



Establishment of Diagnostic Reference Levels for Computed Tomography (Ct) Dose Optimization of Some Selected Hospitals in North Central Nigeria

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ABSTRACT

Computed Tomography (CT) is an essential diagnostic tool, but its increasing use raises concerns about radiation exposure and associated risks. Diagnostic Reference Levels (DRLs) serve as benchmarks for dose optimization, guiding facilities to review practices when doses are unusually high or low. DRLs are not dose limits but investigative tools for improving radiation protection. This study aimed to establish facility diagnostic reference levels (FDRLs) in selected hospitals in North Central Nigeria, providing baseline data for regional and national DRLs. A retrospective cross-sectional study was conducted from May 2017 to October 2018, analyzing CT examinations from 109 patients across three centers (39, 28, and 42 per site). Only patients weighing 67–73 kg were included. Scans were performed using GE BrightSpeed 16-slice (Centre A), GE Optima CT660 64-slice (Centre B), and Philips Brilliance 16-slice (Centre C) scanners. SPSS version 20 was used to obtain 75th percentile dose metrics for establishing DRLs. DRLs (CTDIvol): Head 56.5 mGy, Chest 10.6 mGy, Abdomen 15.5 mGy; corresponding DLPs 1786.4, 844.6, and 1758.2 mGy·cm. FDRLs: Centre A, CTDIvol Head 44.3, Chest 6.9, Abdomen 13.3 mGy; DLP Head 1630.4, Chest 698.5, Abdomen 1646.2 mGy·cm. Centre B, CTDIvol Head 38.6, Abdomen 14.4 mGy; DLP Head 1535.4, Abdomen 1758.2 mGy·cm. Centre C, CTDIvol Head 60.9, Chest 10.6, Abdomen 15.5 mGy; DLP Head 2359.9, Chest 916.6, Abdomen 1913.3 mGy·cm. CTDIvol values aligned with major studies, though DLPs were higher. CTDIvol values were comparable internationally, but elevated DLPs highlight the need for tighter scan length control and dose optimization. Findings from three facilities and 109 patients provide insight but calls for wider validation.

Keywords:

Diagnostic reference levels (DRLs), volume computed tomography dose index (CTDIvol), dose length product (DLP) and facility diagnostic reference levels (FDRLs).

INTRODUCTION

Computed tomography (CT) is a non-invasive imaging technique that generates detailed cross-sectional images of the body by acquiring X-ray projection data from multiple angles and reconstructing them using computer algorithms. These images can also be rendered into three-dimensional representations of internal structures (Zhang *et al.*, 2025). In medical practice, the term CT most often refers to X-ray computed tomography, which is the focus of this study. Nevertheless, other tomographic modalities exist, such as PET/CT (positron emission tomography with CT), SPECT (single-photon emission computed tomography), MRI-based tomography, and industrial CT scanning used in engineering and material sciences (Prakash & Heston, 2025).

CT has become one of the most widely used imaging tools worldwide because it provides rapid, high-resolution visualization of internal anatomy, but at the same time, it is a leading contributor to medical radiation exposure. Reports from the International Atomic Energy Agency (IAEA), the International Commission on Radiological Protection (ICRP), and the American Association of Physicists in Medicine (AAPM) consistently indicate that although CT makes up only a fraction of diagnostic imaging procedures, it contributes more than 50% of the collective radiation dose from medical imaging in many countries (Osipov, 2022; Vañó *et al.*, 2017; Cody *et al.*, 2021). This highlights the importance of dose monitoring and optimization in clinical practice.

Diagnostic Reference Levels (DRLs) are internationally recognized tools for dose optimization and benchmarking in CT. They are typically set at the 3rd quartile which represents the 75th percentile of dose distributions from surveys of standard-sized patients or phantoms and are expressed using dose descriptors such as the volume computed tomography dose index (CTDIvol) and the dose length product (DLP). Regulatory bodies, including the IAEA, recommend that DRLs be regularly established and periodically reviewed at national or regional levels to ensure that radiation doses remain aligned with clinical needs and technological advancements (IAEA, 2022). The size-specific dose estimate (SSDE), introduced in AAPM Reports 204 and 293, provides a more patient-specific measure of absorbed radiation dose by adjusting CTDIvol with a size conversion factor. SSDE is especially valuable for accounting for variations in patient size, such as in pediatric imaging. However, because CTDIvol and DLP are readily available on scanners, practical to use, and comparable across facilities, both international and national DRLs continue to rely mainly on these metrics rather than SSDE (AAPM, 2011; AAPM, 2023).

Dose surveys in Europe and Asia have demonstrated significant reductions in CT dose indices compared with earlier findings, underscoring the effectiveness of dose optimization strategies (Sharma *et al.*, 2021; Takahashi *et al.*, 2020). In contrast, studies from Africa and other low and middle-income regions reveal wide variability in patient doses, reflecting differences in equipment, imaging protocols, and access to dose management systems, this variability highlights the limited implementation of standardized dose optimization practices in these regions (Adekanmi *et al.*, 2025; Rehani *et al.*, 2019; Kgomo, 2021). This study specifically:

1. Established FDRLs and baseline DRLs for head, chest, and abdomen for routine CT examinations to guide dose optimization in CT practice.
2. Compared the obtained CTDIvol and DLP values with European Commission and published DRLs.
3. Evaluated the contribution of scan length to elevated DLP values across centers and the analysis further demonstrated that extended scan lengths contributed significantly to elevated DLP values across centers, underscoring the need for protocol standardization and improved scanning practices.

The elevated DLP values in this study were primarily linked to extended scan lengths rather than increased CTDIvol, while per-slice doses aligned with international reference data, total patient exposure rose due to unnecessarily broad anatomical coverage. Protocol

deviations and operator-dependent variations in scan length are well-documented drivers of elevated DLPs, thus, optimization should target not only exposure parameters but also strict adherence to clinically justified scan ranges. In Nigeria and the North Central region in particular, established CT DRLs are lacking, with no national guidelines in place, while local studies have proposed DRLs for selected examinations such as head or chest, or head and abdominal CT, but broader surveys are needed. So, this study contributes to that effort by collecting data from three purposively selected hospitals in north central Nigeria, chosen for their high patient volumes, strategic locations, and service to low and middle-income populations, and by covering multiple body regions and facilities beyond the single center focus and fewer anatomies common in prior works, this study provides a broader framework for developing regional and ultimately national DRLs.

MATERIALS AND METHODS

This study employed a retrospective cross-sectional design across three purposively selected hospitals in North Central Nigeria to establish FDRLs and subsequently a regional diagnostic reference level (DRLs) for routine computed tomography (CT) examinations. Data were collected from patients who underwent routine head, chest, or abdominal CT scans between May 2017 and October 2018, examinations involving specialized procedures such as CT angiography were excluded. To minimize variability from patient size, only adult patients weighing between 67–73 kg were included, as recommended by the European Commission (1999) for DRLs surveys. A minimum of 10 patients per body region was required for uniformity and statistical adequacy, resulting in a total of 109 eligible patients: 45 for head CT, 23 for chest CT, and 41 for abdominal CT. Patient dose metrics, including CTDIvol, DLP and scan length, were extracted from the Picture Archiving and Communication Systems (PACS) of the participating centers. Three scanners, representing the major systems in routine clinical use at the study sites, were included: GE BrightSpeed 16-slice 0.625 mm (Centre A), GE Optima CT660 64-slice 0.35 mm isotropic (Centre B) and Philips Brilliance 16-slice (Centre C). All scanners were licensed and regularly calibrated by the Nigerian Nuclear Regulatory Authority (NNRA). The achieved sample size reflected the number of eligible patients available in the PACS during the study period. Data collection sheets were used to record scan and dose parameters, while statistical analysis was performed using SPSS version 20. Ethical and administrative approvals were obtained from the relevant institutional review boards [FHREC/2017/01/93/20-11-17 and FCTA/HHSS/ADH/EC/0047/18]. Because the study was retrospective and data were anonymized, formal patient

consent was not required. The research was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki

Table 1: Scanner Type and Sample Size per Centre

STUDY CENTRE	SCANNER TYPE	NO. OF SLICES	SAMPLE SIZE
A	GE-BRIGHTSPEED	16	39
B	GE-OPTIMA	64	28
C	PHILIPS BRILLIANCE	16	42

Acquisition Protocols

Standard clinical protocols for head, chest, and abdominal CT examinations were reviewed across the three participating centers. For each series, detailed acquisition parameters were extracted from DICOM headers and protocol logs.

For **head CT**, the parameters included a tube voltage of 120 kVp, fixed tube current or automatic exposure control (AEC) with noise index settings, collimation of 16–64 × 0.6–1.25 mm, rotation time of 0.5–1.0 s, pitch of 0.75–1.0, and image reconstruction with both soft tissue and bone kernels.

For **chest CT**, acquisitions were performed at 120 kVp with automatic tube current modulation (longitudinal and angular), pitch of 0.9–1.2, rotation time of 0.5 s, collimation of 64 × 0.6 mm, and image reconstruction using soft kernels with iterative or deep-learning algorithms where available.

For **abdominal CT**, the protocol specified 120 kVp with AEC, reference mAs/noise index adjusted for body size, pitch of 0.8–1.2, and collimation of 64 × 0.6 mm, rotation time of 0.5–0.7 s, and reconstruction with standard abdominal kernels and iterative reconstruction.

Dose Metrics

Radiation dose in computed tomography (CT) is standardized using metrics derived from measurements in Polymethylmethacrylate (PMMA) phantoms that reflect scanner output and patient exposure. Two cylindrical PMMA phantoms of **16 cm diameter (head phantom)** and **32 cm diameter (body phantom)** are commonly used, as recommended by the International

Electrotechnical Commission (IEC). These phantoms simulate the attenuation characteristics of the human head and body, respectively, and serve as reference objects for scanner dose calibration (IEC, 2009). Radiation dose assessment in computed tomography (CT) is primarily expressed using standardized metrics that reflect scanner output and patient exposure. The most commonly reported parameters include the volume computed tomography dose index (CTDI_{vol}) and the dose length product (DLP), for every examination, CTDI and Scan length for DLP evaluation were extracted directly from scanner dose reports. The reference phantom size (16 cm for head, 32 cm for chest and abdomen) was documented for each reported CTDI.

Determination of CTDI

Patient dose in CT can be assessed directly using thermoluminescent dosimeters (TLDs) on patients or by applying ionization chambers and TLDs on phantoms. However, these approaches are labor-intensive and unsuitable for large-scale surveys. Consequently, indirect dose indices are more commonly employed, including the Computed Tomography Dose Index (CTDI), its volume form (CTDI_{vol}), the Dose Length Product (DLP), and the Multiple-Scan Average Dose (MSAD). Since the early 2000s, CTDI_{vol} and DLP have been routinely displayed on scanner consoles and are widely accepted as standard metrics for establishing DRLs. Among them, DLP is particularly valuable because it accounts for scan length, thereby reflecting the total radiation energy delivered to the patient. To address variation of CTDI across the field of view, the weighted CTDI (CTDI_w) calculated as the average of central and peripheral CTDI₁₀₀ measurements in a phantom is used to represent the mean dose to a cross-sectional slice.

$$CTDI_w = \left[\frac{1}{3} CTDI_{100}(center) + \frac{2}{3} CTDI_{100}(periphery) \right] \times f$$

The conversion factor f accounts for the difference in radiation absorption between air and soft tissue, enabling exposure measured in C/kg to be expressed as absorbed dose in gray (Gy), the SI unit used for CTDI_w. For CTDI_w calculations, f is assigned a value of 33.7 Gy·C⁻¹·kg⁻¹. The weighting factors of 1/3 (center) and 2/3 (periphery) approximate their respective contributions to the total dose within the scanned cross-section. Consequently, CTDI_w provides a practical representation of scanner radiation output at a given kVp and mAs (Morin *et al.*, 2009).

Determination of Dose Length Product (DLP)

To more accurately represent the total energy delivered during a scan, the absorbed dose is integrated across the scan length to calculate the Dose Length Product (DLP, mGy·cm). DLP, obtained by multiplying CTDI_{vol} by the

scanned range, reflects both the irradiated volume and the patient's overall exposure. It therefore provides a useful indicator of the cumulative biological impact of a CT examination. For instance, an abdomen-only CT and an abdomen–pelvis CT may yield identical CTDI_{vol} values, but the latter results in a higher DLP because of its extended z-axis coverage.

$$DLP = CTDI_{vol} \times \text{Scan length, } L \quad (\text{mGy-cm})$$

where L is the scan length (cm) limited by the outer margins of the exposed scan range ((Jessen *et al.*, 2000).

RESULTS AND DISCUSSION

CT SCAN EXPOSURE PARAMETERS

Table 2: Patient's Demographic Information and Scan Exposure Parameters (Centre A)

		Demographics					CT Scan Exposure Parameters			
Body Region	Sample Size	Gender M	F	% Gender M	F	Age (yrs.) Mean ± SD	Scan Range (mm)	kVp	mA	mAs
Head	15	10	5	66.7	33.3	59.3 ±15.4	121.0 ± 14.5	120	236.1 ± 34.9	NR
Chest	10	5	5	50.0	50.0	54.8 ± 8.3	274.4 ± 29.5	120	158.2 ± 38.5	NR
Abd	14	6	8	42.9	57.1	49.1 ±10.2	384.2 ± 37.9	120	300.6 ± 51.9	NR

NR: NOT RECORDED

Table 3: Patient's Demographic Information and Scan Exposure Parameters (Centre B)

		Demographics				CT scan Exposure Parameters		
Body Region	Sample Size	Gender M F	Gender M F	Age (yrs) Mean± SD	Scan Range (mm)	kVp	mA	mAs
Head	15	8 7	53.3 46.7	53.0 ±13.3	175.5 ± 9.3	120	244.3 ± 9.7	NR
Chest	NA	NA NA	NA NA	NA	NA	NA	NA	NA

Abd	13	6	7	46.2 53.8	49.1 ±10.2	421.1± 5.2	120	193.8 ± 95.1	NR
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NR = NOT RECORDED

NA = NOT AVAILABLE

Table 4: Participants Demographic Information and Exposure Parameters (Centre C)

		Demographics				CT Scan Exposure Parameters		
Body Region	Sample Size	Gender M F	% Gender M / F	Age (yrs) Mean ±SD	Scan Range (mm)	kVp	mAs	mA
Head	15	7 8	46.7/53.3	58.0 ±7.3	195.4 ± 40.8	120	NR	354.0±72.3
Chest	13	4 9	30.8/69.2	52.2± 11.3	359.0±42 .2	120	NR	150.0 ±0.0
Abd	14	5 9	35.9/64.3	51.4 ±11.7	419.3 ± 22.0	120	NR	214.3±9.4

NR = NOT RECORDED

CT DOSE PARAMETERS**Table 5: CT Dose Parameter showing the Minimum, Max & the 3rd Quartile Values (Centre A)**

	CTDI (mGy)				DLP (mGy.cm)			
Body Region	Min. Value	Mean ± SD	Max. Value	3rdquartile	Min. Value	Mean ± SD	Max Value	3rdquartile
Head	37.5	43.9±4.1	55.2	44.3	691.6	1409.0±392.9	2148.9	1630.4
Chest	3.7	6.4±2.4	11.6	6.9	208.9	568.6±154.7	795.9	698.5
Abdomen	7.9	12.1±2.8	17.6	13.3	518.9	1301.6±428.9	2146.4	1646.2

Table 6: CT Dose Parameter showing the Minimum, Max & the 3rd Quartile Values (Centre B)

Body Region	CTDI (mGy)				DLP (mGy.cm)			
	Min. Value	Mean $\pm$ SD	Max. Value	3 rd quartile Value	Min. Value	Mean $\pm$ SD	Max Value	3 rd quartile Value
Head	36.7	38.3 $\pm$ 0.9	40.7	38.6	677.3	1442.2 $\pm$ 455.8	2694.3	1535.4
Chest	NA	NA	NA	NA	NA	NA	NA	NA
Abdomen	3.8	9.9 $\pm$ 4.2	14.4	14.4	495.9	1309.0 $\pm$ 511.3	2373.2	1758.2

(NA = Not Available during the course of this study)

Table 7: CT Dose Parameter showing the Minimum, Max and the 3rd Quartile Values (Centre C)

Body Region	CTDI (mGy)				DLP (mGy.cm)			
	Min. Value	Mean $\pm$ SD	Max. Value	3 rd quartile Value	Min. Value	Mean $\pm$ SD	Max Value	3 rd quartile Value
Head	38.1	55.8 $\pm$ 8.6	61.1	60.9	1149.3	1839.2 $\pm$ 507.8	2481.4	2359.9
Chest	10.6	10.6 $\pm$ 0.0	10.6	10.6	705.2	866.9 $\pm$ 140.2	1248.0	916.6
Abdomen	14.1	15.1 $\pm$ 0.6	15.6	15.5	1019.8	1489.7 $\pm$ 406.5	2202.6	1913.3

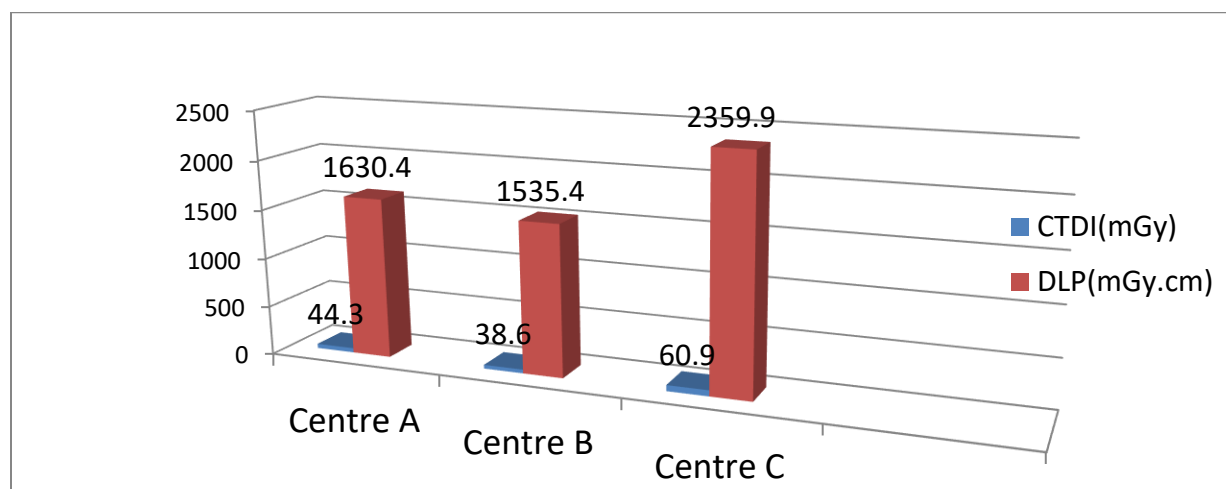


Figure1: CT Dose Parameters CTDIv / DLP from Study Centres A, B & C (Head)

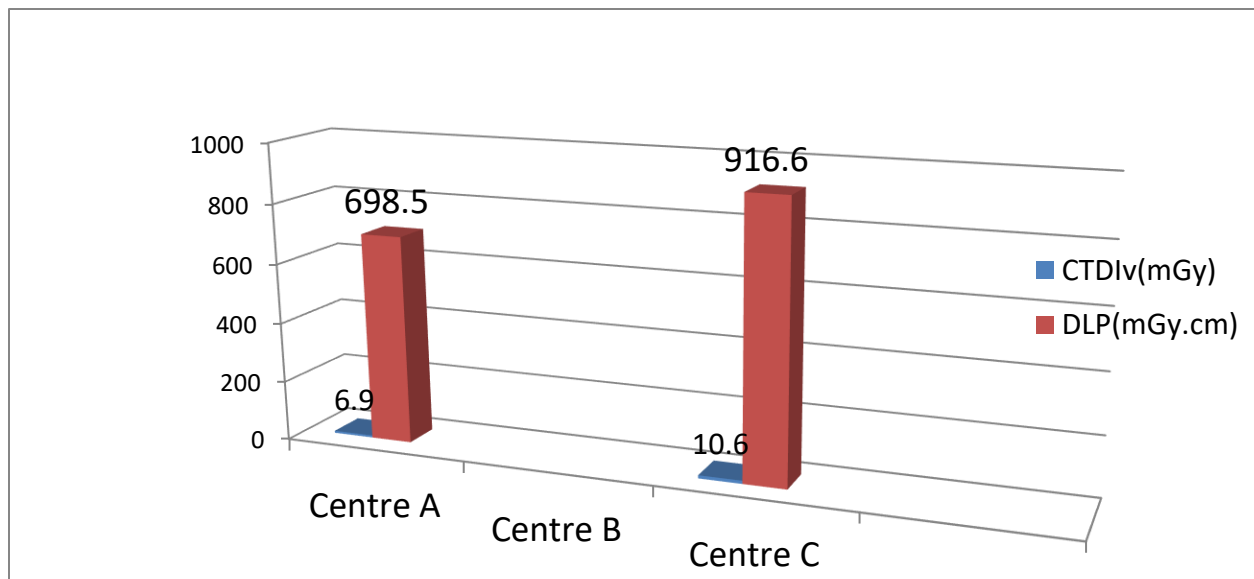


Figure 2: CT Dose Parameters CTDIv /DLP from Study Centres A & C (Chest)

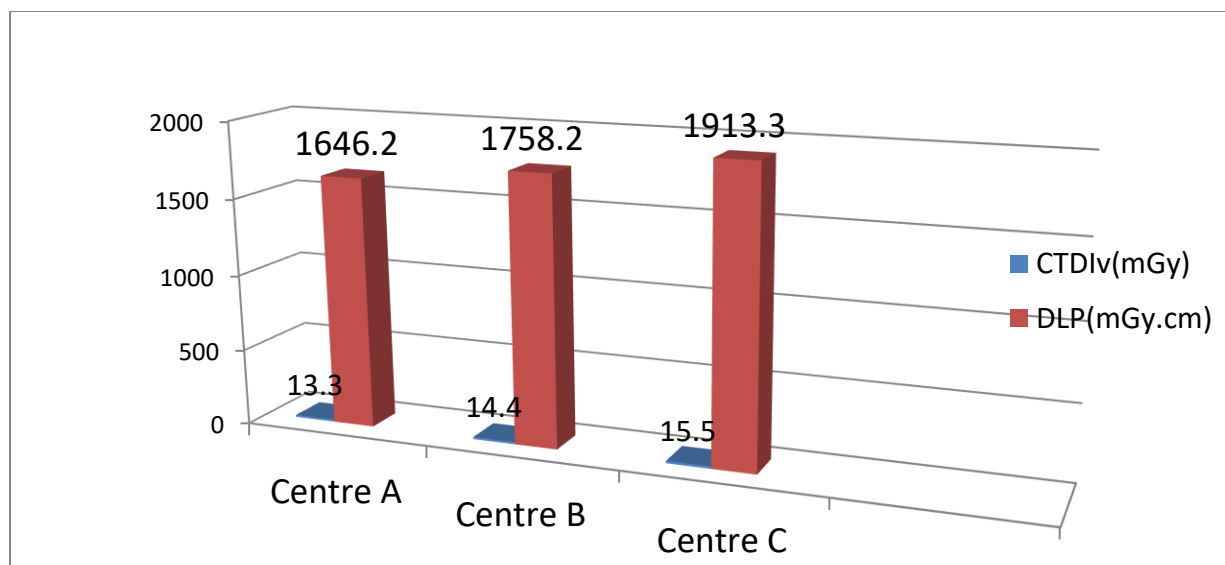


Figure 3: CT Dose parameters CTDIv/DLP from study Centres A, B and C (Abdomen)

Table 8: This Study's Established CTDI_v / DLP values with 3rd Quartile Values

Body Region	CTDI (mGy)				DLP (mGy.cm)			
	Min. Value	Mean $\pm$ SD	Max. Value	3 rd quartile Value	Min. Value	Mean $\pm$ SD	Max Value	3 rd quartile Value
Head	36.7	45.7 $\pm$ 9.2	61.1	56.5	677.3	1549.2 $\pm$ 484.6	2694.3	1786.4
Chest	3.7	8.8 $\pm$ 2.6	11.6	10.6	208.9	774.9 $\pm$ 218.6	1248.0	844.6
Abdomen	3.8	12.4 $\pm$ 15.5	17.6	15.5	795.9	1309.0 $\pm$ 511.3	2373.2	1758.2

Table 9: Comparing this Study's Established DRLs (CTDI_v) with other studies

Volumetric CTDI (mGy)									
This study DRLs					Other Countries DRLs				
Body Region	Mean $\pm$ SD	This Study	EC 1999	Germany 2010	Australia 2013	Portugal 2014	Iran 2013	Syria 2009	Malta 2011
Head	45.7 $\pm$ 9.2	56.5	60	60	47	75	29.7	53.5	12.1
Chest	8.8 $\pm$ 2.6	10.6	12	12	9.5	14	9.8	16.9	13.1
Abd	12.4 $\pm$ 15.5	15.5	15	10	10.9	18	12.9	20.2	41.0

Table 10: Comparing this study's Established DRLs (DLP) with other studies

DLP (mGy.cm)									
This study DRLs					Other Countries DRLs				
Body Region	Mean $\pm$ SD	This Study	EC 1999	Germany 2010	Australia 2013	P/ga l 2014	Iran 2013	Syria 2009	Malta 2011
Head	1549.23 $\pm$ 484.63	1786.4	1050	1050	527	1010	500	668	539
Chest	774.9 $\pm$ 218.63	844.6	650	400	447	470	225	396	492
Abd	130.9 $\pm$ 511.34	1758.2	900	770	696	800	482	567	736

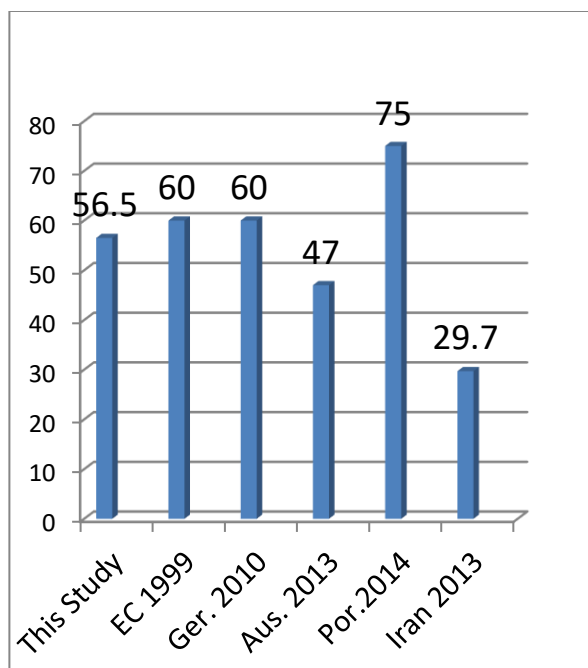


Figure 4: Comparing this study's CTDIV with International Data (Head)

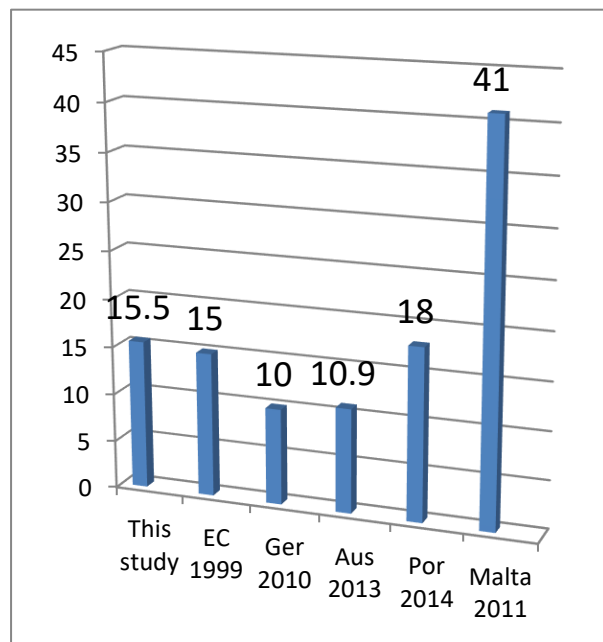


Figure 6: Comparing the Study's CTDIV with International Data (Abdomen)

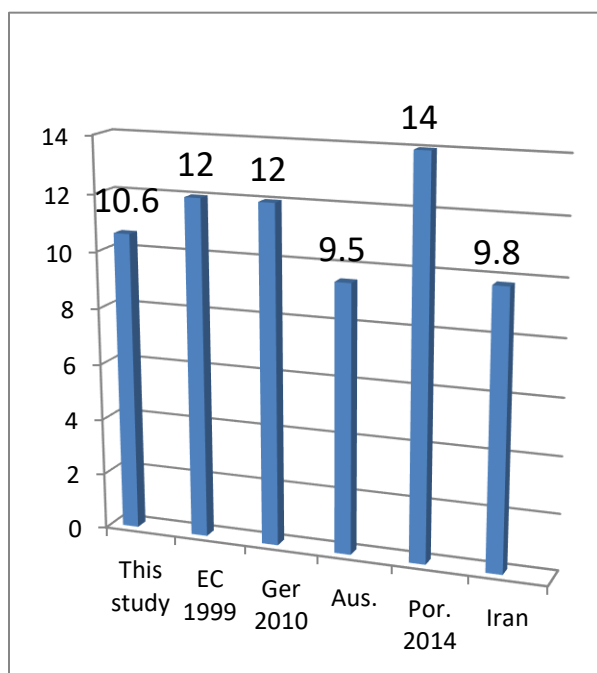


Figure 5: Comparing this Study's CTDIV with International Data (Chest)

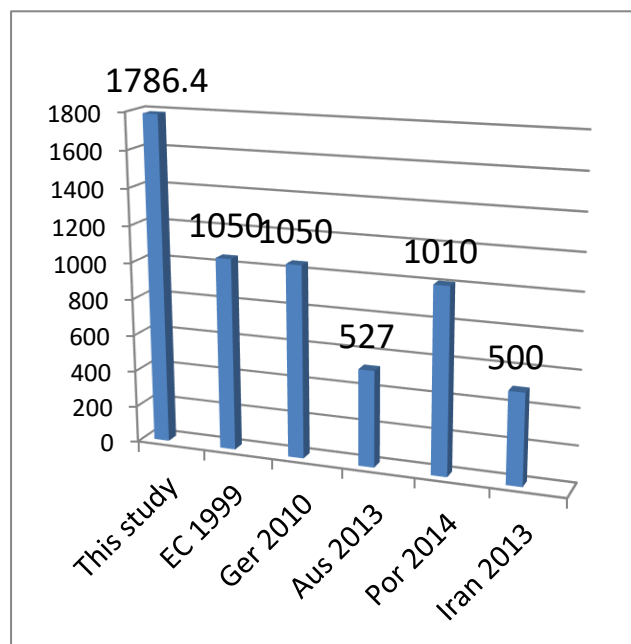


Figure 7: Comparing the Study's DLP with other International Data (Head)

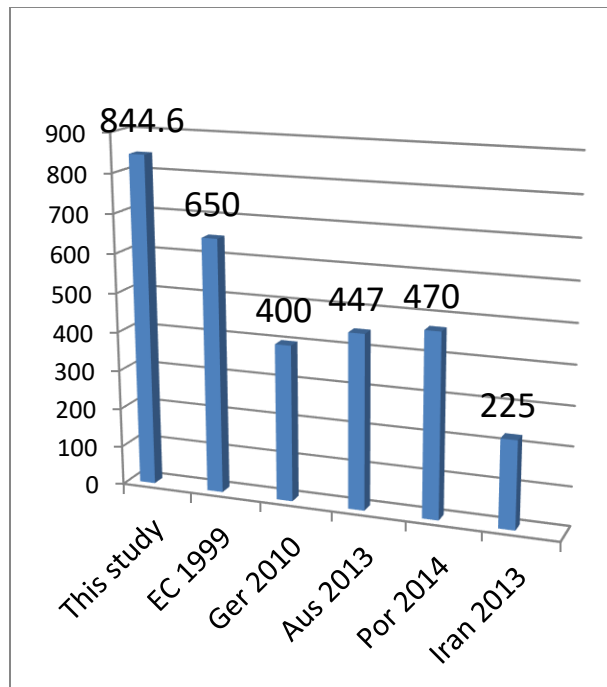


Figure 8: Comparing the Study's DLP with other International Data (Chest)

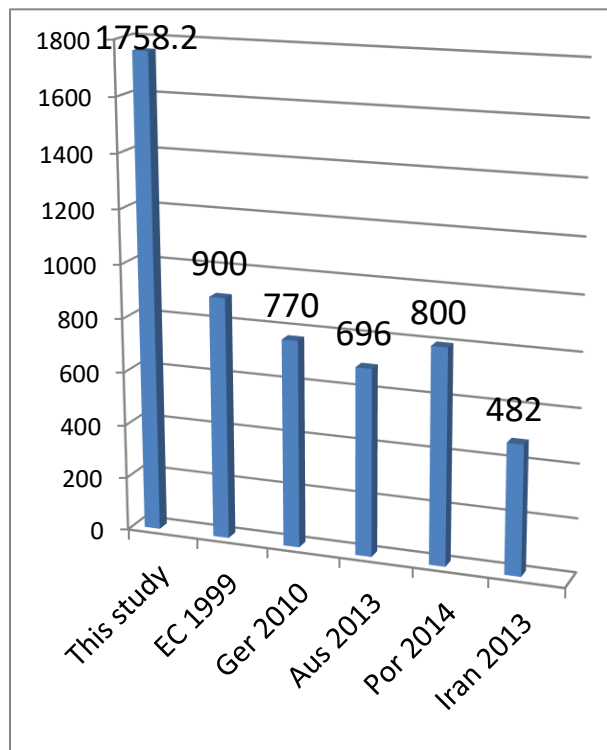


Figure 9: Comparing study's DLP with other International Data (Abdomen)

This study presents dose parameters and scan protocols from three CT facilities (Centres A, B, and C) in North Central Nigeria. Results are organized by centre and body region (head, chest, and abdomen) basis, highlighting variations in tube potential (kVp), tube current-time (mA), and scan length. These values were compared with international reference standards to assess compliance and identify areas for optimization. In this analysis, findings are interpreted in relation to dose optimization, diagnostic reference levels (DRLs), and clinical practice, with emphasis on factors such as scanner model, protocol choice, and patient size.

For head CT, a uniform tube potential of 120 kVp was applied across centres, with tube current ranging from 236.1 ± 34.9 to 354.0 ± 72.3 mA and scan lengths averaging 121.0 ± 14.5 to 195.4 ± 40.8 mm. These settings align with standard head CT protocol, where higher kVp ensures adequate penetration through cranial bone. The relatively narrow variation in scan length reflects the confined anatomy, contributing to consistent DLP values. For chest CT, a tube potential of 120 kVp was also consistently applied, with tube current values ranging from 150.0 ± 0.0 to 158.2 ± 38.5 mA and scan lengths between 274.4 ± 29.5 and 359.0 ± 42.2 mm. Compared with head imaging, chest CT generally requires higher tube current to minimize image noise, owing to the heterogeneity of lung tissue and the wider field of view. However, the extension of scan length beyond anatomical landmarks observed in some cases indicates over scanning, which directly contributes to increased DLP. Notably, the tube current used for chest imaging was lower than that for head CT, this difference reflects anatomical and technical factors, because the dense skull in head CT demands higher tube current to penetrate bone and maintain adequate image quality, whereas the air-filled lungs attenuate X-rays less, allowing for lower current levels. For abdominal CT, a tube voltage of 120 kVp was consistently applied, with tube currents ranging from 214.3 ± 9.4 to 300.6 ± 51.9 mA and scan lengths between 300.6 ± 51.9 and 419.3 ± 22.0 mm. The higher mA reflected the need to compensate for increased abdominal tissue density, while extended scan ranges in some centres likely contributed to unnecessary dose escalation. Overall, while kVp and mA values remained within recommended limits, variation in scan length was the main driver of elevated DLPs. This underscores the importance of protocol standardization, use of automatic exposure control (AEC), and operator training to minimize excess radiation while maintaining diagnostic quality. Establishing facility diagnostic reference levels (FDRLs) and study DRLs based on these results provides a framework for optimizing practice.

FDRLs were determined across three centres using CTDIvol and DLP as recommended indices. CTDIvol values ranges were: Head (44.3 – 60.9 mGy), Chest (6.9 – 10.6 mGy), and Abdomen (13.3 – 15.5 mGy) and the corresponding DLPs were: Head (1535.4 – 2359.9 mGy·cm), Chest (698.5 – 916.6 mGy·cm), and Abdomen (1646.2 – 1913.3 mGy·cm), as presented in Tables 5 to 7 and Figures 1 to 3. The variations reflected differences in scanner models and protocols, head CT consistently showed the highest CTDIvol due to cranial bone attenuation, while chest CT displayed lower CTDIvol, but sometimes elevated DLPs are due to extended scan lengths. Abdominal CT required higher mA and longer ranges, leading to greater cumulative exposure, often from inclusion of pelvic regions beyond protocol defined limits. This study's DRLs were established as: Head (CTDIvol 56.5 mGy; DLP 1786.4 mGy·cm), Chest (CTDIvol 10.6 mGy; DLP 844.6 mGy·cm), and Abdomen (CTDIvol 15.5 mGy; DLP 1758.2 mGy·cm), as shown in Tables 8 to 9 and Figures 4 to 9. These CTDIvol values align closely with international benchmarks, for example, head CT (56.5 mGy) matches the European Commission (60 mGy) and is comparable with Portugal (75 mGy). Similarly, chest CT (10.6 mGy) is consistent with the EC's 12 mGy, while abdominal CT (15.5 mGy) aligns with the EC's 15 mGy. In contrast, the DLPs were generally higher than the EC and some other studies, mainly due to longer scan ranges, the study's DLP (Head 1786.4, chest 844.6, Abdomen 1758.2 mGy·cm) exceeded EC (Head 1050 mGy·cm), Portugal (Chest 470 mGy·cm) and EC (Abdomen 900 mGy·cm), and also exceeded a Kenyan study by (Wanbani *et al.*, 2010), which reported high DRLs of (Head 1364, Chest 745, Abdomen 1143 mGy·cm). This study's DRLs CTDIvol values remained moderate and in good agreement with European standards and others, however, the DRLs DLP values are way higher than the European Commission and other global studies, emphasizing that extended anatomical coverage is the main factor driving high DLPs reinforcing the need for strict adherence to defined anatomical limits. Despite missing chest CT data from Centre B, DRLs were reliably established using Centres A and C, this limitation does not invalidate the DRLs, because DRLs are derived from the collective dose distribution of comparable procedures across multiple facilities, so the inclusion of data from other centres provides a sufficiently representative sample for establishing baseline values. The absence of data from one facility only limits inter facility comparison for that specific examination type. Generally, the establishment of FDRLs and DRLs in this study provides critical baseline data for dose optimization and harmonization of CT practices in North Central Nigeria and indeed Nigeria.

This study has several limitations. It employed a retrospective design, which limited control over protocol

standardization and data completeness across centers. The sample sizes were relatively small and uneven among the participating facilities, potentially affecting statistical power and generalizability. The data were collected between 2017 and 2018, reflecting practices and technologies available at that time. However, in many low and middle income settings, CT scanners are not frequently replaced, and such equipment remains in routine use for several years; making the findings remain relevant for current practice and dose optimization within the region.

Table 11: Recommendations and Remediation Priorities

Priority Level	Recommended Action	Rationale / Evidence Basis
High	Protocol harmonization across centers	Ensures consistency in scan parameters and facilitates meaningful DRL comparisons.
High	Reduction of scan length (z-range) to anatomical limits	Major contributor to DLP; unnecessary scanning increases dose without diagnostic benefit.
High	Activation and proper configuration of Automatic Exposure Control (AEC)	AEC optimizes tube current to patient size, significantly reducing dose variation.
Moderate	Adoption of iterative reconstruction techniques	Reduces image noise at lower doses, enabling dose reduction while maintaining image quality.

Moderate	Routine dose audits and feedback	Facilitates ongoing monitoring, quality improvement, and early detection of protocol drift.
Moderate	Regular staff training and protocol review	Enhances awareness of optimization strategies and promotes adherence to standardized procedures.

CONCLUSION

This study established facility diagnostic reference levels (FDRLs) at 3 CT facilities and hence Diagnostic reference levels (DRLs) for common CT examinations in North Central Nigeria, providing baseline data to support dose optimization and quality assurance efforts. However, the findings should be interpreted in light of certain limitations, including uneven sample size, missing data from one facility, and the use of older scanner models at some centers as obtainable in low and middle income areas, could have influenced the dose estimates, because modern CT scanners come with iterative construction and advanced dose modulation which are known to achieve lower exposures, old scanners may require longer acquisition time, leading to more radiation exposure which could increase stochastic risks (Ojobeagu *et al.*, 2024). The relatively high DLP values observed underscore the need for continuous efforts to enhance patient safety through stricter adherence to optimized scanning protocols, regular staff training on radiation protection, and progressive equipment upgrades to more dose-efficient systems.

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