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DETERMINATION OF INSTITUTIONAL BASED DIAGNOSTIC REFERENCE LEVEL FOR ADULT COMPUTED TOMOGRAPHY EXAMINATION IN NASARAWA STATE, NIGERIA

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ABSTRACT

Background: Diagnostic reference level is important in checkmating excesses and for dose optimization in medical procedures. It has been proven to be very effective in ensuring that patient dose is within the recommended standard of practice.

Objective: The objective of the work was to find out the dose values in each set of CT examinations and the primary examination parameters for the head, chest, and abdomen in adult patients.

Methodology: The work was a retrospective investigation using a CT scanner that was carried out in two tertiary healthcare facilities in Nasarawa State. The average doses for the pre- and post-contrast examinations were obtained. The machine parameters, scan length, field of view, Dose Length Product (DLP), and Computed Tomography dose index (CTDIvol) were documented. The International Atomic Energy Agency's guidelines for average weighted patients were obtained, and the protocol was appropriately followed. The statistical package for social sciences was used to analyze the data, and the IAEA framework was followed.

Results: The established DRLs are (50.6mGy & 1079mGym-1), (15.7mGy and 522mGycm-1) and (14.2mGy & 702.5 mGycm-1) for Head, Chest, and Abdomen respectively. Comparing this study with international studies across the globe for the various body anatomies (Head, Chest, and Abdomen), this study is relatively within the range of variations in the scan protocols used, human errors, and non-coherence to the norms of international best practices.

Conclusion: The local diagnostic reference levels for routine Head, Chest, and Abdomen were established and the CTDI and DLP analysis was done in line with the EC guidelines in all the centers. The estimated values for CTDIv were similar across the centers and in tandem with the EC value. The mean DLP values were in line with the proposed EC values, the high dose values are attributable to technical parameters, untimely quality control initiatives, work fatigue, the unnecessary use of large scan lengths for the abdominal region, generational gaps of the scanners and other unwholesome practices.

1.0 Introduction

Diagnostic Reference levels (DRL) is a useful instrument for maximizing patient protection throughout diagnostic and interventional procedures. But over time, it has become clear that further guidance is required. Definitions of terms used in previous guidance, DRL value determination, the appropriate interval for re-evaluating and updating these values, appropriate use of DRLs in clinical practice, practical DRL application methods, and application of the DRL concept to newer imaging technologies are some of the issues that need to be addressed (ICRP, 2017). It emphasizes the significance of providing information on DRLs in training programs for healthcare workers and makes recommendations for changes to the way DRL surveys are conducted that make use of automated reporting of radiation-dose-related quantities (ICRP,2017).

For now, and the foreseeable future, the goal of ICRP is to avoid uncertainty by offering clarification. Because the goal of offering an optimization tool is the same, the Commission advises that the word "DRL" be kept in use for both diagnostic and interventional treatments, as introducing a new name would only lead to further misunderstanding (ICRP, 2017).

To give standard-sized patients radiation protection benchmarks, the DRLs are also utilized as a tool for evaluating dose variances among facilities. To enable facilities with dosage outliers to initiate optimization efforts, a reference was suggested. DRLs are impacted by examination protocol, equipment, and population variables. Therefore, the ICRP has advised that these issues be considered when establishing DRLs, and that local or regional DRLs.

Computed Tomography (CT) examinations have been characterized by a high radiation source procedure which leads to excess radiation dose to the anatomical region that might result in severe disorder. Nevertheless, the study intends to start with local diagnostic reference levels prior to the establishment of National DRL.

To lower the dose to patients, the public, and staff, the ICRP also suggested that all medical exposures be subject to the radiation safety principles of justification, optimization, and dose limitation (ICRP, 2017). The best way to implement the fundamental optimization principle is to adhere to diagnostic reference levels.

However, this research is narrowed down to the Some Hospital in Nasarawa State, Nigeria, to serve as a precursor to National DRLs. The aim of this work was to ascertain DRLs for computed tomography examinations in Nasarawa State, Nigeria.

2.0 Materials and Methods

2.1 Materials

The Materials needed to carry out this investigation includes, the research center CT scanners, data gathering forms, and SPSS version 22.0 software for data processing.
The participating hospital provided ethical authorization for this study to be carried out.

2.2 Methods

The study adopted a retrospective and quantitative design to determine the absorbed radiation dose to patients undergoing CT scans of the head, chest, and abdomen. A quantitative design was appropriate because the study involved the use of numerical data. The research was conducted retrospectively to ensure more reliable and valid data, and acquired from the computer archive system, where the dose report and exposure parameters are stored.

2.2.1 Population Sample

The study consisted of all adult patients who attended CT scan examinations of the head, chest, and abdomen. A sample size of 119 participants were adopted based on the eligibility criteria and while 40 were selected for each anatomical region. These were obtained through the selection of 40 participants (male and female) who came for CT examinations of the head, chest, and abdomen in the participating center. The purposive sampling technique was considered the most appropriate, as standard-sized patients are essential to the design. Only patients (consented adult participants) that met the inclusion criteria for this research and must be within the weight limits of standard-size patients which is 70 ±5 kg. The European weight limit will be adopted to make comparison with published values easier because a standard-size patient for the Nigerian population could not be found in the literature.

2.2.2 Methods of Data Collection

The data was gathered with the assistance of the CT radiographers who are well-trained, licensed, and certified. The data collected sheet used for the study was adopted from the IAEA, survey and has the following sections: participant demographic information, scan parameters, and dose parameters.

2.2.3 Participant Demographic Information

18 years and above for age to make sure only adult patients were included in the study
The gender of the patient was taken into cognizance and documented.
Weight to ensure that only standard-size patients were included (70±5) kg.
Body region which indicates only patients coming for head, chest, and abdomen CT were included in the study.

2.3 Research Design

This is a retrospective cross-sectional study carried out at the radiology department of some hospitals in Nasarawa state from August 2022 to January 2023 using a simple random sampling technique. Twenty patients were studied based on the recommendation of ICRP for the establishment of a Diagnostic Reference level. The study comprised all adult patients for abdominal computed tomography head and chest. The machine has automatic exposure control modulation. Anatomical information such as age, patient anterior-posterior diameter, lateral diameter (and effective diameter was calculated). CT dose parameters and exposure parameters such as CTDIvol, DLP, kVp, and mAs were also recorded.

2.4 Study Area

The study area comprises of some selected hospitals located in Nasarawa state of Nigeria.
The geographical entity known as Nasarawa State came into existence on the 1st of October 1996. It has a central location in the middle belt region of Nigeria. The state lies between latitude 70 45' and 90 25' N of the equator and between longitude 70 and 90 37'E of the green Meridian (Binbol & Marcus. 2005).
Nasarawa state shares a boundary with Kaduna state in the north Plateau state in the east Taraba and Benue states in the south, while Kogi and Federal capital territory flank it in the west (Binbol 2005).

Figure 1: Map of Mararaba, Nasarawa State (Field Survey, 2023)

Figure 2: Map of Keffi, Nasarawa State (Field Survey, 2023)

2.5 Data Analysis

The data obtained was saved on an excel spread sheet. The data contain the following: the demographic information (age, gender, & weight), the scan parameters (kV, mA, slice thickness & FOV) and dose parameters (CTDIv& DLP). The data was be analyzed using SPSS statistical software version 17. Statistical method was employed for the data analysis as the descriptive analysis. The descriptive analysis is employed to summarize the data for this study. It is used to give a description of the data by determining the measures of location (mean, median, mode and third Quartile (75^{th} percentile). The data obtained was used to compare a local diagnostic reference level with established DRLS in the literature.

3.0 Results

Tables 1 Specification of the CT scan machine used for the study

S/No	Parameter	Hospital A	Hospital B
1.	Manufacture	GE Bright speed Hangwei medical system	Toshiba
2.	Model type	2326492-3	-
3.	Year of manufacture	2011	-
4.	Year of installation	2015	2013
5.	Slice	16 slice	160 Slice
6.	Line frequency	$50/60_z$	-

Table 1 shows the product specification of the CT scan machine used in the study center. The table above indicate the manufacturer, model type, year of manufacture, year of installation, number of slice and the line frequency of the machine used in both CT scan center.

Table 2 Detailed information on the patient demographic from Center A&B

Center	No of female	No of male	Frequency	Mean age
Center A				
Head	9	11	20	49.9500
Chest	6	14	20	65.500
Abdomen	10	10	20	53.4000
Center B				
Head	9	10	19	61.1000
Chest	4	16	20	66.4000
Abdomen	6	14	20	62.65000
Total	44	75	119	

In center A, the total number of 60 patients were used for the study and comprising of 25 Females and 35 Males across the body regions representing a gender distribution of Head (45%, 55%), Chest (30%, 70%) and Abdomen (50%, 50%) for male and female respectively. The mean and values of the ages are: for Hospital (A), Head is (15.5) Chest is (11.5) and Abdomen (15.0).

In center B the total number of 59 patient were recruited for the study and hence the sample size is 59 patient as represented above comprising of 30 Males and 19 Females across the body region representing a gender distribution of Head (47.3%, 52.7%), for Chest(20%, 80%) and(30%,70%) for abdomen respectively. The mean age values of Head is 14.3, Chest is 16.1 and Abdomen 15.8 respectively. The demographic information of ages are included in the study to show that only Adult patient that came for routine CT radiation examination were admissible in study in line with European Commission Guidelines (Ec, 1999).

Table 3 Results of measurement CT scan exposure parameters

CT examination (center)	kV	mAs Gender (M) (F)	Scan Time	DFov (Mean)
Center A				
Head	120	364.0 78.3	29.8	24.0300
Chest	120	154.0 2.6	13.1	30.2020
Abdomen	120	219.3 9.9	15.2	40.0000
Center B				
Head	120	162.5 0.9	0.75	24.4945
Chest	110	100 2.0	0.75	30.1615
Abdomen	120	76.9 4.0	0.65	40.0000

The CT scan exposure parameter i.e the tube voltage (kV) is the same for the body regions, the tube current (mAs) are different with the head region having 364.0 and 78.3, the chest 154.0 and 2.6 and the Abdomen 219.3 and 9.9. For center A, gender was included in the mAs colon as M/F just to indicate the number of male and female. The number of male is on top while F below represent Female. The mean and related value of the CT Scan Exposure parametes for both center A and B are displayed above. From Table 4.3 above center A has tube voltage kV of 120 across the Head, Chest and Abdomen, they all have the same kV but the tube current (mAs) varied. The Scan time for head is 29.8, Chest 13.1 and Abdomen 15.2 respectively. The mean field of views (DFvo) are 24.0, 30.2, 40.0 for Head, Chest and Abdomen respectively.

In center B, the tube voltage varies, Head and Abdomen has the value 120, while for Chest has 110. The surge in tube voltage for the abdominal region can be attribute to a longer Scan length due to the nature of abdomen anatomy. The variation in tube voltage of chest was a result of anatomical region but the Tube current Varies possibly due different scan protocol used and human errors. From the law of thermodynamics no machine is 100% efficiently and also applied to humans. The scan time for all the body region is the same for all the body region but varies in the field of view (DFov). As for Head, Chest and Abdomen has the Value as 24.4, 30.1 and 40.0 respectively.

Table 4a measurement and calculation of CT dose index volume (CTDlvol)

CT examination centers	Mean CTDlvol	S.D CTDIvol	Max range	Min range	Range
Center A					
Head	47.1210	8.41820	64.40	32.57	31.83
Chest	15.2090	1.19678	18.28	12.82	5.41
Abdomen	13.4510	.95189	15.22	15.22	3.19
Center B					
Head	41.8715	8.09498	57.44	29.88	27.56
Chest	16.0525	1.17024	18.23	14.33	3.90
Abdomen	15.1200	.98943	15.97	12.22	3.75

S.D= Standard Deviation

The analysis of the CTDl(mGy) for center A and B are detailed in table 4.4a above, representing Mean, standard Deviation, maximum range, minimum range and Range.

Table 4b Measurement and Calculation of dose length products (DLP)

CT examination center	Mean DLP	S.D DLP	Max range	Min range	Range
Center A					
Head	941.2985	230.94495	1575.56	606.54	969.54
Chest	445.7000	116.22216	622.00	133.00	.04
Abdomen	619.9500	77.49531	780.00	520.00	260.00
Center B					
Head	882.2355	168.79654	1170.22	487.02	683.02
Chest	418.9500	39.19382	502.00	309.00	193.00
Abdomen	607.4500	41.13581	700.00	520.00	180.00

S D = Standard Deviation

The analysis of DLP for center A and B are detailed in table 4.4b above representing the Mean, Standard Deviation, Maximum range and Minimum range and Range.

Table 5 Result of patient at 1st and 3rd Percentile of CTDlvol and DLP

Body Region	No of patient	1st percentile CTDlvol (mGy)	3rd Quartile CTDlvol (mGy)	1st percentile DLP (mGymc^{-1})	3rd Quartile DLP (mGymc^{-1})
Center A					
Head	20	41.0025	50.6950	739.0925	1079.3925
Chest	20	15.0000	15.7325	405.5000	522.0000
Abdomen	20	12.9075	14.2600	548.0000	702.5000
Center B					
Head	19	38.1875	48.9425	771.0250	1015.9175
Chest	20	15.0875	16.9275	401.0000	432.5000
Abdomen	20	14.8100	15.6950	591.2500	611.7500

Table 7 Comparison of Established DRLs with the Literature Studies in terms of CTDvol (mGy and DLP (mGycm^{-1})

Body Region	This study 2024	Kambari (2017)	Kabir (2015)	Abdullahi et al (2020)
Head	50.6	49.8	60	62.5
	1079	1639	1024	2946
Chest	15.7	10.9	10	9.9
	522	432	407	663.3
Abdomen	14.2	12.7	15	13.5
	702.5	560	757.5	1397

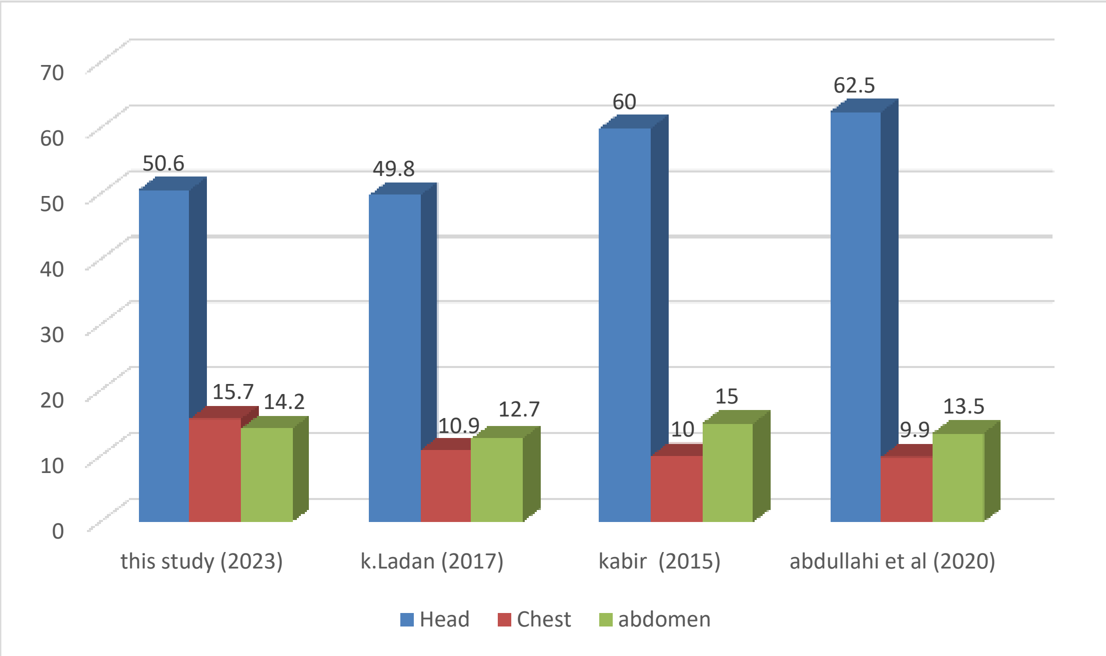

Figure 4 : Comparison of Established DRLs with Literature in terms of CTDlvol (mGy)

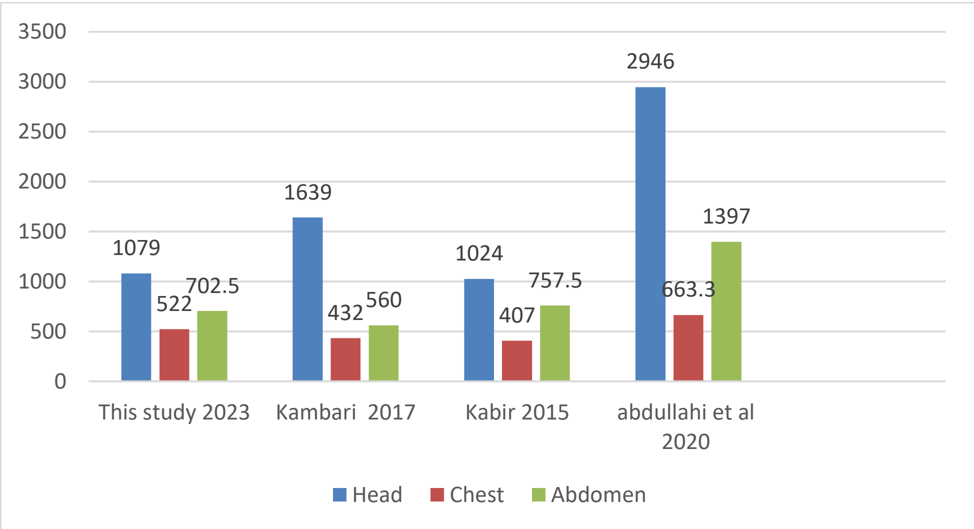

Figure 5: Comparison of Established DRLs with Literature in terms of DLP (mGy cm^{-1})

Tables 8 Comparison of established DRL in term of CTDlvol (mGy) and DLP (mGycm^{-1})

Body Region	This study	Uganda	North east India	Morocco	Europe	Portugal
Reference and Year	(2024)	Geofery *et al*, (2022)	Arnabjyoh *et al* (2022)	Benmessaoud *et al*, (2021)	Francis *et al*, (2011)	Santos *et al* (2014)
Head	50.6 1079	56.02 1260	-	58 1298	41 736	75 1010
Chest	15.7 522	7.82 377.0	18.35 765	15 944	13.1 492	14 470
Abdomen	14.2 702.5	12.54 1418.3	18.25 1870.75	15 1874	12.1 539.4	18 800

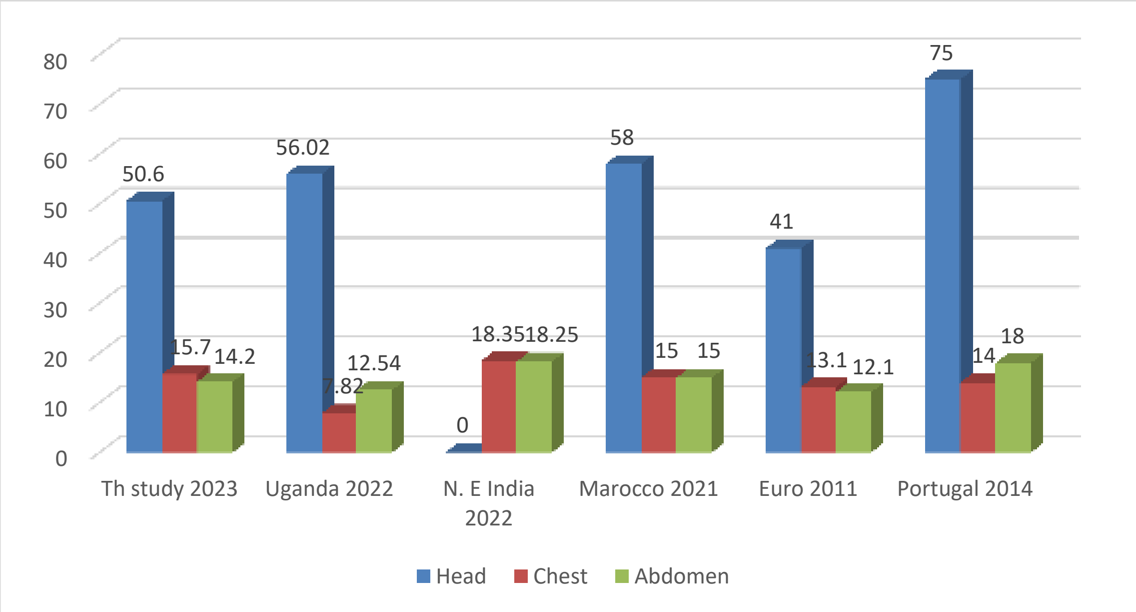

Fig 9: Comparison of international DRLs in terms of CTDlvol with established

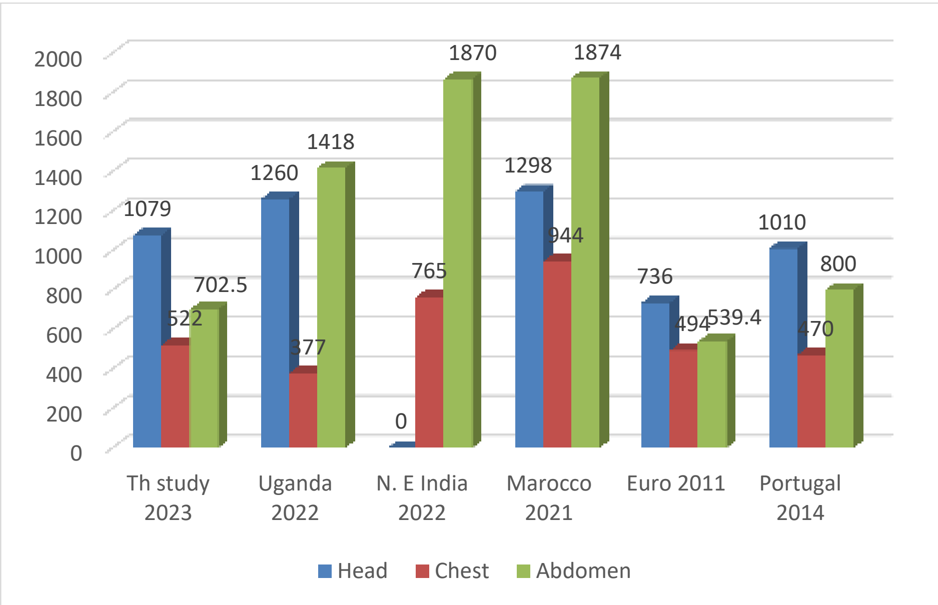

Fig 10: Comparison of international DRLs in terms of DLP with established

4.0 Discussion

The aim of the study was to determine the CTDlvol and DLP adults of standard size ($70^{\pm}$ 3kg) that underwent for routine head, chest and abdomen CT scan in two (2) different Hospitals in Nasarawa State, Nigeria as discussed in table 1, 3, 4 a and b.

According to ICRP pub 103, one of the principles for optimization of protection during medical exposure of patient for diagnostic and interventional procedures. The DRLs are a supplement to professional judgment and do not provide a dividing line between good or bad medical practice (Sora *et al.*, 2021).

A total number of 119 patients were recruited for the study, 60 from center (A) 25 female and 30 males. 20 participants for head 20 for chest and 20 for Abdomen in both centers. In line with IAEA recommendation, minimum of 10 patents and maximum of 20 patient per radiation center in describing CT dose characteristics.

The gender distribution of Head in center A is (45%, 55%), Chest (30%,70%) and Abdomen respectively. For center B 19 Female and 30 males representing the gender distribution of (47.3%, 52.7%), (20%, 80%) and (30%, 70%) for Head, Chest and Abdomen respectively for female and males. The mean values of Head is 14.3, Chest is 16.1 and Abdomen 15.8 respectively.

The measured values of the scan parameters of kV, mAs, scan time and DFov as presented in table 3 while the measurement and calculation of CTDlvol and DLP which comprises of Mean, Standard deviation, Maximum Range, Minimum Range and Range of the DRLs are in table 4 a and b Table 5. summarized the 1st and 3rd percentile of the DRLs and Table 6 showed a detailed explanation on the Mean DRls and the 3rd quartile values of this study.

Table 7 indicate comparative analysis between the study and literature reviews. According to Kambari (2017), who carried out a research on Assessment of Radiation dose in Computed Tomography Examination of Adults patient in Nigeria for Head, Chest and Abdomen, the recommended value for DRL are (49.8 and 1639), (10.9 and 432) and (12..7 and 560) for Head, Chest and Abdomen respectively. And the value of this study are (50.6 and 1079), (15.7 and 522) and (14.2 and 702.5) for Head, Chest and Abdomen respectively. The obtained values are in line with his finding with little variation caused as a result of scan parameters used.

Kabir (2015) conducted a research on Determination of Computed Tomography Diagnostic reference level in North Central Nigeria, He obtained the DRLs value of Head, Chest and Abdomen, as (60 and 1024), (10 and 407) and (15 and 757) respectively. The value do not correspond with the values obtained in this study because of a wide variation of mean doses observed across the center of his study.

Also Abdullahi *et al.*, (2020) posited on radiation dose levels for adult most common computed tomography (CT) examination namely brain, chest and abdomen CT in Nigeria. The values obtained are (62.5 and 2946), (9.9 and 663.3), and (13.5 and 1397) for head chest and abdomen respectively. The CTDIvol of the study is higher in chest and abdomen but lower in head and it observed that the DLP values are comparably higher than the values obtained in this study. This is because of the high value observed at the scan length during the routine procedures the study revealed the estimated DRLs and factors responsible for DRLs variations. The reasons for this variation are mainly attributed to different exposure parameters, radiographic techniques and modalities which are in line with many DRLs studies (saravankumar *et al.*, 2014).

The comparative analysis in terms of international CTDlvol correspond and also the DLP is a bit higher than the European funding. This call for serious concern of optimization of practice. The main objective of a diagnostic Reference level is to help to avoid excessive radiation dose to patient that does not contribute additional clinical information value to the medical imaging task. Diagnostic Reference Levels are used as investigative levels (as a quality assurance too), they are advisory and a dose limit which cannot be exceeded.

For head CT, the volume CTDl increased with an increase in total mAs, examination mAs, reference mAs, scan time. The DLP increased in total mAs, examination mAs reference mAs and the scan time. The kVp, slice thickness and image quality influenced patient CTDlvol volume and DLP values.

For chest CT, the study found that the volume CTDI and the DLP increased with a increase in the total mAs, examination mAs, reference mAs and the scan length. The slice thickness also influenced the DLP.
For abdomen CT, the volume CTDPlvol increased with an increase in examination mAs and reference mAs and it increase as scan times reduced. The DLP increased with an increase in total mAs, reference with an increase in total mAs, reference mAs and the scan length. The study found that kVp, slice thickness and image quality influenced patients' CTDlvol and DLP values.

Conclusion
The introduction of DRLs was to avoid excessive radiation dose to patients and it equally serves as a quality assurance tool, they are not dose limits, but advisory. DRLs should be reviewed annually or when there is a significant change in protocol or where they are consistently exceeded, thus, regular review provides opportunity feedback to ensure that good practice in medical exposure is maintained (ICRP, 1999).

The main aim of the study is the optimization of CT dose in Nasarawa State, Nigeria and ICRP recommends the establishment of diagnostic reference levels as a tool for optimizing the radiation dose delivered to patients in the course of diagnostic and/or therapeutic procedures (ICRP, 2001).

The local diagnostic reference levels for routine Head, Chest and Abdomen were established and the CTDI and DLP analysis were done in line with the EC guide lines in all the centres. The estimated values for CTDIv were similar across the centres and in tandem with EC value. The mean DLP values were in line with the proposed EC values, the high dose values are attributable to technical parameters, untimely quality control initiatives, work fatigue, the unnecessary use of large scan length for the abdominal region, generational gaps of the scanners and other unwholesome practices

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