

Diagnostic Reference Levels for Computed Tomography of the Head in Anambra State of Nigeria

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Abstract

Background: Diagnostic reference levels (DRLs) were first conceptualized in 1996 by the International Commission on Radiological Protection as a result of wide variations in patient dose levels for the same examination. Current works on computed tomography (CT) doses in Nigeria produced significant variations. These observed variations, coupled with unavailable national or regional DRLs have presented the need for the establishment of standards through a dose survey.

Objective: The aim of this study is to establish DRLs for CT of the head in adult populations of Anambra State of Nigeria.

Materials and Methods: The retrospective survey was carried out from February to June 2016 in the four busiest CT centers. The digital CT population considered was those of subjects examined in 2015, and who were aged ≥ 18 years. Two hundred folders, comprising fifty from each center were included. The on-screen volume computed tomography dose index (CTDI_{vol}) and dose-length product (DLP) for the subjects were recorded. The 75th percentile was then calculated for each center to establish center-specific DRLs. Finally, a combined 75th percentile of the CTDI_{vol} and DLP for all centers was calculated to establish the DRLs for the state. Data were analyzed using SPSS version 20.0 (SPSS Incorporated, Chicago, Illinois, USA).

Results: The digital folders of 104 male and 96 female subjects with age range of 18–93 years were analyzed. The specific 75th percentile of the CTDI_{vol} and the DLP of the centers ranged from 46 to 86 milligray (mGy) and 794 to 1785 mGy centimeters (mGy-cm), respectively. The DRLs for the State are 66 mGy and 1444 mGy-cm, respectively.

Conclusion: The DRLs for head CT in Anambra State has been derived. Although the CTDI_{vol} is comparable to the recommendations of the European Commission, the DLP is significantly higher. Further training on dose optimization may help to bring the radiation dose in the locality at par with foreign values.

Keywords: Computed tomography, computed tomography protocol, dose, dose-length product, volume computed tomography dose index

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INTRODUCTION

Diagnostic reference levels (DRLs) were first conceptualized in 1996 by the International Commission on Radiological Protection as a result of wide variations in patient dose levels for the same examination.^[1,2] They are intended for use as a

simple test for the identification of abnormally high dose levels by setting an upper threshold,^[3] beyond which the imaging technique must be optimized to reduce radiation dose.^[4]

The third quartile of each examination included in a dose survey is considered as the acceptable yardstick for DRL.^[2,3]

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Local and regional DRLs are advised as the use of foreign ones are inadequate due to the dissimilar region-specific training of the radiographers, as well as variations in the equipment and populations used in establishing them.^[5]

The International Electrotechnical Commission recommended the volume computed tomography dose index ($CTDI_{vol}$), and dose-length product (DLP) as the dosimetrics for computed tomography (CT).^[6] The $CTDI_{vol}$ with a unit of milligray (mGy), is a standardized measure of the radiation output in a single slice of a CT scanner which allows users to compare different scanners and scan protocols.^[7] DLP combines the $CTDI_{vol}$ (mGy) and the scan range (cm) to quantify the total radiation dose received by the patient during a CT scan and is given in mGy centimeters (mGy-cm) [Figure 1].^[3]

A survey of CT doses in four continents and covering forty countries indicated that brain CT is the most common examination.^[8] The prevalence of these dose surveys are however, higher in Europe than in other continents.^[9] In a pioneering role, the European Commission made widespread recommendations on DRL for its member countries with an adult $CTDI_{vol}$ of 60 mGy and DLP of 1050 mGy-cm for head CT examinations.^[10] Similar recommendations in African countries are sparse, and where available, they are specific to pediatrics,^[11,12] the mean, rather than the third quartile, are used,^[13,14] or comparatively higher CT doses are reported for various examinations.^[15,16]

In Nigeria, in spite of the large number of examinations carried out yearly, the dose information available is grossly inadequate. In addition, there is no evidence of

published data indicating the establishment of national DRLs (nDRL) of common examinations in the country.^[9] A published northern survey,^[17] had significant variations from two other local center-specific studies,^[16,18] and with the recommendations of the European Commission.^[10] These observed variations, coupled with unavailable nDRLs have presented the need for the establishment of a national standard.^[5] The establishment of DRL for a country will involve surveys from its composite regions.^[3,19] The present survey, which aims to establish DRLs for adult head CT examinations, is, therefore, contemplated for a region of Nigeria.

MATERIALS AND METHODS

The design of the work was retrospective, and it involved digital images. Ethical approval from a Teaching Hospital (NAUTH/CS/66/Vol 8/84/of 24-02-2016) and written permissions from all centers to undertake the study were obtained. The survey was carried out from February to June 2016, in a teaching hospital (A), an Anglican Church-owned tertiary hospital (B), a Catholic Church-owned tertiary hospital (C) and a large private diagnostic center (D). Three of the centers are located in Onitsha while one is in Nnewi. Two other privately-owned centers in Onitsha and Nnewi were excluded as they lacked on-screen $CTDI_{vol}$ and DLP dosimetrics.

A general electric BrightSpeed, 4-slice scanner manufactured in 2007 and installed in 2011 was available at center A. Both centers B and C had a similar Toshiba Alexion, 16-slice scanners manufactured in 2013 and installed in 2014. The private diagnostic center had a 16-slice Siemens Somatom-Perspective scanner manufactured and installed in 2015. The scanners in centers A and D were installed and programmed by different engineers while the same people installed and programmed the ones in centers B and C. All the scanners had helical and axial scan modes. The variations in protocols were minimal, and it was not gender biased. The arrangement of the knobs however, varied substantially with the make of the scanner. The scanners were also self-calibrating, and these system software were activated daily. All centers had licensed Radiographers and reporting Radiologists. The newest center had scanned for at least 6 months before the commencement of the survey.

One hundred and four male and 96 female digital folders ($n = 200$) of subjects aged 18–93 years were involved. The head requests were in three broad categories of cranium ($n = 164$), sinuses ($n = 30$) and facial bones ($n = 6$). The four centers utilized a range of tube potential and tube current of 120–140 kVp and of

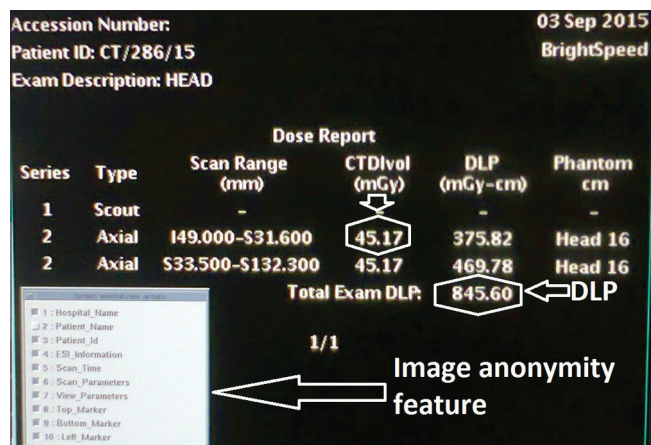


Figure 1: Series “999” showing the dose report at the end of the investigation. There are two “ $CTDI_{vol}$ ” because two slice thickness were used to acquire images. The dose-length product always come as a composite value irrespective of the diversity of slice thickness and number of series. The image anonymity feature on general electric scanners is accessed through the “user preference” icon

220–250 mA, and a modal gantry rotation time of 1 s. Aside center A with adjustable tube current mode, all the other centers operated with a fixed (automatic) mode.

The researchers accessed the digital folders for 2015 on the console and purposively sampled out the head CT population who were ≥ 18 years. Confidentiality of digital information was maintained by the activation of data anonymity features of the scanner to mask every information except age, gender, and date of scan. The folders were examined sequentially and those with scanograms which were generated in supine position, at an azimuth of 90° and 180° , respectively, and with no evidence of bandages, scalp edema or distortion of bony skull tables or facial bones were included. Folders containing acceptable images but with gross noise, as noted by the Radiologist, were omitted. Those also rejected by the Radiologists due to noise and artifacts were excluded.

A minimum of ten cases is considered adequate for the purpose of DRL.^[1,3] However, fifty subjects were included in each center surveyed. The $CTDI_{vol}$ and DLP which is represented on all scanners as series “999” were recorded for the subjects. The mean, mode and 75th percentile was then calculated for each center to establish center-specific DRL. Subsequently, the combined mean, mode and 75th percentile for all centers was calculated to establish the DRL for the State. Data were analyzed with the aid of computer software, SPSS version 20.0 (SPSS Incorporated, Chicago, Illinois, USA).

RESULTS

The digital folders of 104 male and 96 female subjects with age range of 18–93 years were analyzed. Cranial examinations dominated the requests (82%). The modal gantry rotation time used by all centers was 1 s while the tube current (220–250 mA) and tube potential (120–140 kVp) were consistently variable. Aside center A, the other centers programmed their scanner for automatic tube current modulation (auto mA). These are summarized in Table 1. The center-specific 75th percentile of the $CTDI_{vol}$ and the DLP ranged from 46 to 86 mGy and 794 to 1785 mGy-cm, respectively. The composite DRLs are 66 mGy and 1444 mGy-cm, respectively [Table 2]. A comparison with the European Commission values and other foreign works gave a significant variation of 1.5%–52% ($CTDI_{vol}$) and 27.3%–41.1% (DLP) is shown in Table 3.

DISCUSSION

The use of DRL for various patient conditions can be helpful in risk-benefit evaluation.^[24] Our analyses

yielded a significantly variable center-specific $CTDI_{vol}$ and DLP values of 46–86 mGy and 794–1785 mGy-cm, respectively. This variability is often the indication for the establishment of a common DRL.^[2] Our combined $CTDI_{vol}$ and DLP were 66 mGy and 1444 mGy-cm, respectively.

Our $CTDI_{vol}$ is comparable to works from Europe, Canada as well as the European Commission. However, a comparison with a local multi-center survey,^[17] showed a moderate variation of 14.3% in $CTDI_{vol}$ and a considerable variation of 32% in DLP. Since both works emanated from the same locality, the need for a national DRL is, therefore, imperative to bridge the gap.

The volume CTDI is substantially influenced by the tube current-time (mAs) and tube voltage (kVp), which collectively make up the intensity of radiation,^[25,26] and also by pitch and collimation.^[27] When these parameters are kept constant as often happens in automatic tube current modulation, a similar $CTDI_{vol}$ ensues irrespective of patient size or anatomical area scanned. Automatic tube current modulation is a strategy for fluctuating the mAs in tandem with the thickness of the anatomy and for keeping $CTDI_{vol}$ constant in spite of that, and three of the centers surveyed operated in that mode. If the system is programmed *ab initio* with skillful optimization technique, the tendency for dose drop is high as shown by the output from center D.

The skill of the radiographer and their knowledge of radiation dose are relevant in setting up the optimal intensity combination that will reduce radiation dose while still producing images with minimal noise and of high diagnostic quality. The convention of looking up to Europe for guidance and the experience of using similar roving CT engineers in the locality may have been responsible for the similarity in kVp of 120 used as well as the fairly similar mA applied. A kVp of 120 kVp rather than 140 will lead to 20%–40% reduction in patient dose.^[28]

However, while centers A (60 mGy) and B (59 mGy) had comparable $CTDI_{vol}$, centre C had the highest while center D (32 mGy) was the lowest and was fairly comparable to the work from India. It was observed that the radiographers in centers C and D rarely adjusted their protocols as they depended exclusively on the default protocols. Centers B and A however, often manipulated their protocols in response to the age and weight of patients. Although the $CTDI_{vol}$ of center D appeared very low, its wide variation from other works calls for a protocol audit. The derived $CTDI_{vol}$ of 66 mGy for the locality is, therefore, appropriate as it shows minimal variation (<10%) from the works from Taiwan, Canada, and Europe.

Table 1: Clino-technical characteristics of the subjects

Centre	Variables									
	Population		Age (range)	Regions of the head			Radiation intensity			mA mode
	Male	Female		Cranium (%)	Sinuses (%)	Facial bones (%)	kVp	mA	Time (s)	
A	24	26	19-73	38	9	3	120	220	1	Manual
B	25	25	20-82	40	9	1	120	250	1	Auto
C	30	20	18-75	41	7	2	140	250	1	Auto
D	25	25	18-93	45	5	0	120	220	1	Auto
Total	104	96	18-93	164 (82)	30 (15)	6 (3)	120-140	220-250	1	Variable

Table 2: Dose characteristics of the subjects

Centre	CTDI _{vol}			DLP			Combined					
	Mode	Mean	75 th percentile	Mode	Mean	75 th percentile	CTDI _{vol}			DLP		
							Mode	Mean	75 th percentile	Mode	Mean	75 th percentile
A	60	58	60	867	891	945	59	55	66	980	1108	1444
B	58	57	59	980	1195	1414						
C	68	73	86	1785	1612	1785						
D	44	44	46	652	734	794						

DLP – Dose-length product; CTDI_{vol} – Volume computed tomography dose index

Table 3: Comparison with other works

Parameters	Location	Year	Centres sampled	CTDI _{vol} (mGy)	Percentage variation from present study	DLP (mGy-cm)	Percentage variation from present study
Present study	Anambra, Nigeria	2016	4	66		1444	
Garba ^[17]	Northeast, Nigeria	2015	3	77	14.3	985	32.0
Tonkopi ^[26]	Canada	2015	15	67	1.5	1049	27.4
Saravanakumar ^[27]	India	2014	6	32	52.0	925	36.0
Foley ^[3]	Ireland	2012	40	66	0	940	35.0
McCullough ^[7]	America	2011	829	77	14.3	Nil	Nil
Tsai ^[28]	Taiwan	2011	146	72	8.3	850	41.1
Brix ^[29]	Germany	2003	113	61	7.6	1050	27.3
EC ^[10]	Europe	1999		60	9.1	1050	27.3

DLP – Dose-length product; CTDI_{vol} – Volume computed tomography dose index

The DLP is a combination of radiation intensity and scan range.^[3,7] Irrespective of the value of the CTDI_{vol} or the slice capacity of the scanner, a minimal scan range produces a small value of DLP. The <1000 mGy-cm recorded for centers A and D and >1400 mGy-cm for centers B and C are expectedly as a result of decreased and increased ranges, respectively. Centre C (1785 mGy-cm) with about 19% variation from the common DLP (1444 mGy-cm) is almost an extreme statistical outlier. Dose audit convention, however, does not encourage the exclusion of any center which has met the inclusion criteria.^[1,3]

The extent of body length covered in scanning does not affect the CTDI_{vol} value but certainly affects DLP. The scanning length for a particular type of CT examination can vary due to the pathology of the patient, the size of the patient, and the experience of the user. For all these reasons, CT protocols need to be reviewed so as to limit irradiation only to the collimated area of the anatomy under investigation.^[29]

The justification for optimizing the CTDI_{vol} and DLP from this locality to a comparable level with foreign ones

is clear; the present work revealed considerable variation of the CTDI_{vol} (1.5%–52%) and DLP (27.3%–41.1%) from popular works from other countries.^[20-23] Although there were also variations among those works, it was within narrow limits. Achieving this comparable dose levels would need the synergy of requesting Physicians, Radiologists, and Radiographers. They should by all means desire optimum image quality, but that interest should go *parri passu* with a keen concern for the radiation dose their patients are subjected to.

CONCLUSION

The DRLs for adult head CT scans for the population are 66 mGy and 1444 mGy-cm. Centers with fairly lower values of the DLP are more adept at optimization and should retain their values. A DRL that is exactly comparable to international recommendations is achievable in our locality if regular dose audit is carried out.

Recommendation

The observed inter-center variations in the same locality calls for standardization of training and, or regular peer

review of procedures with other centers. Also, requesting Physicians and Radiologists should demand dose output as a slide in the printed films. The Radiologists are also strongly urged to comment on the appropriateness of radiation dose used for the investigation, in their reports. This will place a strong moral and professional obligation on Radiographers to pay more attention to dose optimization. Requesting Physicians and reporting Radiologists are also advised to minimize their desire for lengthy adjoining anatomy to be captured during scan. A maximum adjoining anatomy of 10 mm is advised. Furthermore, a national DRL that will place an ethical obligation on the CT community is strongly recommended.

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Conflicts of interest

There are no conflicts of interest.

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