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Preliminary dose survey in adult Cranial Computed Tomography: towards the establishment of Computed Tomography Diagnostic Reference Levels in Akwa Ibom State, Nigeria

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Abstract

Computed tomography (CT) of the head is a frequently performed diagnostic procedure involving the use of ionizing radiation. The main purpose of this study was to evaluate the dose received by patients undergoing cranial CT examinations in a State in Southern Nigeria using the values of $CTDI_{vol}$ and DLP obtained from the CT scanner. A retrospective study was conducted covering a period of 7 months using cranial CT data of 108 adult patients. The 75th percentile values of $CTDI_{vol}$ and DLP were determined and compared with established or suggested DRLs from related studies locally and internationally. Data was analysed using Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington).

The obtained $CTDI_{vol}$ for cranial CT was 99.3mGy while DLP was 2502.5mGy-cm. The mean effective dose was 5.3mSv. The 75^{th} percentile values for CTDIvol and DLP, hence cranial CT dose, was higher in this study compared to other studies within Nigeria and internationally. A synergy between Radiographers, Radiologists and Physicists to optimize CT parameters and practices can help reduce these values.

Keywords: *Cranial Computed Tomography, Patient Dose, Dose Reference level, practice optimization,*

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I. Introduction

Computed tomography (CT) of the head is a frequently performed diagnostic procedure involving the use of ionizing radiation with its inherent carcinogenic effect. [1,2]. The frequent use of x-ray Computed tomography in head imaging results from its ability to image the human brain and skull in a wide range of disease conditions including trauma, vascular and skeletal diseases [3,4]. This frequent use of head CT accounts for its high contribution to the population dose of ionizing radiation and informs the need for adequate dose monitoring and practice optimization to keep radiation dose as low as reasonably achievable [1,3,5,6]. It has been established that radiation doses for CT examinations vary substantially between patients, institutions and even countries [1, 5]. These variations are attributable to differences in examination-specific protocols used by Radiographers. Other factors include patient age, weight, lebgth of anatomy, and the CT machine configuration [5, 7, 8, 9, 10].

International Commission on Radiological Protection (ICRP) mooted the idea of Diagnostic reference levels (DRLs) in 1990 and subsequently recommended it in details in 1996 [11]. The commission sought to minimize wide variations in patient dose levels for similar CT examinations [11]. Diagnostic Reference Levels are intended for use as a simple test for the identification of abnormally high dose levels by setting an upper threshold beyond which the imaging technique must be reviewed and optimized to reduce radiation dose. This threshold is considered as the 3^{rd} quartile or 75^{th} percentile of each examination included in a dose survey [12, 13, 14, 15, 16]

Local and regional DRLs are now advised for specific examinations and for specific clinical indications. The adoption of international DRLs in local practice are inadequate on its own due to the dissimilar region-specific training of imaging professionals as well as variations in the equipment and patient populations used in establishing them [17, 18]

According to International Electrotechnical Commission recommendations, the volume computed tomography dose index ($CTDI_{vol}$), and dose-length product (DLP) are the dosimetric variables for computing CT DRLs [17]. The $CTDI_{vol}$ has the unit of milligray (mGy) while DLP has the unit of milligray/centimeter (mGy cm^{-1}) [9, 13, 19, 20, 21]. Dose Length Product is the product of $CTDI_{vol}$ and scan length (cm). It represents the total radiation dose received by the patient during a CT scan [21, 22].

The use of DRLs as benchmark for dose optimization has been shown to reduce radiation doses in CT clinical practice. In the United Kingdom for instance, national dose surveys from 1985 to 2000 demonstrated a 50% decrease in doses [23]. Worldwide the use of DRLs as an important tool for radiation dose reduction has been championed by professional Organizations like ICRP, American Association of Physicists in Medicine (AAPM), American College of Radiology (ACR) and International Atomic Energy Agency (IAEA) [18, 24, 25, 26-31]

Radiation dose from head CT and other body parts have been established in similar studies around Nigeria [3, 4, 7, 10, 22]. In spite of the importance of DRLs, there are still many CT facilities in Nigeria without established doses in commonly performed CT examinations. This has also affected the establishment of regional and national dose reference in CT. The CT facility under study has been functional since 2012 though with multiple downtime periods, but patient dose from head CT has never been evaluated. The absence of such dose survey had made it difficult to ascertain radiation dose to patients undergoing cranial CT and to establish the need for practice optimization. The present dose survey aims to assess adult head CT doses with a view to establishing DRLs for adult head CT examination in the facility under study.

II. Materials and Methods

This was a retrospective, cross sectional study and involved data from 108 adult cranial CT examinations performed between October 2021 and April 2022 in the CT facility of University of Uyo Teaching Hospital, Uyo, South-South Nigeria. All examinations were performed using Toshiba Activion-16, 16-slice helical scanner (Toshiba Japan, 2012). This has been the only functional CT machine in Akwa Ibom State since early 2021. All cranial CT scans were done in helical mode using fixed technique factors of 120Kvp and 270mAs with patients in Supine, head first position. A pitch of 1 was used with slice thickness of 5mm and gantry rotation time of 1s. The scan length always extended from skull apex to between C2 and C7 vertebrae. The whole C-spine is included in cases of trauma. While a minimum of 10 subjects is considered adequate for the purpose of DRL establishment, 108 subjects (66 males, 42 females) were included in this study to accommodate all forms of variations in patient, machine and operator factors. The subjects were aged between 18 to 88 years with weights ranging from 56Kg to 77Kg. Data was collected for only non-contrast examination series. Data was recorded using a data capture sheet which included fields for patient age, gender, body weight, CT scan technique parameters and dosimetric parameters. The $CTDI_{vol}$ and DLP were recorded for the subjects. The mean, mode 75th percentile and Effective dose was calculated to establish center-specific DRL for cranial CT. Data was analyzed using Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington). Ethical clearance was obtained from the University of Uyo Teaching Hospital Institutional Review Board

III. Results

A total number of 108 patients' data was analyzed in this study including 66 (61%) males and 42 (39%) females. The ages of the subjects ranged from 18 to 88 years with a mean age of 51.1 ± 16.4. The weights of the subjects ranged from 56 to 77Kg with mean weight of 66.8 ± 5.1. Demographic details are shown in Table 1 below:

Table 1: Range, mean and standard deviation of Age, Weight, CTDI and DLP

No. of Subjects		Age	Weight	CTDI	DLP
Male (66)	Range	18 - 85	56 – 77	49.7 -99.5	1449.8 - 3594.8
	Mean	47.7 ± 16.0	67.2 ± 5.2	96.1 ± 7.9	2348.5 ± 455.1
Female (42)	Range	23 - 88	56 – 77	78.1 -100.8	1696.4 – 3296.8
	Mean	56.5 ± 15.7	66.3 ± 4.8	97.6 ± 3.4	2181.2 ± 362.0
Total (108)	Range	18 – 88	56 – 77	49.7 – 100.8	1449.8 – 3594.8
	Mean	51.1 ± 16.4	66.8 ± 5.1	96.6 ± 6.5	2291.7 ± 419.8

Details of the mean and 75^{th} percentile of DLP and $CTDI_{Vol}$ are shown in Table 2. The mean $CTDI_{vol}$ was 96.6mGy while the 75^{th} percentile of the $CTDI_{vol}$ was 99.3mGy. The mean DLP was 2291.7mGy-cm while the 75^{th} percentile of DLP was 2502.5mGy-cm.

Table 2: 75th Percentile DLP (mGy cm^{-1}) and $CTDI_{vol}$ (mGy)

No. of Patients	DLP Mode	Mean ± SD	75th Percentile	$CTDI_{vol}$ Mode	Mean ± SD	75th Percentile
Male (66)	2093.4	2348.5 ± 455.1	2651.4	99.3	96.1 ± 7.9	99.3
Female (42)	1900.4	2181.2 ± 362.0	2353.5	99.3	97.6 ± 3.4	99.3
Male and Female (108)	2093.4	2291.7 ± 419.8	2502.5	99.3	96.6 ± 6.5	99.3

Figure 1 shows the range of $CTDI_{vol}$ across all 108 subjects in the study. The lowest value of $CTDI_{vol}$ was 49.7mGy while the maximum value was 100.8mGy

Fig. 1: Variations in $CTDI_{vol}$ across the subjects examined

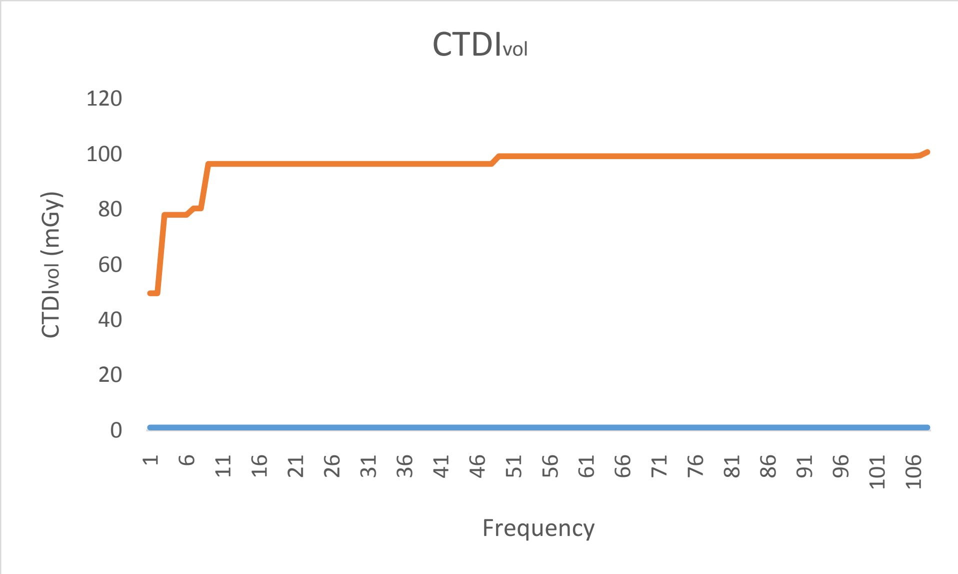

Figure 2 shows the range of DLP across all 108 subjects in the study. The lowest value of DLP was 1449.8mGy-cm while the maximum value was 3594.8mGy-cm.

Fig. 2: Variations in DLP across the subjects examined

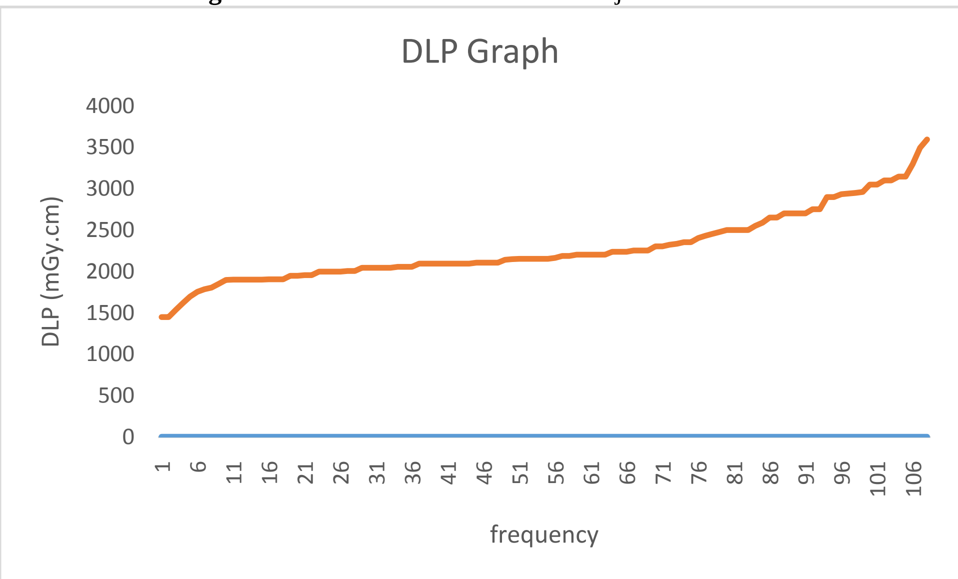

Figure 3 indicates the Effective Dose for cranial CT in the study centre. Mean effective dose for males was 5.6mSv while for females was 4.9mSv. Combined Effective dose in this study was 5.3mSv.

Fig. 3: Effective dose for 108 subjects analysed

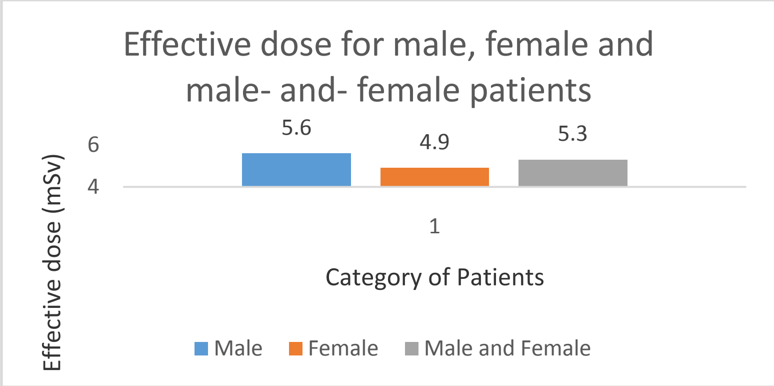

Table 3 compares DRL values obtained in this study with values obtained in other studies in Nigeria and other parts of the world. The $CTDI_{Vol}$ of 99.3mGy in this study is higher than values from all the other eight (8) studies while the DLP value of 2502.5mGy cm^{-1} is also higher than values obtained from all the other studies except for only one (1) study.

Table 3: Comparison of present work with other works carried out in different locations

Author	Location	Year	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)
Present study	Uyo, Nigeria	2022	99.3	2502.5
Ekpo et al (2018)	6 Geographical regions, Nigeria	2016 – 2017	61	1310
Adejoh et al (2017)	Anambra, Nigeria	2016	66	1444
Tonkopi et al (2015)	Canada	2015	67	1049
Saravanakumar et al (2014)	India	2014	32	925
European Commission (2014)	Europe	2014	60	1000
Adullahi et al (2020)	Kano, Nigeria	2019	62.5*	2946
Verinda et al (2020)	Indonesia	2019	61	1350
Korir et al (2015)	Nairobi, Kenya	2014	61	1612

*$CTDI_{vol}$ is volume computed tomography dose index, DLP is dose length product, * is weighted computed tomography dose index ($CTDI_w$).*
NB: in the present study $CTDI_{vol}$ is equal to $CTDI_w$.

IV. Discussion

Based on this preliminary cranial CT dose survey, it has been established that the 75^{th} percentile of $CTDI_{vol}$ is 99.3mGy while 75^{th} percentile of DLP is 2502.5mGy cm^{-1} for the study centre. Mean effective dose was established as 5.3mSv. Both the $CTDI_{vol}$ and the DLP in this present study are significantly higher than values from studies in other parts of Nigeria and in other Countries [5-7, 11, 13, 16, 20]. On the average the current study demonstrated a 50% variation in $CTDI_{vol}$ and 40% variation in DLP with studies by European Commission in Europe [11], Korir et al in Kenya [27], Sarayanakumar et al in India [20], Verinda et al in Indonesia [20] and Ekpo et al in Nigeria [7]. Inter-patient doses among patients studied were quite uniform. The uniformity could be because all the radiographers performing CT scans at our study centre deployed the same preset protocols for cranial CT of all patients irrespective of age or body weight. A similar case of radiographers performing CT examinations using preset protocols without adjustment resulting in high doses was also reported in a study in Nigeria (4). This inability of radiographers to adjust exposure parameters according to patients' size could be one of the reasons for the high $CTDI_{vol}$ recorded in this study. The practice of scanning a longer anatomical length during cranial CT (lower neck to skull apex) in our study center could also be a reason for the high value of DLP obtained. The ideal practice is for the radiographer to restrict the radiation beam to the area of interest which will lower the DLP. However, it seems that in our study centre the rule is to cover longer scan length in a bid to avoid missing any lesion, hence the high DLP recorded.

Our high DLP finding in this study therefore agrees with a study of International variation in radiation dose for CT examinations which found that the differences in dose among the countries studied were not attributable to patient or institutional characteristics or even machine manufacturers or models but almost entirely attributable to how the end users used the machines to acquire the CT images [1]. A study in South-West Ethiopia found DLP in cranial CT up to 2716.2mGy cm^{-1} and suggested that the scan length used in the study location was longer than what was necessary [13] and is thus in alignment with our study result.

The need for optimization of practice and CT protocols in the study location is underscored. Radiographers, Radiologists and Medical physicists should be willing to collaborate and optimize the CT scanning parameters, protocols and practices to bring the $CTDI_{vol}$ and DLP levels comparable to what is obtainable elsewhere in Nigeria and other Countries.

V. Conclusion

Preliminary dose survey in cranial CT was carried out. The 75th percentile CTDIvol was 99.3mGy while DLP was 2502.5mGy cm-^{1}. Mean Effective Dose was 5.3SvThe obtained CT dose variables were comparatively higher than that seen in other relevant studies and operator-dependent variables were seen to be the key factor in this. Practice optimization including exposure factors adjustments, scan length reduction and examination justification will bring these dose variables down considerably hence such optimization is advocated.

Limitation

This was the only functional CT facility in the entire State at the time of this study, hence it was not possible to include more CT centres in this study. Thus only data from one CT scanner was used to represent the whole State.

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Conflict of Interest

The authors declare that they have no conflict of interest

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