 5 and 6:** Manufacturer: GE, Model: Brivo, Number of slices: 64, Aperture: 70, Tilt: $\pm$30°. **Centre 3:** Manufacturer: GE, Model: Bright speed, Number of slices: 4, Aperture: 50, Tilt: $\pm$30°. **Centre 4:** Manufacturer: Siemens, Model: Somatom, No. of slices: 16, Aperture: 70, Tilt: $\pm$ 30°.

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The study target population is children between ages 0-19 years. This was in reference to the study population of 1,871,982 children between ages 0-15 years reported by National Population Commission (NPC, 2006 cited in city population, 2023).

Sample Size

The sample size was derived using the z-scores unlimited population sample size determination.

$$n' = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

Where:

z is the z score = 1.16

ε is the margin of error 95%

$\hat{p}$ is the population proportion (0.25)

Thus:

$$n' = \frac{(1.16)^2 \times 0.25(1-0.25)}{(0.05)^2}$$

$$\frac{1.3456 \times 0.1875}{0.0025} = \frac{0.2523}{0.0025}$$

$$= 100.92 \cong 100$$

Therefore, the sample size for the study is 100 paediatrics for head CT Scan.

Sampling Technique

Children who had a government-certified birth certificate and had undergone a referred CT head scan examination within two months of the data collection were eligible for inclusion. They could also have been undergoing CT scan exams while the research was being conducted at the facility. Subjects without a valid birth certificate were excluded. The patients' birth certificates were used to determine their ages. Basic anthropometric measurements include BMI, stature (height), and body mass index (BMI). The following instructions for measuring height serve as an example of how to take the measurement. The person must touch an upright surface with their heels, buttocks, and back while standing straight. The heels ought to be flat on the ground and paired. It is calculated in meters. With a height meter set to the nearest meter (m) and a weight scale set to the nearest kilogram (kg), measurements of height and weight were taken. With respect to their ages, the children were grouped into four viz Group 1 (<1-<5 yrs); Group 2 (5-<10 yrs); Group 3 (10-<15 yrs) and Group 4 (15-<19 yrs).

Computed Tomography Dose Index: Is derived using (Dowsett *et al.*, 2006):

We calculated the CTDI value using the following formula: (1)

CTDI = CTDIw x DLP x Kf (1)

Where CTDIw is the weighted CTDI, DLP is the dose-length product, and Kf is the conversion factor. The next step is to calculate the weighted CTDI (CTDIw). This value is calculated using the following formula:

CTDIw = CTDI100 x k (2)

Where CTDI100 is the CTDI value at 100 mm, and k is a scaling factor. The scaling factor depends on the size of the patient and the region being scanned. To calculate the dose-length product (DLP). This is a measure of the total amount of radiation exposure during a scan, and it is calculated using the following formula:

DLP = CTDI x scan length (3)

A scan length of 200 mm was used, which is appropriate for pediatric head scans. This gives a DLP value of:

DLP = 0.017 x 0.623 x 200 = 2.1182 mGy.cm. (4)

Using a scaling factor of 0.623 and a conversion factor of 0.017 to convert the CTDIw value to the effective dose. This means that the patient will be exposed to a total dose of 2mGy.

Results were calculated to the 75th percentile. Statistical analysis was performed using Microsoft Excel software.

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Dose and scan parameters were expressed as mean, range and third quartile ($CTDI_{vol}$, and DLP).The study also used SPSS v.22 to perform the analyses for Kruskal-Wallis H Kolmogorov-Smirnov Tests at 0.001 degree of significance while variance was determined using Kruskal-Wallis, Test (Kruskal &Wallis, 1952), of which the result for four groups are related presented in Tables and charts. The results obtained was compared to both national and international best practices to arrive at acceptable head scan CT ranges for Paediatrics in Port Harcourt.

Results

The result of the mean values of the basic anthropometric variables of the different age groups for head scan is shown in Figure 1.

The results of the Computed Tomography dose index $CTDI_{vol}$ (mGy) and dose length product (mGy. cm) on head scans at the 75th percentile for paediatrics in Port Harcourt is as recorded in Table 1 below.

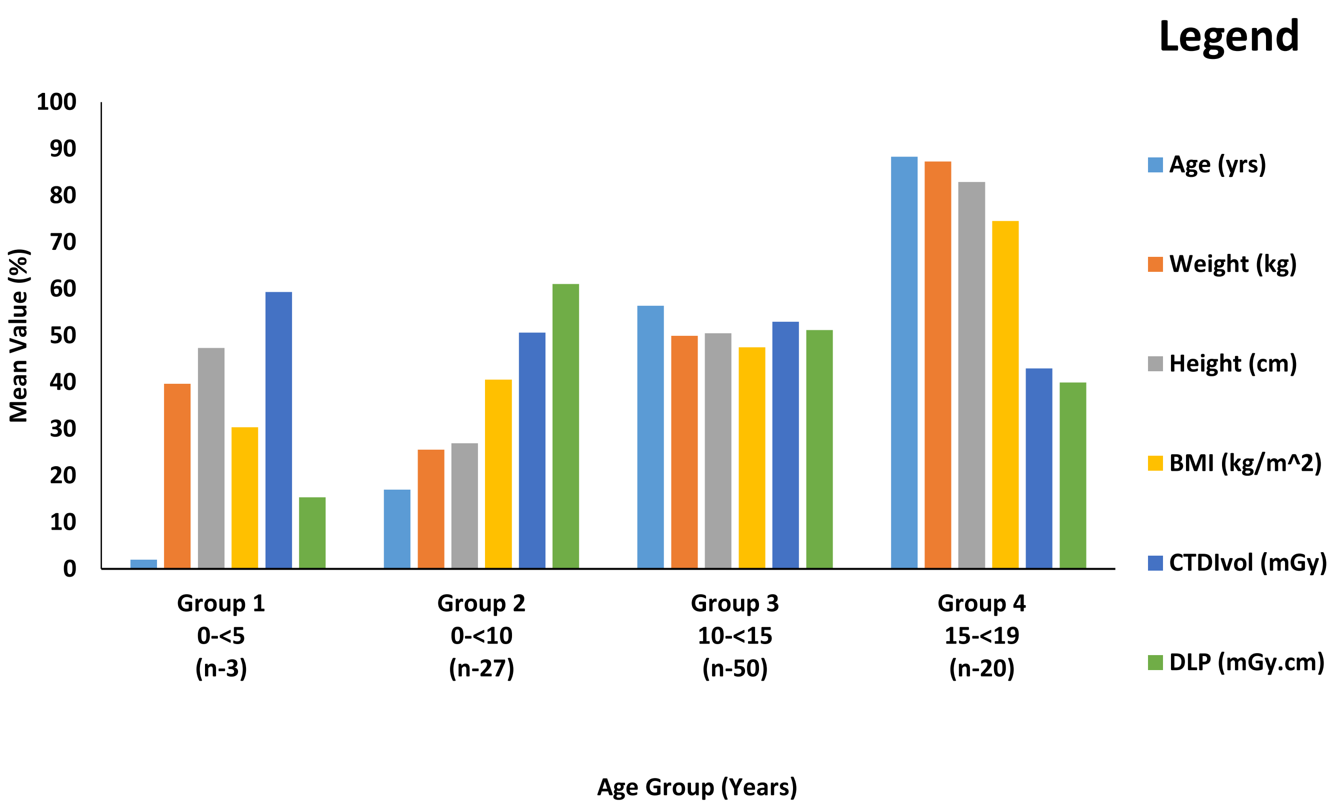

Fig. 1: Mean values of anthropometric variables of age groups for head scan

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Table 1: Basic anthropometric variables and Computed Tomography dose index $CTDI_{vol}$ (mGy) and dose length product (mGy. cm) on head scans for paediatrics in Port Harcourt

Parameters	N= 100	Mean	Range Min-Max	Percentiles 25th	50th (Median)	75th	Kruskal-Wallis H Df=3	Asymp. Sig	Mean Rank Group 1 0-<5 (n-6)	Group 2 0-<10 (n-31)	Group 3 10-<15 (n-42)	Group 4 15-<19 (n-21)
Age (years) (<1 - <19)		10.65±3.93	1.00-18.00	8.0000	11.0000	14.0000	83.871	0.000	3.50	22.31	59.50	87.55
Weight (kg)		38.75±14.05	9.30-80.00	28.5000	39.0000	48.7500	49.970	0.000	17.58	28.87	55.82	81.19
Height (cm)		2.12±5.46	38-46.50	1.2500	1.3700	1.5600	38.293	0.000	19.17	31.66	55.95	76.36
Body Mass (kg/m^2)		19.46±4.09	1.14-26.80	17.7900	19.6500	21.2000	30.826	0.000	31.50	34.21	51.67	77.64
$CTDI_{vol}$ (mGy)		27.01±13.519	5.06-53.75	11.6800	30.2700	39.0100	1.513	0.679	52.25	45.84	54.08	49.71
DLP $(mGy.cm)$		532.27±273.42	46.60-1034.54	286.9500	522.9800	777.6925	1.860	0.602	50.67	48.39	54.81	44.95

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Discussion

This present study has revealed the estimated values of the Computed Tomography (CT) scan ranges of Computed Tomography dose index $\mathrm{CTDI_{vol}}$(mGy) and dose length product DLP (mGy. cm) for head scan in selected medical facilities in Port Harcourt, Rivers State, Nigeria. The study has also revealed the anthropometric variables of the paediatrics.

Results in Table 1, showed that, the acceptable dosages were 52.25 mGy and 50.67 mGy.cm for Group 1 (ages <1–5), 45.84 mGy and 48.39 mGy.cm for Group 2, 54.08 mGy and 54.81 mGy.cm for Group 3; 49.71 mGy and 44.95 (mGy.cm) for Group 4 (ages 15≤19). Our results presented a lower value suitable for paediatrics than that presented in (Griciene and Siuksteryte, 2021). He estimated median DLP values for routine head CT as 116.1 mGy·cm for 0−3 months old group, 163.4 mGy·cm for 3 months − 1 year old group, 231.9 mGy·cm for 1–6 year old group, 284.2 mGy·cm for ≥ 6 year old group and suggested it should be reduced by 50%. Additionally, Figure 1 demonstrated that age and weight increased across Groups (1-4), with Group 1 experiencing the least increase and Group 4 experiencing the greatest. Additionally, it was found that patients' height rose from Groups 1 through 3, but fell in Group 4. We also noted that BMI dropped throughout Group 1 but steadily rose from mid-Group 2 to Group 4. More importantly, the data reveals that there is an increase from the middle of Group 2 until early in Group 4, when it took another decrease.

This result is also validated by (Griciene, Bareike and Krynke, 2018). Notably, there was a decrease in Group 1. This is significant because it shows that dosage needs to go down with very young babies and only go up as they age, though as they get even older they need less dosage. However, there was a decrease in $\mathrm{CTDI_{vol}}$ (mGy) and DLP (mGy. cm) across the Groups as recorded in the Head Scans.

Determined Computed Tomography Dose Index and Dose Length Product

This study determined that the 75th percentile of pediatric CTDIvol for head and the corresponding DLP values are 45.84 - 54.08 (mGy) and 44.95 (mGy.cm) 54.81 (mGy.cm) is acceptable for head scans. This results agrees with Suleiman and Ibrahim (2019) who obtained the paediatric head based on age group 0 - 1 yr, 1 - 5 yrs, 6 - 10 yrs and 11 - 15 years are 28.18 mGy, 32.12 mGy, 32.13 mGy and 28.20 mGy and corresponding DLP values 399.75 mGy·cm, 514.38 mGy·cm, 578.42 mGy·cm and 487.11 mGy·cm respectively and for paediatric abdomen from 1 - 5 years to 11 - 15 years are 3.98 mGy, 4.26 mGy and 5.92 mGy and the corresponding DLP 99.36 mGy·cm, 160.84 and 235.85 mGy·cm. The model and make of the equipment used may have had an impact on the results. It also in line with the findings of American College of Radiology Dose Index Registry (Kanal *et al.*, 2021) as the results meet up with dictates of ALARA – As Low As Reasonably Achievable, and safety for practice of the Nigerian Radiation Safety in Diagnostic and Interventional Radiology Regulations, (FGN, 2006). As similar result for head scan by the American College of Radiology Dose Index Registry were $\mathrm{CTDI_{vol}}$(mGy) (19 to 55) mGy, and DLP(mGy. cm) (267 to 910) mGy. cm for head Scan.

In conclusion, this study that was designed to determine safe paediatric CT scan ranges for head scan in selected medical facilities in Rivers State, Nigeria successfully determined Diagnostic Reference Ranges for Paediatric Computed Tomography (CT) in Port Harcourt, Rivers State, Nigeria was based on retrospective and prospective analysis of $\mathrm{CTDI_{vol}}$ (mGy) and DLP (mGy. cm) dosages for paediatrics varied from ages 0-18 years both for males and females used for the study.

Howbeit, their dosages can be adjusted to fall between the determined dose range developed in this study, with consideration to their weight and height.

Although CTDIvol and DLP dose values for heads are significantly higher, the 75th percentile of these values for routine head scans are comparable to those reported internationally in literature. High doses may be caused by technical factors, thus, choosing the right parameters and optimizing dose variation are highly recommended.

Furthermore, this dosage is suitable for all radiographic head paediatric CT procedures which ranges from soft tissue monitoring, head injuries and bone fractures, even as they strive to improve their performance.

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