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Radiation dose metrics assessment during 64 slice Computed Tomography examination

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ABSTRACT

Background: Computed Tomography (CT) is a medical imaging device. The study is aimed at evaluation of the scan parameters, dose metrics, and their reference levels during 64 slices brain computed tomography.

Methodology: It was an empirical study with patients referred for brain CT scan using 64 slice CT scanner. Participation in the study was voluntary, and ethical clearance was obtained before commencement of the study. The head circumference was measured with a measuring tape that was tightly fitted around the widest aspect of head circumference. The tube current and voltage were selected during the study, and the Volumetric Computed Tomography Dose Index (CTDIvol) obtained by measuring the beam width, width of a single acquired slice, and the radiation dose profile.

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The Dose Length Product (DLP) was obtained by multiplying the total scan length with the CTDI. A descriptive statistical tool was used to analysis the data, and the obtained results were presented in tables and charts.

Results: The age of participants ranges from 49-74years with a mean age of 61.00±9.12 years. The mean kVp and mAs (±standard deviation) were 87.60±10.91 and 108.20±8.28 respectively. While the mAs reference range was 100 to 120. The CTDI reference range was 20.65 mGy to 380.79 mGy with a mean (±standard deviation) CTDI of 59.31±68.48 (mGy). The DLP reference ranges from 256.60mGy-cm to 1144.80mGy-cm with a mean of 704.43±267.07 mGy-cm. There was a strong positive correlation between kvp and mAs with a Pearson's Correlation coefficient (r) of 0.689. No correlation was seen between Kvp and CTDI.

Conclusion: The study provided the reference ranges of the kVp, mAs and CTDI. Information concerning the use of the KvP to predict mAs was also provided by the study. There is a need for a multicentre study with increased study population to obtain a multicentre perspective of the reference levels.

Keywords: Computed Tomography, Computed Tomography Dose Index, Dose Length Product, Brain Computed Tomography, tube current and tube voltage

Background

Computed Tomography (CT) is a medical imaging machine that is used medically in the diagnosis and treatment of diseases. The device has the ability to provide anatomical and functional information concerning the internal organs of the body. There has been a very significant and rapid increase in the use of device globally in the past years. The device uses ionising radiation in the form of x-rays, which is produced when very high-energyfast-moving electrons strike a target material. During imaging, the CT, the x-rays penetrate the human body and are attenuated, which results in the production of cross-sectional images for the purposes of diagnosis. According to Burshberg et al., 'Radiation is the energy that comes from a source which travels through space with the speed of light'. 'The absorbed radiation is the amount of radiation energy that is absorbed per unit mass, expressed in joules per kilogram." During imaging, the ionizing radiation passes through the body, some of which is absorbed and the others attenuated. The attenuated energy is received by the detectors and displayed as axial images. The tube voltage is the voltage applied to determine the energy of the radiation. The tube voltage is the exposure factor that determines the quality and quantity of the x-rays during the process of imaging. The amount of radiation energy produced during imaging is proportional to the square of the tube voltage.

During imaging, the operator manually selects the peak kilovoltage with the objective of obtaining good quality image. The amount electrons that are accelerated across the tube towards the anode material is determined by the tube current.

Therefore, the quantity of electrons that are accelerated across the tube to the anode is directly on the applied tube current (mA). This is to say that the more the tube current, the higher the number of x-rays production. The dose metrics, which is the standardized measure of the CT Scanner radiation dose output, is called the Volumetric Computed Tomography Dose Index (CTDI) which is measured in mGy. The dose metrics of CT scanners that show the overall dose output by putting into consideration the scan length is the dose-length product (DLP). The dose-linear product (DLP) is the product of the CTDI-vol and the scan length in centimeters, thus a measure of CT tube radiation output. 'The DLP is meant to be a comparison metric for different CT machines. Appropriate exposure factors such as peak kilovoltage and mAs are required to achieve a good radiologic image that is justified with radiation dose that is as low as possible.

The study is aimed to evaluate scan parameters, dose metrics, and reference levels during 64 slice Computed Tomography examination.

MATERIALS AND METHOD

The study was a descriptive study with 25 participants that were referred for brain CT scan investigation. The study was carried out in the Rivers State University Teaching Hospital with 64 slice computed tomography scanner. The 64 slice GE computed tomography machine was having recent calibrations and quality control measurements. Participation on the study was voluntary. Ethical clearance for the study was obtained from the Rivers State University Teaching Hospital Health Research Ethics Committee.

A well-calibrated measuring tape was used to measure the head circumference of the participants in centimeters (cm). The head circumference was measured with a measuring tape that is tightly fitted around the widest possible circumference of the head from the most prominent part of the forehead 2cm above the eyebrow to the occipital protuberance, which the widest part of the back of the head.

During the procedure, the tube current and tube voltage (exposure factors) were selected and recorded for each patient, while the Volumetric Computed Tomography Dose Index ($CTDI_{vol}$) was obtained using equation below.

(1) $$\boldsymbol{CDTI = \frac{1}{nT}\int_{-z}^{+z} D(z)dz}$$

Where: n is the number of slices acquired per single axial rotation, nT is the nominal beam width, T is the width of a single acquired slice, D(z) is the radiation dose measured at position z along the scanner's main axis - the dose profile.

The Dose-Length Product (DLP) **was** obtained from values of the CTDI. It is the product of the CTDI and total scan length as shown in the equation below [9].

(2) $$\boldsymbol{DLP = CTDIvolxnT}$$

Where *nT* is therefore the total scan length.

The data obtained was analysis using descriptive statistical tool. Pearson correlation coefficient and linear regression analysis models were used to evaluate the correlation between variables. The Statistical Package for Social Sciences (SPSS) Windows version 22.30 statistical software (SPSS Inc, Chicago, Illinois, USA) was used to analyze the collated data. The results obtained were later presented in tables and charts.

RESULTS

The age of participants ranges from 49-74years with a mean age of 61.00±9.12 years (Table 1). The mean kVp (±standard deviation) for the 64 slice CT scanners was 87.60±10.91, while the mAs range from 100 to 120 with a mean (±standard deviation) mAs of 108.20±8.28 (Tables 1 and 2). As shown in Tables 1 and 2, the CTDI ranges from 20.65 mGy to 380.79 mGy with a mean (±standard deviation) CTDI of 59.31±68.48 (mGy). The DLP ranges from 256.60mGy-cm to 1144.80mGy-cm with a mean of 704.43±267.07 mGy-cm (Tables 1 and 2). Table 2 also shows that the mAs range from 100.00 to 120.00 with a mean value of 108.20±8.28.

The male participants account for 48% (n=12) with a mean age of 61.00+9.12(table 3). The mean BMI of the male participants was 26.02+4.39 while the tube voltage product was 88.33+9.37 (table 3). The CTDI and DLP of the male participants were 75.97+97.05 and 719.27+284.19 respectively (table 3).
As shown on tables 4 females accounted for 13(52%). The mean age of the males participants was 64.46+8.05 years. The females have a slightly higher BMI when compared to the males, while the mean DLP among females was 690.74+261.15 (mGy-cm) as also shown on tables 3 and 4. The mean head circumferences of the male and female participants were 58.35±1.72 and 54.89±2.03 respectively (tables 3 and 4).

The kvP showed no correlation with the CTDI but revealed a strong positive correlation with the mAs, and DLP with Pearson's correlation coefficient (r) of 0.689 and 0.577 respectively, within a confidence interval of 0.01 (*p* value of 0.01) as demonstrated on table 5. The CTDI correlation with kVp, mAs, and DLP showered no correlation. However, there was a strong correlation between mAs and DLP with a Pearson Correlation 0.913 within a confidence interval of 0.01 (*p* value of 0.01) as shown on table 5. Table 5 also shows a weak positive correlation between head circumference and mAs with a Pearson's correlation coefficient (r) of 0.165 while the correlation between head circumference and CTDI and head circumference showed a no significant correlation with a Pearson correlation coefficient (r) of 0.033. Table 6 shows the CTDI values of the present study compared with other Nigeria-based studies showed that the present study was slightly higher than the other of Nzotta et al 2016 (54 mGy), Ogbole et al 2014 (73.5±4.2 mGy) and Adejoh et al 2016 (48 mGy).

The DLP values of the present study compared with other studies (table 7) showed that the values of the present study was lower than the other of Korir et al (15) , Ogbole et al (11), Adejoh et al (12) and Wardlaw (14) in Canada. The scatter plot Scatter plot of age against head circumference of participants shows a non-patterned distribution of variable which signifies a non-linear relationship between age and head circumference (figure 1). Linear regression analysis yielded a linear equation where y is head circumference (cm) and x is age in years (Figure 1).

(3) y=-0.0538x+59.932 r2 = 0.0327

The scatter plot Scatter plot of KVP against head circumference, mas against head circumference, CTDI against head circumference, and DLP against head circumference of participants showed a non-patterned distribution of variable which was suggestive of a non-linear relationship between variables (kvp, mas, CTDI and DLP) and head circumference (figures 3-5). Linear regression analysis yielded a linear equation where y is head circumference and x is kvp, mas, CTDI and DLP as shown on equations 4-7 respectively.

(4) y=0.0262x+58.849 r2= 0.0125
(5) y=0.051x+51.034 r2= 0.0273
(6) 0.0012x+56.47 r2= 0.0011
(7) y=0.0006x+56.141 r2= 0.0037

Table 1. Patient exposure parameters (KV and mAs) with resultant CTDI (vol) and DLP of each patient using 64 slice CT scanner

S/N	Age (Years)	Head Circumference (cm)	KV	mAs	CTDI (mGy)	DLP (mGy-cm)
1.	49.00	57.8	100.00	120.00	69.60	1024.46
2.	50.00	61.1	80.00	110.00	58.14	732.08
3.	57.00	59.9	90.00	120.00	69.06	1044.35
4.	56.00	54.1	80.00	100.00	29.23	423.10
5.	74.00	57.9	100.00	100.00	40.81	382.28
6.	66.00	51.7	120.00	120.00	69.06	1048.50
7.	67.00	58.5	80.00	100.00	30.81	366.38
8.	68.00	55.6	100.00	120.00	59.26	1054.60
9.	39.00	59.1	80.00	100.00	50.80	256.60
10.	61.00	56.2	80.00	100.00	380.79	468.30
11.	63.00	60.5	100.00	120.00	69.06	1144.80
12.	60.00	54.3	80.00	100.00	30.30	479.80
13.	67.00	58.1	80.00	100.00	30.61	361.08
14.	64.00	57.5	80.00	100.00	40.82	385.04
15.	65.00	58.1	100.00	120.00	39.45	1044.30
16.	53.00	51.7	80.00	100.00	20.65	503.90
17.	64.00	54.8	100.00	110.00	58.34	683.80
18.	56.00	55.6	90.00	115.00	48.20	842.80
19.	68.00	56.2	80.00	110.00	38.30	860.69
20.	68.00	56.8	80.00	110.00	28.20	780.30
21.	69.00	55.3	90.00	110.00	48.03	668.70
22.	70.00	54.1	80.00	110.00	48.20	722.97
23.	70.00	57.2	80.00	100.00	38.30	698.27
24.	72.00	52.9	80.00	100.00	38.50	785.70
25.	74.00	58.8	80.00	110.00	48.13	848.00

Table 2. KVp, mAs, DLP and radiation doses ($CTDI_{vol}$) 64 SLICE MACHINE

VARIABLES	N	REFERENCE LEVELS	Mean ± Std. Deviation
Head Circumference (cm)	25	51.70 to 61.10	56.55±2.55
KV	25	80.00 to 120.00	87.60 ±10.91
mAs	25	100.00 to 120.00	108.20±8.28
CTDI(mGy)	25	20.65 to 380.79	59.31±68.48
DLP(mGy-cm)	25	256.60 to 1144.80	704.43±267.07

CTDI: Computed Tomography Dose Index, DLP: Dose Length Product

Table 3. Patients age, Head circumference, exposure parameters, CTDI and DLP of males participants

Variables	N	Mean	Std. Deviation
AGE (years)	12	61.00	9.12
Head circumference (cm)	12	58.35	1.72
Tube voltage product	12	88.33	9.37
Mean tube current	12	109.58	8.11
Computed Tomography Dose Index	12	75.97	97.05
Dose Length Product (mGy-cm)	12	719.27	284.19

Table 4. Patients age, Head circumference, exposure parameters, CTDI and DLP of females participants

Variables	N	Mean	Std. Deviation
AGE(years)	13	64.46	8.05
Head circumference (cm)	13	54.89	2.03
Mean tube voltage product	13	86.92	12.51
Mean tube current	13	106.92	8.55
Computed Tomography Dose Index	13	43.92	14.54
Dose Length Product (mGy-cm)	13	690.74	261.15

Table 5. The correlation between exposure parameters (kVp, mAs,), head circumference (HC), CTDI, and DLP

		KVp	mAs	CTDI	DLP	HC
kVp	Pearson Correlation	1	.689**	-.007	.577**	-.112
	Sig. (2-tailed)		.000	.974	.003	.594
mAs	Pearson Correlation	.689**	1	-.048	.913**	.165
	Sig. (2-tailed)	.000		.820	.000	.430
CTDI	Pearson Correlation	-.007	-.048	1	-.047	.033
	Sig. (2-tailed)	.974	.820		.823	.874
DLP	Pearson Correlation	.577**	.913**	-.047	1	.061
	Sig. (2-tailed)	.003	.000	.823		.772
HC	Pearson Correlation	-.112	.165	.033	.061	1
	Sig. (2-tailed)	.594	.430	.874	.772	

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 6. Comparison of 64 slice CT slices CTDI values with results from other studies.

S/N	Author/Year	Study topic	Result (mGy)
1	Nzotta et al 2016 (Nigeria) [10]	Radiation dose from exposure to computed tomography scan of the brain in a reference hospital in Nigeria	54
2	Ogbole et al 2014 (Nigeria)[11]	Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria	73.5±4.2
3	Adejoh et al 2016 (Nigeria)[12]	Tomography: Dose output and relationship with anthropotechnical parameters	48
4	64 slice CT	This study	59.31(±68.48)

Table 7. Comparison of 64 slices CT DLP with results from other studies.

S/N	Author/Year	Study Topic	Result (mGy-cm)
1	Ogbole et al 2014 (Nigeria) [11]	Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria	1898
2	Adejoh et al 2016 (Nigeria)[12]	Tomography: Dose output and relationship with anthropotechnical parameters	874
3	Ekpo et al 2018.(Nigeria)[13]	Diagnostic reference levels for common computed tomography (CT) examinations: results from the first Nigerian nationwide dose survey.	1179 (median) 1310(75th percentile)
4	Wardlaw (2017). (Canada)[14]	Diagnostic Reference Levels (DRLs): Concepts, Canada, and Constraints, in Health Canada	1098
5	Korir et at (2016) Kenya [15]	National diagnostic reference level initiative for computed tomography examinations in Kenya	1612
6	64 slice CT	This study	704.43±267.07

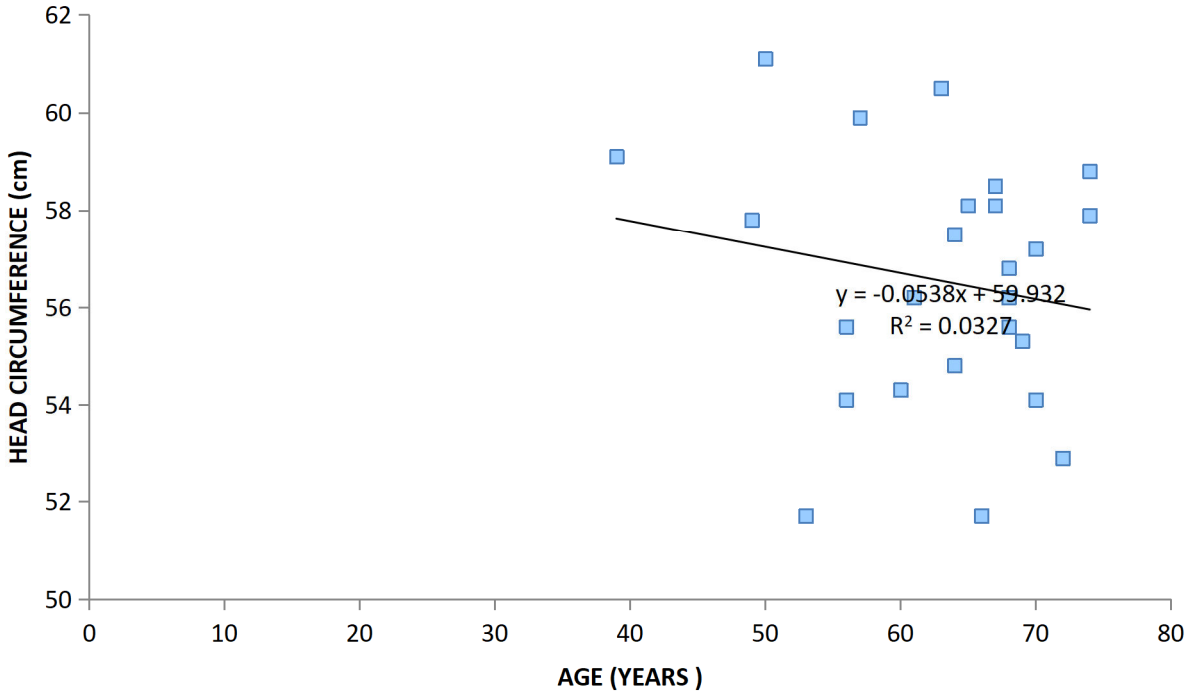

Figure 1. Scatter plot of age against head circumference of participants

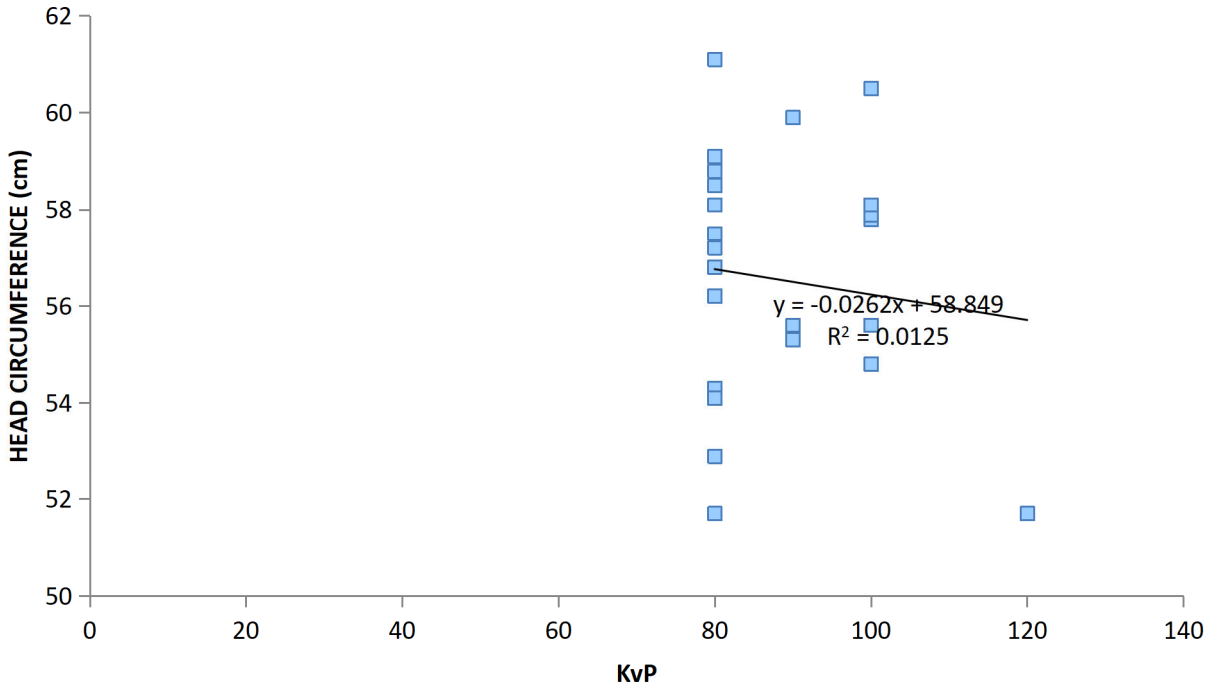

Figure 2. Scatter plot of patients KvP against Head Circumference

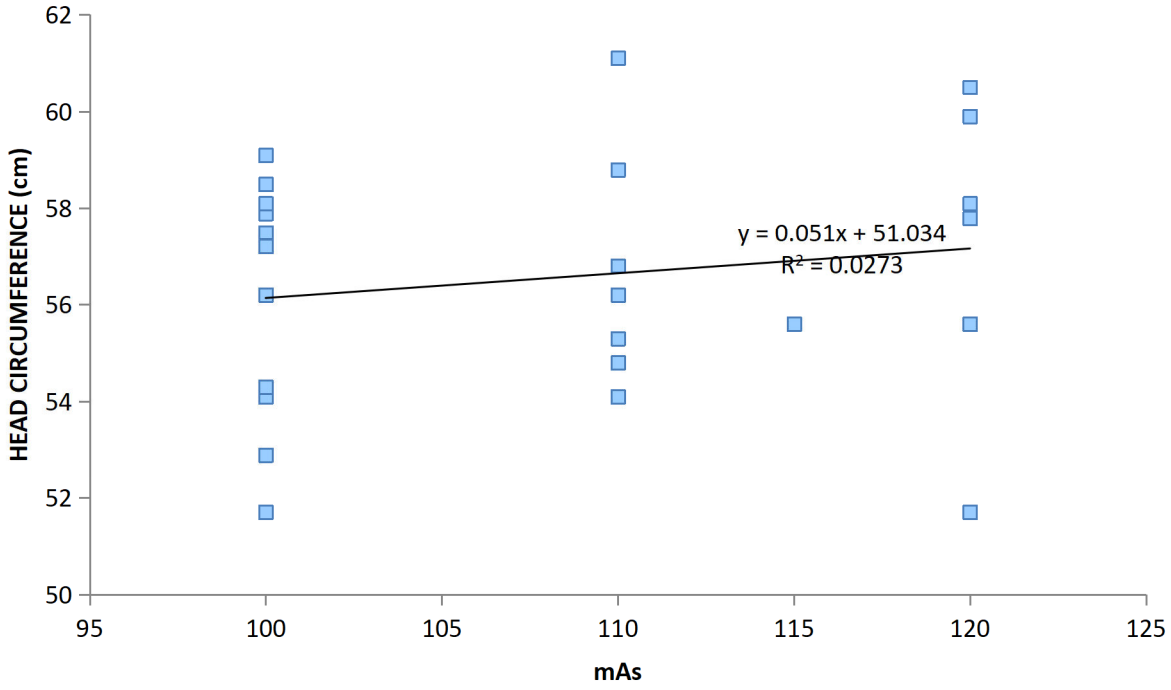

Figure 3. Scatter plot of patients mAs against Head Circumference

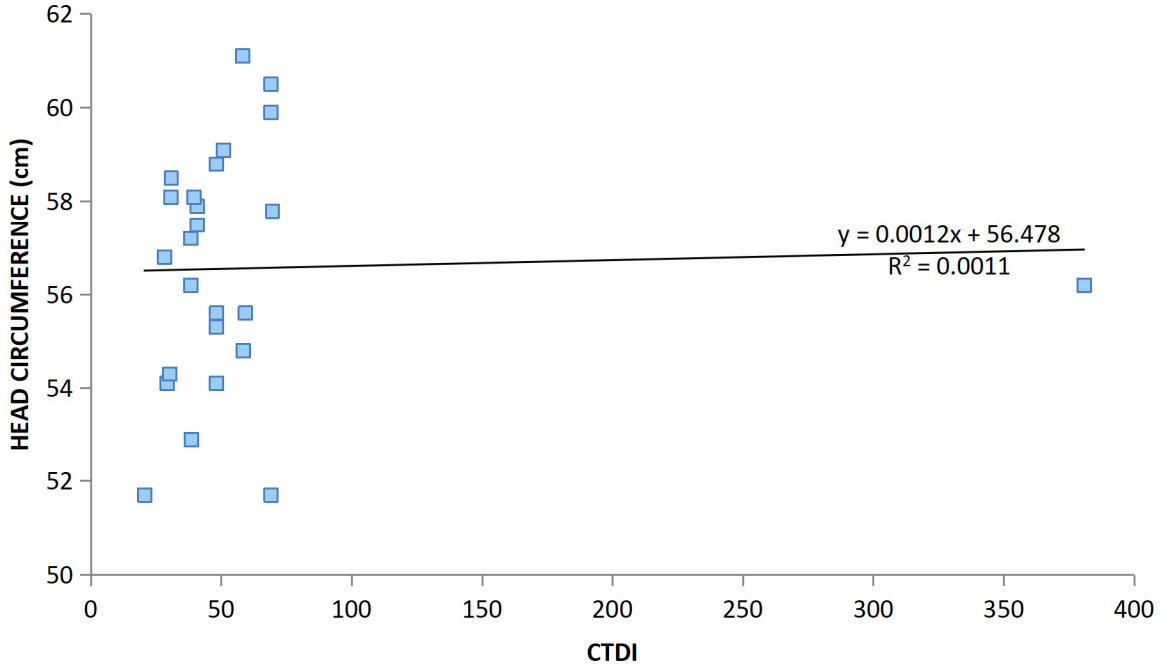

Figure 4. Scatter plot of patients CTDI against Head Circumference

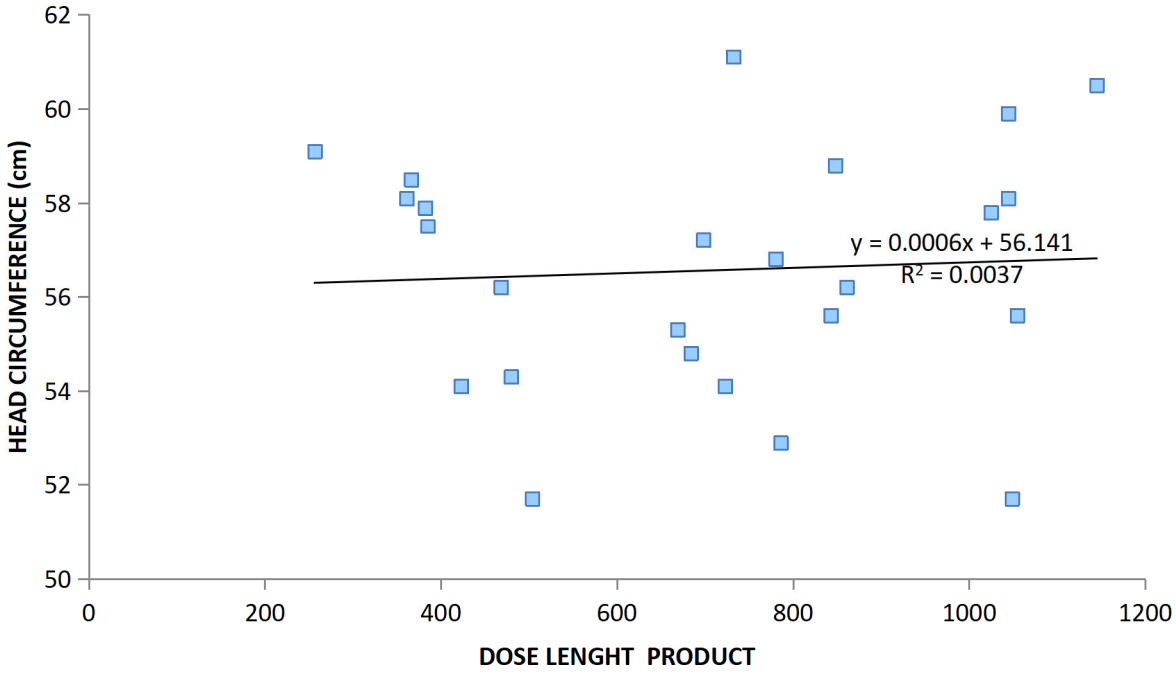

Figure 5. Scatter plots of patients Dose Length Product against Head Circumference

DISCUSSION

Concerning the CT scan parameters, the mean tube voltage product (kVp) was 87.60±10.91, however, in similar study to evaluation of radiation risks during CT brain procedures among adults (16) with 60 participants showed a mean tube voltage product (kVp) (kVp) of 120 using a 64 slice CT scanner. The value obtained in the present study was comparatively lower than that by Semghouli et al. (16) in morocco. The difference in the mean tube voltage product (kVp) may be due to the availability of a diagnostic reference level (DRL) in morocco, which is yet to be established in Nigeria. It could also be due to the sample size, were the sample size in their study (16) was twice that of the index study. Meanwhile in another study by Robinson & Nzotta (17) in Port Harcourt Rivers state Nigeria using a 64 slice CT scanner showed a mean kVp of 86.67±10.84. The value obtained in the study by Robinson & Nzotta (17) is close to that obtained in the present study.

The tube current time (mAs) in the present study ranged from 100 to 120 with a mean value of 108.20±8.28. The mean tube current time (mAs) obtained in the study by Semghouli et al. (16) in morocco was higher than the values obtained in the present study. Whereas, the study by Robinson & Nzotta (17) was marginally higher than that of the index study, which was 110±7.48.

From the results of the present study, the CTDI ranges from 20.65 mGy to 380.79 mGy with a mean CTDI of 59.31±68.48 mGy. In a Sudanese study to evaluate Radiation Dose Associated with Multi-Detector 64-Slice Computed Tomography Brain Examinations in Khartoum State, Sudan revealed a mean values range of 62.9 to 65.8 mGy (18). The value in the study by Elmahdi et al. (18) was close to that obtained in the index study.

The mean DLP value was 704.43±267.07 mGy-cm with a range of 256.60mGy-cm to 1144.80mGy-cm. The DLP values from other studies were 890 mGy-cm (19), 371.4 mGy-cm (20). The values obtained in a Sudanese study showed a DLP value range from 1003.7 to 1192.5 mGy-cm (18) which is higher than the values obtained in the present study.

The study showed a strong positive correlation between kvp and mAs with a Pearson's Correlation coefficient (r) of 0.689, but showed no correlation between Kvp and CTDI. There was also strong positive correlation between kvp and DLP.

The study showed a non-patterned distribution of variable which signifies non-linear relationship between head circumference and other variables like age, KvP, mAs, CTDI and DLP. The finding from the index study was in consonance with the study by Zunaide et al (21) to evaluate 'Radiation doses and size-specific dose estimate from CT brain examinations according to head sizes in a tertiary hospital in Malaysia'. According to Zunaide et al, (21), CT dose exposure during brain CT investigation is not influence by ethnicity or the patient's head size, rather it is mainly influenced by the types of examinations. However, this finding from the index study was contrary to that documented by Huda et al (22). The study by Huda et al (22), revealed that CT doses takes into consideration patients age, head size, body composition, as well as the type of radiographic technique. The conclusion concerning this was drawn from the experimental fact that during radiographic investigation, the energy imparted for infants is 50% lower than that of adults; however, the adult effective dose was four times lower than that for infants (22). The variance observed from both study could be due to difference in the study population, of which that of the index study was lower.

CONCLUSION

The scan parameters, dose Metrics and diagnosticc Reference Levels when using a 64 slice Computed Tomography scanner was established. The study also provided the reference range of the CTDI to be 20.65 mGy to 380.79 mGy and that of the DLP to be 256.60mGy-cm to 1144.80mGy-cm. The study showed that there was a strong positive correlation between kvp and mAs but no correlation between Kvp and CTDI.

LIST OF ABBREVIATIONS

CT	Computed Tomography
kvP	Kilovoltage Peak
mA	Mean tube current
CTDI	Computed Tomography Dose Index
DLP	Dose Length Product
SPSS	Statistical Package for Social Sciences
DRL	Diagnostic Reference Level
mAs	Tube Current Time

Declarations

Ethics approval: Ethical clearance for the study was obtained from the Rivers State University Teaching Hospital Health Research Ethics Committee in a correspondence dates letter date 12thApril 2022 with reference RSUTH/REC/2022/163.

Consent to participate: Participation on the study was voluntary, and all participants gave consent before been involved in the study.

Consent for publication: “Not applicable”

Competing interests: There are no financial and non-financial competing interest associated with this study.

Funding: No funding from any source.

Availability of data and materials: Not applicable.

Authors' contributions: All the authors were involved in the conceptualization of the study. They were also all involved in the collation of data, analysis and review of the study. They also contributed in the writing and proofreading of this study.

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