Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 194 (2024) 203-213 EISSN 2392-2192

Characterization of scan parameters and their reference levels using 2 and 16 slices computed tomography scanners

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ABSTRACT

Computed Tomography (CT) is an ionising radiation based imaging device. The study is aimed at characterizing scan parameters and reference levels using 2 and 16 slices CT scanners. It was an empirical study with 50 participants referred for brain CT scan using 2 and 16 slice CT scanners. Participation was voluntary and ethical clearance was obtained. During procedure the tube current and voltage were selected and the Volumetric Computed Tomography Dose Index ($CTDI_{vol}$) obtained. Dose Length Product (DLP) was calculated by multiplying the CTDI with the total scan length. Descriptive statistical tool was used for data analysis and results presented in tables and charts. For 2 slices CT, the DLP reference ranges from 84.50mGy-cm to 398.08 mGy-cm. While for 16 slice CT, the CTDI and DLP reference range were 9.90 mGy to 59.06 mGy, and 116.10 mGy-cm to 586.36 mGy-cm respectively. The mean kVp and mAs for 2 slice CT were 87.60±10.91 and 108.20±8.28 respectively. There was a positive correlation between kVp and DLP yielding a Pearson's correlation coefficient (r) of 0.252 with 2 slice CT scanner. With 16 slices CT there was also a positive correlation between DLP and mAs with a Pearson's correlation coefficient (r) of 0.908. The mean kVp for 16 slice CT was higher than that of 2 slice CT while the mAs reference values for both 2 and 16 slices CT was 80.00 to 120.00. The study has provided information regarding the reference levels for 2 and 16 slice CT scanners.

Keywords: Computed Tomography, characterizing scan parameters, Dose Length Product

(Received 14 May 2024; Accepted 16 June 2024; Date of Publication 18 June 2024)

1. INTRODUCTION

Computed Tomography (CT) is an imaging device used for medically to provide valuable information on the internal structures of the body [1, 2]. In the past 10 years, there has been significant and rapid increase in the use of CT all over the world [3]. This imaging machine uses ionising radiation which is in the form of X-Rays. The X -Ray used in CT is produced when fast moving very high energy electrons strike a target material [3-5]. During the CT investigation, the x-rays have enough energy to penetrate the human body with a resultant production of axial images for diagnosis [6]. Radiation is the energy that comes from a source and travels through space with the speed of light. This radiation energy has both particulate and wave-like properties [5, 7]. During the process of imaging with ionizing radiation the radiation energy is absorbed into the body and the absorbed radiation is the amount of radiation energy that is absorbed per unit mass expressed in joule per kilogram.

The voltage applied to determine the energy of the radiation is the tube voltage which determines the quality and quantity of the x-rays produced during imaging. The amount of radiation produced during imaging increases as the square of the kilovoltage reason been that the amount of radiation produced is proportional to the square of the tube voltage. During imaging the peak kilovoltage is selected manually by the operator. In other to obtain an image of good quality appropriate facture will be selected which should be within a diagnostics reference ranges for optimal images contrast within a reduced radiation dose. Tube current determines the amount electrons accelerated across the tube. The quantity of electrons accelerated across the tube is directly on the applied tube current (mA). This implies that the greater the tube current, the higher the amount of electrons and resultant higher number of x-rays production.

Volumetric Computed Tomography Dose Index is a dose index which is a 'standardised measure of the CT Scanner radiation dose output [8, 9]. The Volumetric Computed Tomography Dose Index is measured in mGy'. [8, 9]. The CTDI helps to ensure the comparison of the radiation output of different CT scanners. During the process of scanning, the machine acquires multiple slices during a single rotation with a single beam.

The dose-length product (DLP) is a dose index of CT scanner which show overall dose output by considering the scan length. The dose-linear product (DLP) is a measure of CT tube radiation output/exposure and it is the product of the CTDI-vol, and the number of centimetres scanned. The DLP accounts for the length of the output of the radiation along the long axis of the patient which is referred to as the z axis. It is meant to be a comparison metric for different computed tomography scanners.

Achieving a good quality image with optimal diagnostic content requires appropriate exposure factors. The study is aimed to evaluate computed tomography scan parameter and determine their reference levels using 2 and 16 slice computed tomography scanners while achieving good quality images within acceptable dose limit.

2. MATERIALS AND METHOD

Computed Tomography Machine: Two different CT machines each having 2 and 16 slices were used for the examination. The 2 Slice was a Toshiba CT Machine manufactured in USA in 2000 while the other was a 16 Slice Philips CT Machine manufactured in Germany in 2004. Both scan machines have recent calibrations and quality control measurements.

ZT standard scale for height and weight measurement: A ZT WHO standard measuring scale was used to measure the patients' height and weight. The scale has an error level of ±0.05. Weight was recorded in kilograms while the height was recorded in meters. Body Mass Index (BMI) of the participants was calculated by dividing the weight in kilogram by the square of the height in meters (kg/m^2). The study was an empirical study with 50 participants referred for brain CT scan examination. The study was carried out in two separate radiology facilities having 2, and 16 slice computed tomography scan machines in Port Harcourt. Participation was voluntary as refusal does not in any way affect the services been rendered to the patient. In line with the Helsinki declaration ethical clearance for the study was obtained from the Rivers State University Teaching Hospital Health Research Ethics Committee. The study was faced with some limitations such as high examination cost, power supply challenges and long machine down time.

Data Collection

During the investigation the peak kilovoltage is manually selected to optimal images contrast and image quality with as low as reasonably achievable dose. During the procedure the selected exposure factors were the tube current and tube voltage for each of the patients was recorded.

Volumetric Computed Tomography Dose Index ($CTDI_{vol}$)

During the procedure the Volumetric Computed Tomography Dose Index ($CTDI_{vol}$) was obtained for the 2 and 16 slice CT scans. The CTDI is obtained by using equation 1 formula below [9]:

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

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

Dose-Length Product (DLP)

The DLP was calculated from the CTDI. The DLP IS THE product of the CTDI and the total scan length which is expressed in mGy*cm as shown in equation 2 below [10].

$$\text{DLP} = \text{CTDIvol x nT} \qquad (2)$$

where *nT* is therefore the total scan length

Method of Data Analysis

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

3. RESULTS

The DLP and radiation doses ($CTDI_{vol}$) of CT examinations during 2 slice CT examination is shown on tables 1, while that of 16 slice CT is shown on Table 2. Tables 1 and 2 also showed other exposure parameters like the KVp and mAs with 2 and 16 slice CT scanner respectively. Table 3 showed the KVp, mAs, DLP and radiation doses ($CTDI_{vol}$) reference levels during each CT investigation with 2 and 16 slice CT scanners. The age of the patients, BMI, and exposure parameters according to gender distribution for both 2 and 16 slice CT scanners were demonstrated on Tables 4 and 5 respectively.

Table 6 shows the correlation between among the radiation doses parameters (kVp, mAs, CTDI, and DLP) with 2 slice CT scanner. Whereas table 7 shows the correlation among the same dose parameters using 16 slice CT scanners. Comparison of the obtained CTDI and DLP values from this study with that of other studies was shown on tables table 8 and 9 respectively. As shown on Table 1 and 3 the CTDI (mGy) ranged from 5.50 mGy to 39.40 mGy using 2 slice CT scanner with a mean CTDI (±standard deviation) of 14.32±7.20 mGy.

The tables (table 1 and 3) also show that the DLP (mGy-cm) using 2 slice CT Machine ranges from 84.50mGy-cm to 398.08mGy-cm.

As shown in table 2 the mean kVp for 16 slice CT scanners was 88.80±13.638, whereas the mAs ranged from 100 to 120 with a mean (±standard deviation) for the 16 slice CT's machine as 107.80±8.426 (tables 2 and 3). Table 3 shows the mean kVp and mAs for the 2 slice CT scanners to be 87.60±10.91 and 108.20±8.28 respectively. The mAs ranged from 100 to 120. The mean DLP for 2 slice CT scanner (±standard deviation) was 173.48±80.46 mGy-cm. The CTDI using 16 slice CT scanner ranges from 9.90 mGy to 59.06 mGy with a mean (±standard deviation) of 23.79±12.403 mGy as shown on tables 2 and 3. While the DLP ranges from 116.10 mGy-cm to 586.36 mGy-cm with a mean (±standard deviation) of 330.94±147.17 mGy-cm. Table 4 shows the mean (±standard deviation) KVp, and mAs among females to be 86.36±9.24 and 107.73±8.17 respectively. The table also shows the CTDI and DLP to be 13.07±5.52 mGy and 207.64±98.19 mGy-CM respectively.

The mean (±standard deviation) CTDI and DLP among the females were 22.22±9.90 mGy and 347.39±118.32 mGy-cm respectively during 16 slice CT scanner investigation (Table 5). Table 6 illustrates the correlation among the dose parameters (kVp, mAs, CTDI, and DLP) during 2slice CT scanner. The correlation revealed a positive correlation between kVp and mAs, kVp and CTDI, as well as kVp and DLP yielding a Pearson's correlation coefficient (r) of 0.689, 0.895 and 0.252 respectively. Correlation between DLP and kVp, DLP and mAs, as well as DLP and CTDI showed a positive correlation yielding a Pearson's correlation coefficient (r) of 0.695, 0.908 and 0.726 respectively as also shown in Table 7.

Table 1. Patient exposure parameters (KV, and mAs) with resultant CTDI (vol) and DLP of each patient using 2 slice CT scanner

S/N	Age (Years)	KV	mAs	CTDIvol (mGy)	DLP (mGy-cm)
1.	39.00	100.00	120.00	19.00	244.20
2.	49.00	80.00	110.00	12.00	102.84

3.	54.00	90.00	120.00	19.60	124.36
4.	54.00	80.00	100.00	8.00	113.93
5.	48.00	100.00	100.00	16.80	91.08
6.	56.00	120.00	120.00	39.40	216.36
7.	57.00	80.00	100.00	10.02	90.38
8.	57.00	100.00	120.00	19.40	124.46
9.	67.00	80.00	100.00	8.60	106.50
10.	58.00	80.00	100.00	10.80	100.03
11.	58.00	100.00	120.00	20.15	289.30
12.	49.00	80.00	100.00	12.50	179.68
13.	67.00	80.00	100.00	9.00	86.90
14.	63.00	80.00	100.00	6.60	84.50
15.	65.00	100.00	120.00	18.90	300.50
16.	65.00	80.00	100.00	9.85	103.20
17.	66.00	100.00	110.00	21.00	193.50
18.	66.00	90.00	115.00	18.50	202.00
19.	67.00	80.00	110.00	10.26	260.00
20.	68.00	80.00	110.00	5.50	201.00
21.	67.00	90.00	110.00	14.50	148.50
22.	67.00	80.00	110.00	18.70	200.97
23.	70.00	80.00	100.00	11.80	188.20
24.	72.00	80.00	100.00	10.50	186.40
25.	74.00	80.00	110.00	6.50	398.08

Table 2. Patient exposure parameters (KV, and mAs) with resultant CTDI (vol) and DLP of each patient using 16 slice CT scanner

S/N	Age (Years)	KVp	mAs	CTDIvol (mGy)	DLP (mGy-cm)
1.	42.00	110.00	120.00	29.90	544.36
2.	53.00	100.00	110.00	28.30	302.84
3.	44.00	120.00	120.00	39.80	544.36

4.	54.00	80.00	100.00	10.00	203.93
5.	45.00	80.00	100.00	20.81	161.38
6.	56.00	120.00	120.00	59.06	500.36
7.	66.00	80.00	100.00	10.28	162.08
8.	58.00	90.00	120.00	29.06	484.90
9.	57.00	80.00	100.00	10.80	116.10
10.	59.00	90.00	100.00	20.20	168.93
11.	58.00	100.00	120.00	39.10	514.36
12.	39.00	80.00	100.00	20.82	249.78
13.	61.00	80.00	100.00	9.90	151.38
14.	53.00	80.00	100.00	10.02	128.54
15.	55.00	110.00	120.00	39.06	586.36
16.	65.00	80.00	100.00	10.25	203.90
17.	66.00	100.00	110.00	36.14	383.85
18.	66.00	80.00	115.00	28.14	382.97
19.	67.00	80.00	110.00	12.16	430.69
20.	67.00	80.00	100.00	14.17	350.26
21.	67.00	80.00	100.00	24.20	248.90
22.	67.00	80.00	110.00	28.14	302.90
23.	70.00	80.00	100.00	28.11	338.20
24.	72.00	80.00	110.00	18.10	395.90
25.	75.00	80.00	110.00	18.20	416.20

Table 3. KVp, mAs, DLP and radiation doses ($CTDI_{vol}$) during each CT examinations in the three facilities with associated reference levels

CT MACHINE TYPE	**VARIABLES**	**N**	**REFERENCE LEVELS**	**Mean ± Std. Deviation**
2 SLICE MACHINE	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	5.50 to 39.40	14.32±7.20
	DLP(mGy-cm)	25	84.50 to 398.08	173.48±80.46

16 SLICE MACHINE	KV	25	80.00 to 120.00	88.80±13.64
	mAS	25	100.00 to 120.00	107.80±8.43
	CTDI(mGy)	25	9.90 to 59.06	23.79±12.40
	DLP(mGy-cm)	25	116.10 to 586.36	330.94±147.17

CTDI: Computed Tomography Dose Index, DLP: Dose Length Product, ED: Effective dose, ABS: Absorbed dose

Table 4. Patients age, BMI, and exposure parameters with resultant CTDI, absorbed dose, effective dose in facility A according to gender distribution

2 SLICE CT SCANNER						
Variables	GENDER					
	FEMALE			MALE		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation
AGE	11	64.7273	6.69464	14	57.9286	9.05933
BMI	11	27.3515	3.86485	14	24.9058	1.89474
KVp	11	86.3636	9.24416	14	88.5714	12.31456
mAs	11	107.7273	8.17424	14	108.5714	8.64438
CTDI	11	13.0691	5.50700	14	15.2943	8.36540
DLP	11	207.6418	98.19077	14	146.6293	52.64455

CTDI: Computed Tomography Dose Index, DLP: Dose Length Product, , ED: Effective dose, ABS: Absorbed dose; mAs: Mean tube current time; kVp: Mean tube voltage product

Table 5. Patients age, BMI, and exposure parameters with resultant CTDI, using 16 slices CT scanner according to gender distribution

16 SLICE CT SCANNER						
VATRIABLES	GENDER					
	FEMALE			MALE		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation
AGE	12	65.83 ±	6.23529	13	53.2308	8.19709
BMI	12	25.5590	4.00769	13	26.0165	5.86063
KVp	12	84.1667	9.96205	13	93.0769	15.48366

mAs	12	107.0833	6.89477	13	108.4615	9.87096
CTDI	12	22.2242	9.89637	13	25.2331	14.60025
DLP	12	347.3892	118.31618	13	315.7508	173.1002

CTDI: Computed Tomography Dose Index, DLP: Dose Length Product, ED: Effective dose, ABS: Absorbed dose; mAs: Mean tube current; kVp: Mean tube voltage product (kVp)

Table 6. The correlation between radiation doses to the brain with kVp, mAs, CTDI, and DLP using 2 slice CT scanner

		kVp	mAs	CTDI	DLP
kVp	Pearson Correlation	1	.689**	.895**	.252
	Sig. (2-tailed)		.000	.000	.225
mAs	Pearson Correlation	.689**	1	.669**	.532**
	Sig. (2-tailed)	.000		.000	.006
CTDI	Pearson Correlation	.895**	.669**	1	.207
	Sig. (2-tailed)	.000	.000		.322
DLP	Pearson Correlation	.252	.532**	.207	1
	Sig. (2-tailed)	.225	.006	.322	

Table 7. The correlation between radiation doses to the brain with kVp, mAs, CTDI, and DLP with 16 slice CT scanner

		kVp	mAs	CTDI	DLP
kVp	Pearson Correlation	1	.756**	.826**	.695**
	Sig. (2-tailed)		.000	.000	.000
mAs	Pearson Correlation	.756**	1	.763**	.908**
	Sig. (2-tailed)	.000		.000	.000
CTDI	Pearson Correlation	.826**	.763**	1	.726**
	Sig. (2-tailed)	.000	.000		.000
DLP	Pearson Correlation	.695**	.908**	.726**	1
	Sig. (2-tailed)	.000	.000	.000	

4. DISCUSSION

The mean tube voltage product (kVp) for the 2 and 16 slice CT scan machines were 87.60±10.91, and 88.80±13.64 respectively. However, the maximum kVp used in both slices was 120. In a study to evaluation of radiation risks during CT brain procedures for adults by Semghouli *et al*., [11] showered a mean kVp of 120 and 118 for 2 and 16 slice CT procedures respectively.

The result also showered that the mean kVp was marginally higher using 16 slice CT when compared to 2 slice CT scanner. In a study to assess radiation dose during 16 slices CT examinations by Mkimal *et al*., [12] using 16 slice CT scanner for both man and females was higher than that obtained in the study. The difference may be attributed to variation in population of study, availability of diagnostic reference range and the calibration status of the machines used in their study.

The index study revealed that the tube current time (mAs) ranged from 100 to 120 in both slices although the mean (±sd) of the mAs for 2 slice CT scanner was 108.20±8.27647 while that of 16 slices was 107.80±8.42615. A study by Mkimal *et al.,* [12] showed a mean mAs of 100 using 16 slice CT scanner. The value used in their study was marginally lower than that recoded in the present study.

The mean CTDI for 2 and 16 slice CT were 14.32±7.20 mGy and 23.79±12.40 mGy. The CTDI the 16 slice CT scanner was higher than that of the 2 slice CT scanner suggesting that the CTDI increases with increase in CT slice number. In a study by Abdullahi *et al* [13] to determine the Diagnostic reference level for adult brain computed tomography scans: A case study of a tertiary health care center in Nigeria ravelled a CTDI of 38 mGy. Nzotta *et al* [14] in a study to evaluate radiation dose from exposure to computed tomography scan of the brain in a reference hospital in Nigeria showed a CTDI of 54 mGy. Ogbole *et al* in 2014 [15] determined the Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria. the study revealed a CTDI dose of 73.5±4.2 mGy. Other studies revelled a CTDI of 58mGy in the UK [16], 66mGy in Ireland [17] where as a study at Abuja showed a CTDI of 38mGy [13].

Another study recorded a CTDIvol using a 16-Slice Computed Tomography Scanner to be f 10 mGy [18]. This value is lower than that that obtained in the present study. The difference may be attributed to calibration methodology, machine model and the exposure factors used (kVp and mAs).

The mean DLP using 2 and 16 slice CT scanners were 173.48±80.46 mGy-cm. and 330.94±147.17 mGy-cm. The value of DLP using 2 slices CT was lower than the value obtained when using 16 slice CT scanner. Adejoh *et al* [19] in their study in Nigeria to revealed a DLP of 874 mGy-cm. Another study by Wardlaw [20] in Canada showed a DLP of 1098 mGy-cm, while a study in Kenya by Korir *et al* [21] to determine a National diagnostic reference level initiative for computed tomography examinations revelled a mean DLP of 1612 mGy-cm. the results from the mentioned study where higher than the result abstained from the index study for both 2 and 16 slices CT scanner machines. Where was a strong positive correlation between kvp and mAs using 2 and 16 slice CT scanners with a Pearson's Correlation coefficient (r) of 0.689 and 0.756 respectively.

The present study showed a positive correlation between kVp and CTDI while using both 2 and 16 slcie CT scanner machines. There was also strong positive correlation between kvp and DLP with 16 slice CT scan.

5. CONCLUSION

The study has provided information concerning the exposure parameters, DLP and radiation doses ($CTDI_{vol}$) using 2 and 16 slice CT scanner machine. The exposure parameters, DLP and $CTDI_{vol}$ were analysed to obtain the reference levels with 2 and 16 slice CT scanner machine. The DLP (mGy-cm) using 2 slice CT scanner ranges from 84.50 mGy-cm to 398.08 mGy-cm while when using 16 slice CT scanner the DLP ranged from 116.10 mGy-cm to 586.36 mGy-cm. The present study showed a CTDI mGy reference value of 5.50 mGy to 39.40 mGy using 2 slice CT scanner with a mean of 14.32±7.198 mGy and a reference range of 9.90 mGy to 59.06 mGy using 16 slice CT scanner. The mean tube voltage product (kVp) for the 2 and 16 slice CT scanners varied in the study. The mean tube voltage product (kVp) using 16 slice CT scanner was higher kVp than that obtained using 2 slice CT scanner.

References

[1] Robinson, E.D., Nzotta, C.C., & Onwuchekwa, I. (2019). Evaluation of scatter radiation to the thyroid gland attributable to brain computed tomography scan in Port Harcourt, Nigeria. *International Journal of Research and Medical Sciences*, 7, 2530-5

[2] Noriko, K., Takayasu, Y., Koji, O., Michiaki, K., Graham, B., & Joachim, S. (2020). Computed tomography of the head and the risk of brain tumours during childhood and adolescence: results from a case–control study in Japan. *Journal of Radiological Protection*, 40(10), 61-69

[3] Pearce, M.S. (2011). Pattern in paediatric CT use: an international and epidemiological perspective. *Journal of Medical Imaging and Radiant Oncology*, 55, 107-109

[4] Suliman, I.I., Abdalla, S.E., Ahmed, N.A., Galal, M.A., & Isam, S. (2011). Survey of Computed tomography technique and radiation dose in Sudanese hospitals. *European Journal of Radiology*, 80, 544-551

[5] Bushberg, J.T., Seibert, J.A., Leidholdt, J.R., Edwin, M., & Boone, J.M. X-Ray Production, X-Ray Tubes, and Generators. Essentials of physics of medical imaging (3rd ed.) Lippincott Williamas and Wilkins. (2020).

[6] Brenner, D.J., & Hall, E.J. Computed tomography—an increasing source of radiation exposure. Neglected *English Journal of Medicine*, (2007). 357, 2277-84

[7] Huda, W., Magill, D., & He, W. (2011). CT effective dose per dose length product using ICRP 103 weighting factors. *Medical Physics*, 38,1261–1265.

[8] Cao, C.F., Ma KL., Shan H., Liu TF., Zhao SQ., Wan Y., et al. (2022). CT Scans and Cancer Risks: A Systematic Review and Dose-response Meta-analysis. *BMC Cancer*, 22(1), 1-13

[9] Bashir, U., Jones, J., & Murphy, A., (2021). CT Dose Index. https://doi.org/10.53347/rID-18981.

[10] Deak, P.D., Smal, Y., & Kalender, W.A. (2010). Multi-section CT protocols: sex- and age-specific conversion factors used to determine effective dose from dose length product. *Radiology*, 257, 158–166

[11] Semghouli, S., Amaoui, B., Hakam, O.K., & Choukri, A. (2019). Radiation exposure during pelvimetry CT procedures in Ibn Sina Children's Hospital of Rabat. *Radiation Physics and Chemistry*, 5(2), 79-83

[12] Mkimel, M., El Baydaoui, R., Mesradi, M.R., Tahiri, Z., Saad, E., & Hilali, A. (2019). Assessment of the radiation dose during 16 slices CT examinations. International *Journal of Recent Technology and Engineering*, 8(4), 2277-3878

[13] Abdullahi, M., Shittu, H., Joseph, D., Aribisala, A., Eshiett, E.P., & Richard, I. (2015). Diagnostic reference level for adult brain computed tomography scans: A case study of a tertiary health care center in Nigeria. *IOSR Journal of Dental Medical Science*, 14(1), 66-75

[14] *Nzotta, C.C., Egbe, N., Adejoh, T., Nkubli, B.F., & Ezeador, I.S.* (2016), Radiation dose from exposure to computed tomography scan of the brain in a reference hospital in Nigeria. *Pakistani Journal of Radiology*, 26 (2), 77-80

[15] Ogbole, G.I., & Obed, R (2014). Radiation doses in computed tomography: Need for optimization and application of dose reference levels in Nigeria. *West African Journal of Radiology*, 21(1), 1-6

[16] Hart, D., Wall, B., Hillier, M., & Shrimpton, P. (2010) Frequency and collective dose for medical and dental x-ray examination in the UK. Chilton Publisher.

[17] Foley, S.J., McEntee, M.F., Rainford, L. (2014). Establishment of CT diagnostic reference levels in Ireland. *British Journal of Radiology*, 85(1018), 1390-1397.

[18] Mekonin, T.S., & Deressu, T.T. (2022). Computed Dosimeter Dose Index on a 16-Slice Computed Tomography Scanner and Dose Response. *Radiography*, 20(3), 15-29.

[19] Adejoh, T., & Nzotta, C.C. (2016), Head Computed Tomography: Dose output and relationship with anthropotechnical parameters. *West African Journal of Radiology*, 23(2), 113-117

[20] Wardlaw GM, Martel N. (2016). Sci-Thur PM–Colourful Interactions: Highlights 07: Canadian Computed Tomography Survey: National Diagnostic Reference Levels. *Medical Physics*. 43(8Part3): 4932-3

[21] Korir GK, Wambani JS, Korir IK, Tries MA, Boen PK. (2016). National diagnostic reference level initiative for computed tomography examinations in Kenya. *Radiat Prot Dosimetry*. 168(2): 242-52. doi: 10.1093/rpd/ncv020