ORIGINAL ARTICLE

COMPUTED TOMOGRAPHY DOSE REFERENCE LEVEL FOR NON-CONTRAST AND CONTRAST EXAMINATION IN 13 CT FACILITIES IN SOUTH-WEST NIGERIA

Michael Onoriode Akpochafor, Akintayo Daniel Omojola, Samuel Olaolu Adeneye, Victor Ekpo, Nusirat Adeola Adedewe, Aderonke Rashidat Adedokun, Dare Joseph Adewa, Moses Adebayo Aweda, Mary-Ann Etim Ekpo

Department of Radiation Biology, Radiotherapy, Radiodiagnosis and Radiography, College of Medicine, Lagos University Teaching Hospital, Idi-Araba, Lagos, Nigeria

PJR October - December 2018; 28(4): 285-293

ABSTRACT

BACKGROUND: The use of computed tomography (CT) has further taken imaging a step forward but at higher dose to the patient. This has made relevant bodies to create dose reference level (DRL) as an investigational tool to identify unusually high radiation dose associated with the use of CTs. **AIMS AND OBJECTIVES:** This study intends to verify the current state of dose level of Volume CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) for common CT examinations in South-West Nigeria, it also seek to compare differences for non-contrast and contrast examination and to compare and correlate its findings with International and national DRL for $CTDI_{vol}$ and DLP at 50th and 75th percentile. **MATERIALS AND METHODS:** The study used 13 CT units which represent over 60% of functional CT facilities across Lagos. All scanners were multi-detector CT (MDCT) technology, with 2 to 128 slices with four different vendor: General Electric, Toshiba, Siemens and Philips. More than half of the CT used were 16-slice scanners. This retrospective study collected data from 702 male (317 non-contrast and 385 contrast agent) and 937 female (403 non-contrast and 534 contrast agent) respectively. **RESULTS:** There was no difference in mean age, $CTDI_{vol}$ and DLP for non-contrast and contrast examinations for the 3 body regions. There was no difference in CT dose outputs ($CTDI_{vol}$ and DLP) with media at 50th (P = 0.956) and 75th (P = 0.963) percentile. Comparison of $CTDI_{vol}$ and DLP at 75th percentile for the 3 body region for non-contrast agent between this study and other studies were not statistically different. However, significant difference in DLP was seen in Kenya and Nigeria (P = 0.028 and P = 0.039). Comparison of $CTDI_{vol}$ at 75th percentile with contrast agent between this study and USA was different (P = 0.038), however, there was no difference in $CTDI_{vol}$ and DLP between this study and United Kingdom, Ireland and European Commission. **CONCLUSION:** $CTDI_{vol}$ and DLP were lower compared to other studies. $CTDI_{vol}$ and DLP in this study was in line with other studies for non-contrast examinations at 75th percentile.

Keywords: Computed Tomography, Volume CT Dose Index, Dose Length Product, Contrast, Dose Reference Level

Introduction

The use of Computed Tomography (CT) for medical imaging has been on the increase in the last decade.[1-7] This is largely due to its fast acquisitions time, improved contrast, sensitivity and ability to image soft tissue and bone without superimposition. Images acquired by CT in the axial plane can be readily reconstructed

Correspondence : Michael Onoriode Akpochafor
Department of Radiation Biology, Radiotherapy, Radiodiagnosis and Radiography, College of Medicine, Lagos University Teaching Hospital, Idi-Araba, Lagos, Nigeria
Email: akpochafor@yahoo.com

Submitted 9 June 2018, Accepted 19 August 2018

in sagittal and coronal planes.[8,9] Clinical utilization of CT and its proliferation has increased in developing countries.[10-13]

Generally, the increased utilization of CT for imaging has improved the quality of clinical diagnosis, but also it has significantly increased the total annual exposure of the population to radiation.[13-16] In the United States alone, medical exposures contribute at least 48% of the total annual exposure, with CT alone contributing more than half.[17] A single CT examination is up to 10-100 times more dose than a conventional X-ray.[18] It is therefore necessary to monitor doses to patients, and to adhere to the three general principles applying to exposure situation which are justification, optimization and dose limit. The optimization goal is to ensure that the dose to the patient for any procedure is kept as low as reasonably achievable (ALARA) while still achieving the clinical objective of such procedure, and considering other factors - such as economic, societal and environmental factors.[19,20] As part of the optimization goal of radiation protection, the International Commission on Radiological Protection (ICRP) recommends the establishment of diagnostic reference levels (DRLs). This is synonymous with guidance levels recommended by the International Atomic Energy Agency (IAEA). DRLs are used as a practical tool and guide 'to indicate whether, in routine conditions, the levels of patient dose or administered activity from a specified imaging procedure are unusually high or low for that procedure. DRLs are not meant to serve as dose constraints, but rather as a guide and benchmark figure for comparing common diagnostic procedures.[21-26]

DRLs are set with CT dose parameters - volume CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP). CTDI is a measure of radiation dose output of a CT scanner at the centre of the scan, while DLP is a measure of radiation dose output of a CT scanner over the length of a scan. Mathematically expression of CTDI for a single scan and DLP are given as:

$$CTDI = \frac{1}{T}\int_{-\infty}^{+\infty} D(Z)dz \quad (1)$$

$$DLP = CTDI_{vol} \times L \quad (2)$$

Where T is the nominal beam collimation thick-ness in mm, D(z) is the dose profile and L is the scan length.

DRLs are set at the 75th percentile (third quartile) of typical values of dose parameters ($CTDI_{vol}$ and DLP) for a patient group (either as adults or children) across a range of facilities/machines for a specific type of examination/procedure. Achievable Doses (ADs) were also computed at the 50th percentile (median) of the dose distribution.

To ensure appropriate comparisons, the ICRP recommends the establishment of DRLs at local, regional and national levels. With the increasing number of CTs now in use in Nigeria, a CT DRL is necessary as a guide for optimization and to ensure best practices. Although, a first nationwide survey has been carried out in Nigeria to determine CTDIvol and DRL for non-contrast examinations. The purpose of this study was to focus on Lagos (South-West Nigeria) which has one of the largest population in Nigeria and hence highest number of CTs.[27,28] The study intends to determine $CTDI_{vol}$ and DLP for non-contrast and contrast examinations. It also seeks to compare obtained $CTDI_{vol}$ and DLP with national and international studies at 50th and 75th percentile.

Materials and Methods

In this retrospective study, CT dose output data ($CTDI_{vol}$ and DLP) were collected on-site from the CT console at each of the CT facilities directly by the researcher. In order to ascertain the functionality of the CT scanner in these facilities, a survey was undertaken across Lagos from a list drawn up of all known centres. A total of 30 CT facilities were reviewed. Each facility was contacted to ascertain status of their CT scanner either via email or telephone or by physical inspection. Of this number, 21 were found to be operational at the time of enquiry. Request for ethical approval was then sent to each facility. Prerequisites included that the research does not interfere with patient's investigations and patients' private information (especially names) are kept confidential. Following decision meetings with the management, radiologists and radiographers at each centre, ethical approval was received at 13 out of the 21 CT facilities, representing over 60% of all functional CT facilities in the region (Tab. 1).

All CT facilities were located in Lagos, Nigeria. There were located either in teaching or private hospitals

Centre	Slices	Brand	Model	Year of Manu-facturer	Year of Instal-lation	No. of patient per week
XD1	16	Toshiba	Alexion CGGT-028A	2016	2016	60
XD2	64	Toshiba	Asteion CGGT-015A	2016	2016	42
XD3	16	GE	Brivo CT 385	2016	2016	65
XD4	16	GE	Brivo CT 385	2016	2016	42
XD5	16	Siemens	Somatom Emotion DE	2013	2014	50
XD6	128	Toshiba	Aquillon CGGT-021B	2012	2013	98
XD7	16	GE	Brivo CT 385	2015	2015	70
XD8	64	GE	Optima CT 660	2017	2017	100
XD9	16	GE	Brivo CT 385	2013	2015	70
XD10	64	Philips	Brilliance CT 64	2007	2017	30
XD11	16	Toshiba	Alexion CGGT-028A	2011	2013	10
XD12	2	Siemens	Somatom Spirit	2013	2014	98
XD13	8	GE	BrightSpeed Edge Select	2008	2009	48

Table 1: CT specifications and average patients scanned per week

or privately dedicated radiology centre (Fig. 1). The study acquired data from 2,196 examinations from 1,132 patients. A minimum of 10 examination per protocol for the head, chest and abdomen was adopted in each CT facility used, any facility with <10

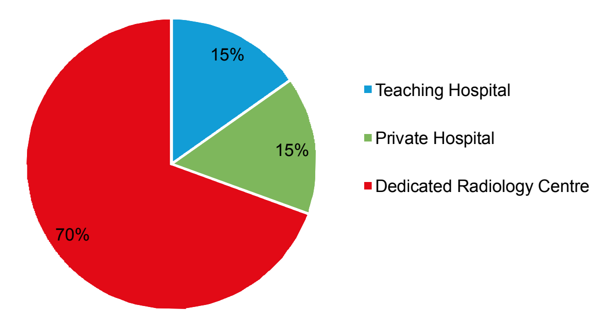

Figure 1: Distribution of CT facilities used

examination was excluded. In total, 1,639 examinations from 13 CT scanners were recorded (Fig. 2). The data was collected 12 weeks (July - September 2017) for head, chest and abdomen CT. There was no functional CT machine in other general hospitals in the region, except in Teaching and private hospitals. Most of the facilities were privately owned dedicated radiology centres. The mean number of patient per week across all centres was 60. All thirteen (13) CT scanners were multi-detector CT (MDCT) that are able to scan in both axial and helical modes. There

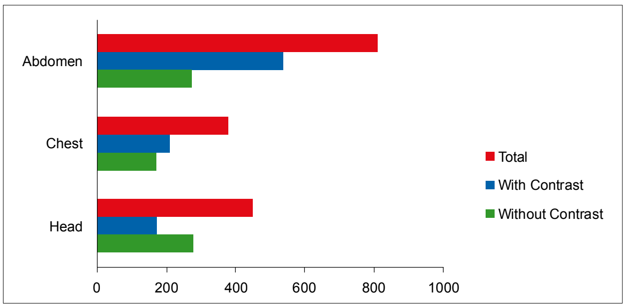

Figure 2: Distribution of non-contrast and contrast examination for head, chest and abdomen

was one dual-slice CT scanner, one 8-slice, seven 16-slice, two 64-slice, and one 128-slice CT. A pilot study had considered head, chest and abdomen as most requested examinations. Other than that primary dose parameters ($CTDI_{vol}$ and DLP), some secondary data were also noted such as age and gender. Scan and machine parameters noted included field of view, kV, mA, mAs, scan technique (axial/helical), scan time and scan range. Examinations without any secondary data were not included in the study.

No size and weight were recorded on the console, and could not be retrieved. We noticed that most CT unit do not keep record of their patient weight and size. Patient weight were estimated to be 67Kg on the average based on a few patient case note that were retrieved. This value was close to the nominal body mass of 70Kg.[29-31] CT dose data was collected on-site from the CT console in each facility via a "Dose Report" system. Research was done under supervision by a facility staff. Data had to be collected during off-peak hours (but during work hours) in order not to interfere with patient's investigations. In many ways, this was helpful, as clarifications could be made instantly. Data for male and female for two media (non-contrast and contrast examinations) were copied out from the CTs.

Collected data was already stored on the CT workstation. Data were analysed using descriptive statistics, Two Way ANOVA, Independent Sample t test, One Sample t test and correlation using SPSS. $P < 0.05$ was considered to be statistically significant.

Results

Head CT distribution for centre XD1-XD13 according to male and female indicated that a total of 134 male and 143 female examinations were non-contrast based and 79 male and 172 female were contrast based. The minimum number of persons per examination was 10. Centres that did not meet this criterion were XD1, XD4, XD10 and XD11. There was no difference in age for non-contrast and contrast examinations (P = 0.718). No significant difference in $CTDI_{vol}$ and DLP was seen for non-contrast and contrast examinations respectively (P = 0.706 and P = 0.794) (Tab. 2).

Head (Non-contrast)				Head (contrast)			
CT centres	Age	$CTDI_{vol}$	DLP	CT centres	Age	$CTDI_{vol}$	DLP
X2	49.90	65.39	1179.29	X2	59.64	114.32	2031.87
X3	50.09	34.03	520.66	X3	44.58	34.30	539.51
X5	47.69	51.29	999.30	X5	48.71	51.29	959.52
X6	49.71	48.26	1130.21	X6	42.4	47.50	1058.18
X7	54.16	18.25	275.49	X7	55.58	18.10	270.17
X8	52.42	16.92	271.95	X8	53.78	16.99	265.93
X9	51.35	37.43	901.53	X9	41.00	30.48	710.46
X12	48.29	13.04	221.93	X12	50.60	12.35	210.36
X13	44.71	47.96	798.76	X13	44.32	48.54	800.02

Table 2: Mean age, $CTDI_{vol}$ and DLP for head non-contrast and contrast examinations

Chest CT distribution for centre XD1-XD13 according to male and female indicated that a total of 69 male and 102 female examinations were contrast based and 86 male and 123 female were contrast based. The minimum number of persons per examination was 10. Centres that did not meet this criteria were XD2, XD10 and XD11. There was no difference in age for non-contrast and contrast examinations (P = 0.604). No significant difference in $CTDI_{vol}$ and DLP was seen for non-contrast and contrast examinations respectively (P = 0.812 and P = 0.769) (Tab. 3).

Abdomen CT distribution for centre XD1-XD13 according to male and female indicated that a total of 114 male and 158 female examinations were non-contrast based and 220 male and 318 female were contrast based. The minimum number of persons per examination was 10. XD2 did not meet this criterion. There was no difference in age for non-contrast and contrast examinations (P = 0.780). No significant difference in $CTDI_{vol}$ and DLP was seen for non-contrast and contrast examinations respectively (P = 0.106 and P = 0.411) (Tab. 4).

Chest (Non-contrast)				Chest (contrast)			
CT centres	Age	$CTDI_{vol}$	DLP	CT centres	Age	$CTDI_{vol}$	DLP
X1	48.00	8.12	320.78	X1	53.00	11.02	413.23
X3	52.04	5.61	208.11	X3	52.53	5.23	201.16
X4	51.12	7.21	278.09	X4	54.18	8.23	327.57
X5	50.30	5.21	145.15	X5	49.73	5.77	164.26
X6	54.00	10.59	440.50	X6	50.82	10.88	455.62
X7	49.57	6.04	228.40	X7	48.80	6.09	231.09
X8	55.65	9.70	369.43	X8	56.86	9.53	369.85
X9	45.18	5.33	204.65	X9	47.00	5.51	204.35
X12	51.33	4.30	147.54	X12	50.60	4.27	146.53
X13	53.79	15.43	437.07	X13	44.32	14.64	417.13

Table 3: Mean age, $CTDI_{vol}$ and DLP for chest non-contrast and contrast examinations

Abdomen (Non-contrast)				Abdomen (contrast)			
CT centres	Age	$CTDI_{vol}$	DLP	CT centres	Age	$CTDI_{vol}$	DLP
X1	53.25	10.81	553.66	X1	53.13	12.17	513.23
X3	44.63	6.47	326.85	X3	45.79	6.48	317.48
X4	52.21	6.88	360.22	X4	54.09	6.97	358.61
X5	53.27	6.90	335.84	X5	54.18	7.69	371.79
X6	53.50	16.08	874.99	X6	53.00	25.9	1064.24
X7	56.17	7.89	388.72	X7	57.00	7.43	364.66
X8	52.17	6.15	321.07	X8	51.53	6.56	288.95
X9	53.83	10.49	544.44	X9	55.10	8.59	439.38
X10	51.58	10.84	547.11	X10	51.97	11.16	560.8
X11	38.70	5.67	271.93	X11	37.65	6.00	287.79
X12	47.64	4.76	233.99	X12	46.56	4.08	195.02
X13	46.73	12.32	515.45	X13	35.33	14.77	615.19

Table 4: Mean age, $CTDI_{vol}$ and DLP for abdomen non-contrast and contrast examinations

The $CTDI_{vol}$ and DLP range among the 13 centres without contrast for the head was 12.9-51.29mGy and 213.38-1055.8mGy.cm, the chest was 4.09-16.55mGy and 139.33-454.83mGy.cm and the abdominal region was 5-16.45mGy and 234.71-890.45mGy.cm. Similarly, the $CTDI_{vol}$ range among the 13 centres with contrast media for the head was 12.1-100.6mGy and 204.7-1871mGy.cm, the chest was 4.28-14.94mGy and 147.4-444.1mGy.cm and the abdominal region was 4.42-15.86mGy and 214.9-836.7mGy.cm (Tab. 5).

A two way mixed ANOVA show that at 50th percentile CT dose outputs ($CTDI_{vol}$ and DLP) were different

(P = 0.013). Also, there was no difference in CT dose outputs with media (P = 0.956). Also, both media used was not different (P = 0.957). Similarly, a two way mixed ANOVA show that at 75th percentile, CT dose outputs ($CTDI_{vol}$ and DLP) were different (P = 0.007). Also, there was no difference in CT dose outputs with media (P = 0.963). Also, both media used was not different (P = 0.966) (Tab. 5).

	Head (without contrast)		Head (with contrast)	
	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
75th Percentile	48.82	935.4	48	940.58
50th Percentile	37.92	820.15	34.58	752.27
	Chest (without contrast)		Chest (with contrast)	
	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
75th Percentile	9.5	364.27	9.88	380.86
50th Percentile	6.28	237.49	7.71	279.53
	Chest (without contrast)		Chest (with contrast)	
	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
75th Percentile	10.12	512.6	9.5	455.72
50th Percentile	7.56	378.75	7.34	364.87

Table 5: $CTDI_{vol}$ and DLP at 50th and 75th percentile for non-contrast and contrast examination in mGy

There was good correlation in $CTDI_{vol}$ for non-contrast/contrast examinations for the 3 body region at 50th and 75th percentile (P = 0.030 and P = 0.014) respectively. Likewise, good correlation DLP for non-contrast/contrast examinations for the 3 body region at 50th (P = 0.041). There was no correlation in DLP for non-contrast/contrast examinations for the 3 body region at 75th (P = 0.082) (Tab. 5).

Comparison at 75th percentile for head, chest and abdomen for non-contrast agent between this study and United Kingdom (UK),[32] Ireland,[33] United States of America (USA),[34] Japan,[35] European Commission (EC),[36] Kenya[37] and Nigeria[38] show that there were no significant difference in CTDI (P = 0.782, P = 0.853, P = 0.701, P = 0.549, P = 0.683, P = 0.615 and P = 0.642 respectively) (Tab. 6).

Also Comparison at 75th percentile for head, chest and abdomen for non-contrast media between this study and United Kingdom (UK), Ireland, United States of America (USA), Japan and European Commission (EC) show that there were no significant difference in DLP (P = 0.086, P = 0.658, P = 0.079, P = 0.105 and P = 0.227 respectively). However, significant difference in DLP for Kenya and Nigeria was noticed (P = 0.028 and P = 0.038) (Tab. 6).

$CTDI_{vol}$ value at 75th percentile for non-contrast examinations								
Body region	This study	UK	Ireland	USA	Japan	EC	Kenya	Nigeria
Head	49	60	58	57	85	60	61	61
Chest	10	12	11	15	15	10	19	17
Abdomen	10	15	12	20	20	25	20	20
DLP value at 75th percentile for non-contrast examinations								
Body region	This study	UK	Ireland	USA	Japan	EC	Kenya	Nigeria
Head	535	570	540	1011	1350	1000	1612	1310
Chest	364	610	390	545	550	400	895	735
Abdomen	513	745	600	1004	1000	800	1842	1486

Table 6: Comparison of at 75th percentile for different countries in mGy

Comparison at 75th percentile for head, chest and abdomen for contrast media between this study and UK, Ireland and EC show that there was no significant difference in CTDI (P = 0.145, P = 0.778 and P = 0.423 respectively). However, there was a significant difference with our study and USA (P = 0.038). Comparison at 75th percentile for head, chest and abdomen for contrast media between this study and UK, Ireland, USA and EC showed that there was no significant difference in DLP (P = 0.079, P = 0.328, P = 0.204 and P = 0.467 respectively) (Tab. 7).

$CTDI_{vol}$ value at 75th percentile for contrast examinations								
Body region	This study	UK	Ireland	USA	Japan	EC	Kenya	Nigeria
Head	48	-	66	-	-	60	-	-
Chest	10	12	-	16	-	10	-	-
Abdomen	10	15	13	19	20	25	-	-
DLP value at 75th percentile for contrast examinations								
Body region	This study	UK	Ireland	USA	Japan	EC	Kenya	Nigeria
Head	941	-	940	-	-	-	-	-
Chest	381	610	-	596	-	400	-	-
Abdomen	456	745	1120	995	1000	800	-	-

Table 7: Comparison of at 75th percentile for different countries in mGy

Discussion

Private dedicated CT centres (75%) were considered to be more in Lagos metropolis than those in the government teaching (15%) and private (15%) hospitals. In all cases, ages of adult male and female for non-contrast and contrast examinations were not different, this information created balance for analysing $CTDI_{vol}$ and DLP in this study since age irrespective of sex was not different from one another. Similarly our findings show that $CTDI_{vol}$ and DLP for non-contrast and contrast examination were not different ($P < 0.05$).

This study (49 mGy) was 20.18% lower than that of UK and EC (60 mGy) for head $CTDI_{vol}$ with non-contrast examination at 75th percentile. Also, differences was seen when this study's $CTDI_{vol}$ was compared with Ireland (58 mGy) and USA (57 mGy), the percentage difference was 16.8% and 15.09% lower when compared to both. A look at the comparison of this study with Kenya (61 mGy) and a national survey conducted in Nigeria (61 mGy) showed a difference of 21.8% lower than both. The highest percentage difference in $CTDI_{vol}$ was between this study and a national study conducted in Japan (85 mGy), which was quite higher than our study with difference of 53.7%. This study $CTDI_{vol}$ for the head was lower than the recommended values of the International Commission on Radiological Protection (ICRP) with a difference of 20.2%.[39] Similarly this study was lower in DRL compared to the American College of Radiology (ACR) recommended values, the difference between this study and ACR was 42%.[40] This differences could be associated with the kind of protocol used, patient attenuation effect and the algorithms of the CT scanners. Furthermore, DLP for the head at 75th percentile for this study was the least (535mGy.cm). The highest value was with a study conducted in Kenya in which the DLP for the head was 1612mGy.cm, this study was 100.3% lower in percentage differences and three times higher than this study.

CTDIvol for chest in this study and EC were the same (10mGy). This study $CTDI_{vol}$ value for chest was also the least among UK, Ireland, USA, Japan, Kenya and Nigeria with a difference of 9.5-62.1%. This study DRL was lower than that of ICRP, which was three times higher than this study. Also, DLP for the chest for this study was the least (364mGy.cm).

$CTDI^{vol}$ for abdomen in this study was also the least (with 10 mGy). The highest percentage difference was between this study and EC, which was 85.7% lower than EC. Similar trend in percentage difference was noticed when this study was compared to ACR, both were 2.5% higher than this study. It was observed that radiation dose to the head was more compared to those of chest and abdomen. In general, this study had the least CTDIvol for the head region compared to other studies. Similarly, this study had the least DLP for the abdominal region (513mGy.cm)

There were less available data for contrast examination for $CTDI_{vol}$ and DLP than non-contrast examination with other studies. $CTDI_{vol}$ for the head for contrast examination at 75th percentile in this study (48mGy) was lower than those of Ireland (66mGy) and EC (60mGy), with significant difference among the 3 studies ($P = 0.008$). Similar, differences were seen for the chest in this study (10 mGy) with UK (12mGy) and USA (16mGy). This study result for the chest was the same as EC (10mGy). This study also had the least $CTDI_{vol}$ for the abdomen when compared to UK, Ireland, USA, Japan and EC, showing statistically significant difference in $CTDI_{vol}$ ($P = 0.001$). All DLP results with contrast examinations were higher than this study except for the head where this study (941mGy.cm) was relatively higher than a study conducted in Ireland (940mGy.cm). There was statistically significant difference among this study, UK, Ireland, USA, Japan and EU for abdomen ($P < 0.001$).

Generally, this study $CTDI_{vol}$ and DLP for non-contrast and contrast media did not show any significant difference ($CTDI_{vol}$ was mostly comparable for both media). However, Slight differences were seen between non-contrast and contrast examinations (higher) in DLP for head and chest. Studies from Sahbaee et al who investigated the effect of contrast material on radiation dose using an Anthropomorphic Phantoms, showed that there were increased radiation dose to various organ (not $CTDI_{vol}$) with contrast materials compared to non-contrast examination.[41,42] Dose distribution in a cylindrical phantom have been shown to have difference 200% or 300% at peak doses, this study was seen to have differences below these value.[43]

Conclusion

This study showed remarkably lower $CTDI_{vol}$ and DLP for non-contrast and contrast examinations compared to other studies. The current state of these two CT dose parameters in South-West Nigeria could be a potential good tool in standardizing $CTDI_{vol}$ and DLP for other regions in the country. There is need for quick harmonization of this study and other related studies in Nigeria so as to further reduce radiation dose to patients during CT examinations.

Conflict of Interest: Note

References

1. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. N. Engl. J. Med. 2007; **357:** 2277-84.

2. Brenner DJ. Should we be concerned about the rapid increase in CT usage? Rev. Environ. Health. 2010; **25:** 63-8.

3. Bellolio MF, Heien HC, Sangaralingham LR Jeffery MM, Campbell RL, Cabrera D, et al. Increased Computed Tomography Utilization in the Emergency Department and Its Association with Hospital Admission. West. J. Emerg. Med. 2017; **18:** 835-45.

4. Brenner DJ, Hall EJ. Computed tomography - an increasing source of radiation exposure. N. Engl. J. Med. 2007; **357:** 2277-84.

5. Berrington de Gonzalez A, Mahesh M, Kim KP, et al. Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch. Intern. Med. 2009; **169:** 2071-7.

6. Smith-Bindman R, Lipson J, Marcus R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch. Intern. Med. 2009; **169:** 2078-86.

7. Hess EP, Haas LR, Shah ND, Stroebel RJ, Denham CR, Swensen SJ. Trends in computed tomography utilization rates: a longitudinal practice-based study. J. Patient. Saf. 2014; **10:** 52-8.

8. Liang CR, MSc, Chen XH, Kapur J, Ong KL, Quek ST, Kapur SC. Establishment of institutional diagnostic reference level for computed tomography with automated dose-tracking software, J Med. Radiat. Sci. 2017; **64:** 82-9.

9. Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. The Essential Physics of Medical Imaging. Baltimore: Lippincott Williams and Wilkins; 2002.

10. Kak AC, Slaney M, Principles of computerized tomographic imaging, Society for Industrial and Applied Mathematics. 2001

11. Karim MKA, Hashim S, Bakar KA, Muhammad H, Sabarudin A, Ang WC, Bahruddin NA. Establishment of multi-slice computed tomography (MSCT) reference level in Johor, Malaysia. J. Phys.:Conf. Ser. 694, 2016.

12. Dovales AC, da Rosa LA, Kesminiene A, Pearce MS, Veiga LH. Patterns and trends of computed tomography usage in outpatients of the Brazilian public healthcare system, 2001-2011. J. Radiol. Prot. 2016; **36:** 547-60.

13. Rehani B. Imaging overutilization: Is enough being done globally? Biomed. Imaging. Interv. J. 2011; **7:** e6

14. McCollough CH, Primak AN, Braun N, Kofler J, Yu L, Christner J. Strategies for Reducing Radiation Dose in CT. Radiol. Clin. North. Am. 2009; **47:** 27-40.

15. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR. 2001; **176:** 289-96.

16. Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, et al. Radiation Dose Associated with Common Computed Tomography Examinations and the Associated Lifetime Attributable Risk of Cancer. Arch. Intern. med. 2009; **169:** 2078-86.

17. National Council on Radiation Protection and Measurements (NCRP). Ionizing radiation exposure of the population of the United States. Report No. 160. Bethesda, Md: NCRP, 2009.

18. Kim YY, Shin HJ, Kim M-J, Lee M-J. Comparison of effective radiation doses from X-ray, CT, and PET/CT in pediatric patients with neuroblastoma using a dose monitoring program. Diagn. Interv. Radiol. 2016; **22:** 390-4.

19. Do K-H. General Principles of Radiation Protection in Fields of Diagnostic Medical Exposure. Journal of Korean Medical Science. 2016; **31(1):** S6-S9.

20. International Commission on Radiological Protection Radiological protection in medicine. ICRP Publication 105. Ann ICRP. 2007; **37:** 1-63.

21. Kim J, Seo D, Choi I, Nam S, Yoon Y, Kim H, et al. Development of Diagnostic Reference Levels Using a Real-Time Radiation Dose Monitoring System at a Cardiovascular Center in Korea. J. Digit. Imaging. 2015; **28:** 684-94.

22. International Commission on Radiological Protection. Radiological Protection and Safety in Medicine (Report 73). Annals of the ICRP. 1996; **26:** 1-31.

23. International Commission on Radiological Protection Managing patient dose in digital radiology. ICRP publication 93. Ann ICRP. 2004; **34:** 1-74.

24. International Commission on Radiological Protection. 1990 Recommendations of the International Commission on Radiological Protection (Report 60). Annals of the ICRP. 1991; **21(1-3).**

25. International Commission on Radiological Protection. Avoidance of radiation injuries from medical interventional procedures. ICRP Publication 85; 2000

26. International Atomic Energy Agency. Applying radiation safety standards in diagnostic radiology and interventional procedures using x ray. Safety Report Series No. 39, Vienna. 2006

27. Akpochafor MO, Omojola AD, Habeebu MY, Ezike JC, Adeneye SO, Ekpo ME, et al. Computed Tomography Organ Dose Determination Using ImPACT Simulation Software: Our Findings In South-West Nigeria. Eurasian. J. Med. Oncol. 2018; **2:** 165-72.

28. Adejoh T, Onwujekwe EC, Abba M c, Ali AM, Imo AS, Nzotta CC, et al. Computed tomography scanner census and adult head dose in Nigeria. Egypt. J. Radiol. Nucl. 2018; **49:** 66-70.

29. Christner JA, Kofl er JM, McCollough CH. Estimating effective dose for CT using dose length product compared with using organ doses: consequences of adopting International Commission on Radiological Protection publication 103 or dual-energy scanning. AJR Am J Roentgenol 2010; **194:** 881-9.

30. McCollough CH, Christner JA, Kofl er JM. How effective is effective dose as a predictor of radiation risk? AJR Am J Roentgenol 2010; **194:** 890-6.

31. Cristy M, Eckerman K. Specifi c absorbed fractions of energy at various ages from internal photon sources. Parts I-VII (ORNL/ TM-8381). Oak Ridge, Tenn: Oak Ridge National Laboratory, 1987; pp. 1-74.

32. Shrimpton PC, Hillier MC, Lewis MA, Dunn M. National survey of doses from CT in the UK: 2003. Br J Radiol. 2006; **79:** 968-80.

33. Foley SJ, McEntee MF Rainford LA 2012 Establishment of CT diagnostic reference levels in Ireland Br. J. Radiol. 85 1390-7.

34. Kanal K M, Butler PF, Sengupta D, Bhargavan-Chatfield M., Coombs LP, Morin RL. United States Diagnostic Reference Levels and Achievable Doses for 10 Adult CT Examinations. J Rad 2017; **284:** 120-33.

35. Medical Information Research Information Network (JRIME). Diagnostic Reference Levels Based on Latest Surveys in Japan 2015. Available from: http://www.radher.jp/JRIME/report/DRLhoukokusyoEng.pdf. 2015, Nov 10.

36. European Commission. Medical Radiation Exposure of the European Population (Part2). Radiation Protection No 180. Luxemburg: Publications Office of the European Union. 2014

37. Korir GK, Wambani JS, Korir IK, Tries MA, Boen PK. (2015). National diagnostic reference level initiative for computed tomography examinations in Kenya. Radiat Prot Dosimetry. 2016; **168:** 242-52.

38. Ekpo EU, Adejoh T, Akwo JD, Emeka OC, Modu AA, Abba M, et al. Diagnostic reference levels for common computed tomography (CT) examinations: results from the first Nigerian nationwide dose survey. J. Radiol. Prot. 2018; **38:** 525-35.

39. ICRP. The 2007 recommendations of the international commission on radiological protection. ICRP publication 103. Ann ICRP 2007; **37:** 1-332.

40. American College of Radiology (ACR). ACR practice guideline for diagnostic reference levels in medical X-ray imaging. ACR practice guideline. Resolution 3, Virgina, United States: ACR; 2008.

41. Sahbaee P, Abadi E, Segars WP, Marin D, Nelson RC, Samei E. The Effect of Contrast Material on Radiation Dose at CT: Part I. Incorporation of Contrast Material Dynamics in Anthropomorphic Phantoms. Radiol. 2017; **283:** 739-48.

42. Sahbaee P, Abadi E, Segars WP, Marin D, Nelson RC, Samei E. The Effect of Contrast Material on Radiation Dose at CT: Part II. A Systematic Evaluation across 58 Patient Models. Radiol. 2017; **283:** 749-57.

43. Nishizawa K, Maruyama T, Takayama M, Okada M, Hachiya J, Furuya Y. Determination of organ doses and effective dose equivalents from computed tomographic examination. Br J Radiol. 1991; **64:** 20-8.