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ORIGINAL RESEARCH ARTICLE

Radiation Dose Optimization in CT Imaging: Benchmarking CTDIvol and DLP Against International DRLs in Nigeria

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ABSTRACT

Computed Tomography (CT) is an indispensable diagnostic imaging system, but it contributes significantly to patient radiation exposure. To safeguard patients and ensure best practice, the International Commission on Radiological Protection recommends compliance with Diagnostic Reference Levels (DRLs). The Federal Teaching Hospital Birnin Kebbi (FTHBK), newly established in 2024, recently introduced CT services, making it crucial to evaluate baseline dose levels against international standards. A prospective cross-sectional study design was conducted on 100 patients who underwent CT examinations between 2025 and 2026. The sample included head (n = 45), chest (n = 10), and abdomen (n = 45) scans, ensuring representation across common protocols. Data collected included patient demographics (age, sex, weight) and technical parameters (kVp, mAs, pitch, slice thickness, and scan length), as well as dose indices (CTDIvol and DLP). Standard CT protocols used at FTHBK were documented and compared with established protocols. Statistical analysis was performed using Minitab. Descriptive statistics (mean, standard deviation, and 95% confidence intervals) and the 75th percentile (for DRL comparison) were calculated. Regression analyses were conducted to assess relationships between dose indices, machine settings, and patient characteristics. Dose values were compared with internationally published DRLs, including those from the UK and the European Commission. The mean CTDIvol values were 41 mGy (head), 9.0 mGy (chest), and 12 mGy (abdomen), while the mean DLP values were 2205, 768, and 941 mGy·cm, respectively. The corresponding 75th percentile values were 28 mGy (head), 8 mGy (chest), and 12 mGy (abdomen). Tube voltage (120–126 kV) was consistent with international norms. However, higher tube currents led to higher dose indices, particularly in head CT. Regression analysis demonstrated a strong positive correlation between mA and both CTDIvol and DLP ($R^2 > 0.8$, $p < 0.005$), indicating that tube current is the dominant determinant of patient dose. kV showed only a weak correlation with dose outcomes. Patient weight demonstrated a statistically significant association with dose ($p < 0.05$), whereas age did not. Comparison with international DRLs (UK and EU) showed that chest and abdominal CT doses were largely compliant, whereas head CT exceeded reference thresholds, mainly due to extended scan lengths and higher mA settings. FTHBK demonstrates general compliance with international standards for chest and abdominal CT protocols, but head CT examinations require optimization. However, these findings are limited by the single-center design and relatively small sample size. Priority should be given to tube current modulation, scan length reduction, and weight-based dose protocols to align practice with the ALARA principle. The findings underscore the need for establishing localized Nigerian DRLs to improve patient safety, inform national radiation protection policies, and strengthen radiology training.

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INTRODUCTION

The Federal Teaching Hospital, Birnin Kebbi (FTHBK), is a newly commissioned teaching institution established in 2024. The Radiology Department initially operated with conventional X-ray imaging and expanded its services by installing a modern CT scanner the same year. Since its commissioning, CT utilization has increased steadily, averaging approximately 50 patients per week. This rapid growth in CT usage at an early operational stage necessitates systematic evaluation of patient radiation doses to establish baseline benchmarks and ensure safe practice from the outset.

Computed Tomography is a high-dose imaging modality compared to conventional radiography and is a major

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contributor to population radiation exposure from medical imaging (IAEA, 2012; Maidamma, 2020). Despite its clinical benefits, CT presents significant challenges in dose optimization, particularly in newly established facilities where standardized protocols and local dose benchmarks may not yet be fully developed. Monitoring key dose indices such as the Computed Tomography Dose Index (CTDIvol) and Dose Length Product (DLP) is therefore essential for assessing radiation burden and guiding optimization strategies.

A critical knowledge gap exists in Nigeria, particularly in the Northwestern region, where published data on CT dose distributions and Diagnostic Reference Levels (DRLs) are limited **(**Maidamma 2020**).** While DRLs have been widely adopted internationally following recommendations by the International Commission on Radiological Protection, their implementation in many developing countries remains inconsistent due to insufficient local data (ICRP, 2007). Existing Nigerian studies have provided preliminary DRL values; however, these are largely region-specific and do not adequately represent emerging centers such as FTHBK. This underscores the need for localized dose assessments that reflect current practices, equipment, and patient demographics.

Establishing baseline dose levels in a newly operational hospital is scientifically important because it enables early identification of suboptimal imaging practices, supports protocol standardization, and provides a reference point for continuous quality improvement (Abimbola et al., 2022; Adamu & Salisu, 2024; Kabir et al., 2022; Maaruf et al., 2022; Ogunsina et al., 2023; Saidu et al., 2024)**.** Without such baseline data, there is a risk of unrecognized dose escalation, particularly in high-demand settings where workflow pressures may influence scanning parameters such as tube current and scan length. Furthermore, baseline evaluation is essential for developing institution-specific DRLs, which can later contribute to national dose reference frameworks in Nigeria (ICRP, 2007).

For a teaching hospital like FTHBK, the importance of this evaluation extends beyond patient safety. It provides an evidence-based foundation for training radiographers, radiologists, and medical physicists in dose optimization and radiation protection principles, particularly adherence to the ALARA (As Low as Reasonably Achievable) concept (Elshami et al., 2022). In addition, early implementation of dose monitoring practices enhances institutional credibility and aligns the facility with global best practices in radiological safety.

This study aims to evaluate radiation doses from CT examinations at FTHBK and assess their compliance with internationally established DRLs. This involves analyzing patient dose indices (CTDIvol and DLP), comparing them with reference values from established benchmarks, and identifying factors influencing dose variation. By addressing the current lack of regional dose data, this study seeks to bridge an important gap in the Nigerian radiology literature and provide a foundation for future multi-center DRL development.

The significance of this work lies in its contribution to both clinical practice and policy development. It not only ensures safe and optimized CT imaging in a newly established facility but also supports the broader goal of developing national DRLs in Nigeria. As CT utilization continues to expand in resource-limited settings, such assessments are essential to ensure that improvements in diagnostic capability are not achieved at the expense of patient safety (Ferrari et al., 2014; AAPM, 2014). Ultimately, this research positions FTHBK as a key contributor to radiation dose optimization efforts in Northwestern Nigeria.

MATERIALS AND METHODOLOGY

This study was conducted as a prospective observational study involving 100 consecutive patients who underwent Computed Tomography (CT) examinations at the Federal Teaching Hospital, Birnin Kebbi (FTHBK). This sample size meets the minimum recommended number of patients (≥10 per examination type) for establishing National Diagnostic Reference Levels (NDRLs) (Garba et al., 2015).

Patient Inclusion and Exclusion Criteria

The study included adult patients (≥18 years) referred for routine CT examinations of the head, chest, and abdomen. Pediatric patients, pregnant women, and patients undergoing contrast-enhanced or repeat scans were excluded to ensure dose homogeneity and comparability with standard DRL practices.

All examinations were performed using a multi-detector CT (MDCT) scanner installed at FTHBK in 2025. Details of the scanner, including manufacturer, model, number of detector rows, and year of installation, were documented to ensure reproducibility**.** Acquisition parameters recorded included tube voltage (kV), tube current (mA), pitch, rotation time, slice thickness, collimation, and scan length. Standard clinical protocols for head, chest, and abdomen CT examinations were followed throughout the study period.

Data Collection

Data were collected using a structured form adapted from the United Kingdom Diagnostic Reference Level study (2003), ensuring consistency and reliability (Garba, 2014). Patient-related variables included identification number (ID), age, sex, and body weight. Scanner-generated dose indicators Computed Tomography Dose Index volume (CTDIvol) and Dose Length Product (DLP) were recorded directly from the console without modification. All data were anonymized to maintain patient confidentiality and prevent bias.

Ethical Considerations

Ethical approval for the study was obtained from the FTHBK Institutional Review Board/Ethics Committee dated: 24-07-2026-BK-HP-045-P-517-VOLV-092, and all procedures complied with established guidelines for research involving human subjects. Informed consent was obtained where required.

Data Analysis

Statistical analysis was performed using Minitab. Descriptive statistics, including mean, standard deviation (SD), and 75th percentile values, were calculated for all variables. The 75th percentile values were used as proposed local DRLs and compared with established international DRLs reported in the literature to assess compliance.

Regression and Inferential Analysis

Regression analysis was conducted to evaluate the relationships between radiation dose indices (CTDIvol and DLP) and independent variables, including tube current (mA), tube voltage (kV), patient weight, and scan length. The coefficient of determination (R^2) was used to quantify the strength of these relationships, while statistical significance was assessed at $p < 0.05$. It should be noted that DRLs were not treated as dependent variables in regression analysis; rather, they were used solely as benchmark values for comparison.

Estimation of Effective Dose

To provide a more clinically meaningful measure of radiation risk, effective dose (E) was estimated from DLP using region-specific conversion coefficients (k-factors) as recommended in the literature (IAEA, 2012). This allowed for an approximate assessment of stochastic risk associated with CT examinations.

This methodological approach provides a comprehensive framework for evaluating radiation dose levels, identifying determinants of dose variation, and assessing compliance with international standards. It also ensures reproducibility and supports the development of localized DRLs in alignment with the ALARA (As Low As Reasonably Achievable) principle.

RESULT

The collected data were analyzed using descriptive and inferential statistics. Regression analysis was conducted to determine the relationship between radiation dose indices and technical parameters, with CTDIvol and DLP compared against international DRLs. Compliance and variation trends were assessed to evaluate optimization practices at FTHBK.

Patients Demographic Data

The mean patient age was 40 years (head), 48 years (chest), and 50 years (abdomen). Mean weight ranged from 59–61 kg, higher than international averages, suggesting that patient body habitus in Kebbi may contribute to elevated dose indices. These demographic patterns highlight the importance of developing localized DRLs (Table 1).

Table 1: Mean Patients Demographic

Classification	Head	Chest	Abdomen
Age	40	48	50
Weight (kg)	59	61	61
Height (cm)	159	162	161

The mean age distribution shows that patients undergoing CT scans at FTHBK ranged from 40 years for head examinations to 50 years for abdominal examinations (Table 1). Weight distribution was slightly higher than reported in some literature, averaging 59–60 kg, suggesting that patient body habitus in the Kebbi population may be larger than in published studies from Europe and Asia (Foley et al., 2016). This is important because patient weight directly influences CT technical settings (mA, kV) and consequently radiation dose. The relatively higher mean weight may partially explain the higher dose metrics recorded in this study compared with those reported in the international literature. Optimization strategies at FTHBK should consider local patient body composition when comparing with international DRLs, as weight differences can bias direct dose comparisons.

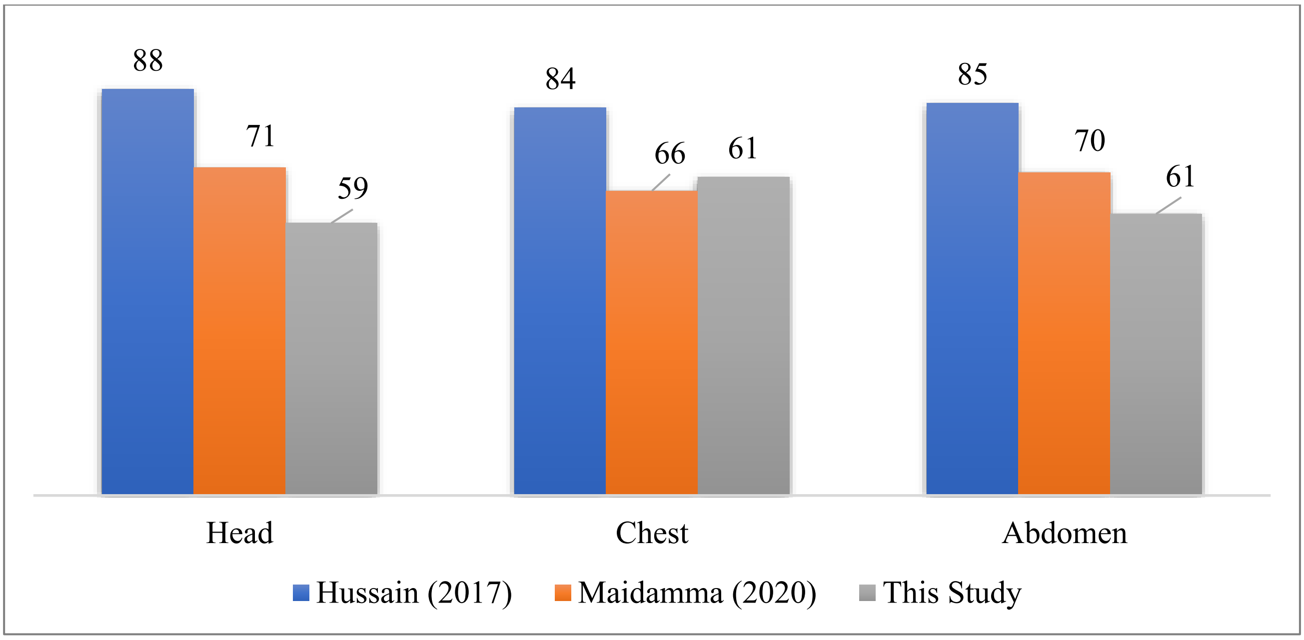

Figure 1: Comparison of Weight with Literature

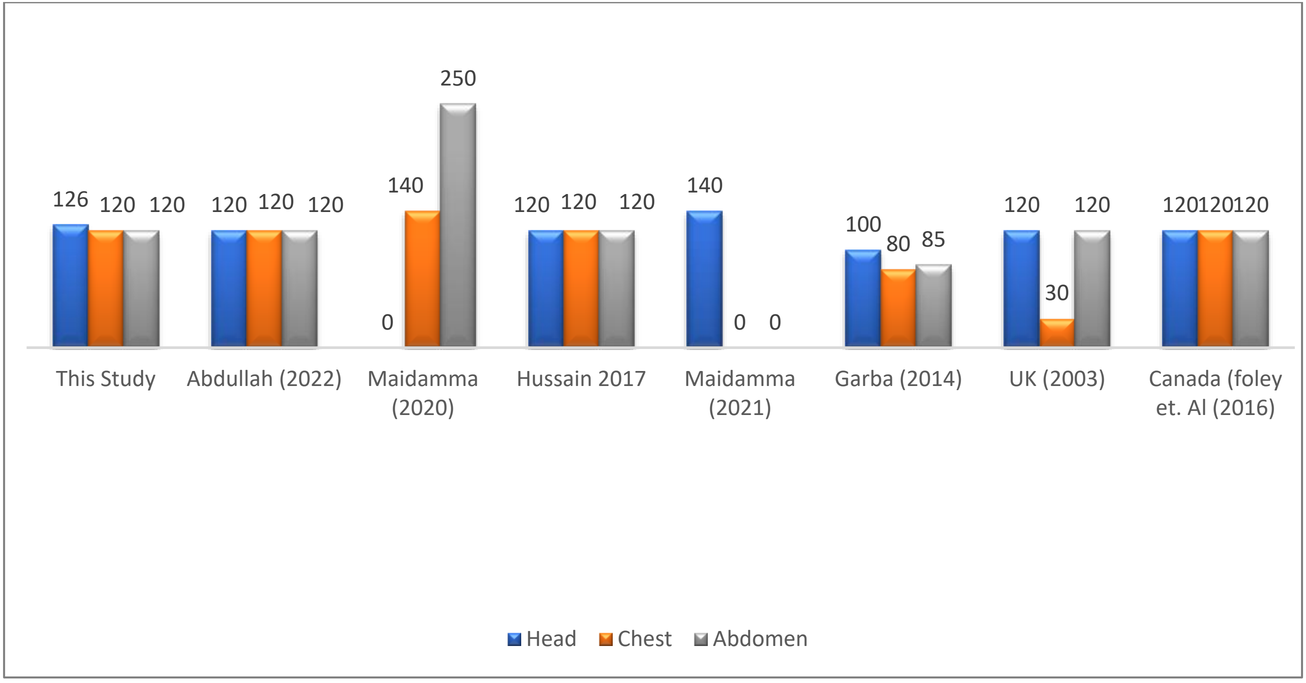

Figure 2: Comparison of kV with Literature

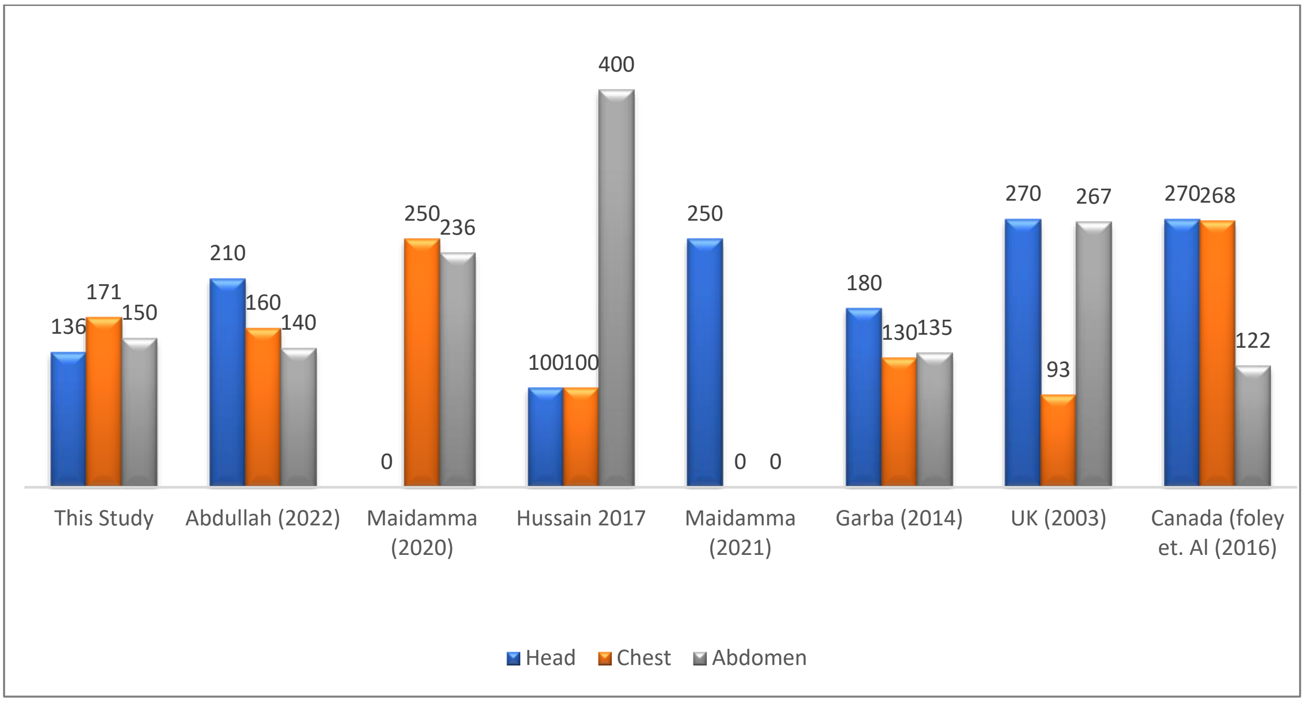

Figure 3: Comparison of kV with Literature

Comparison of patient weight with Literature

Compared with Maidamma (2020) and Husseiny et al. (2017) (Figure 1), patient weights in this study were consistently higher. This indicates a demographic variation that could affect DRL compliance. There is a need to generate localized DRLs for Nigeria that reflect regional anthropometric characteristics, rather than relying solely on international datasets.

Scan Parameters

Tube voltage remained consistent at 120-126 kV across the scan regions, in line with international practice. Mean tube currents were higher, 136 mA (head), 171 mA (chest), and 150 mA (abdomen), indicating limited dose-reduction strategies. This suggests mA optimization, rather than kV adjustment, is most critical for reducing patient dose.

Table 2: Mean Scan Parameters

Parameters	Head	Chest	Abdomen
(kV)	126	120	120
(mA)	136	171	150

Mean values of kV were 126 kV (head), 120 kV (chest & abdomen), Table 2. These are within common international practice ranges, consistent with the UK 2003 and Canadian literature. The tube currents were 136 (head), 171 (chest), and 150 (abdomen), which are higher than those reported in some earlier Nigerian studies. kV use is standard and optimized; the higher mA values suggest less aggressive use of dose-reduction techniques (Abdullah et al., 2022). This could be a key factor contributing to elevated radiation dose indices in the center.

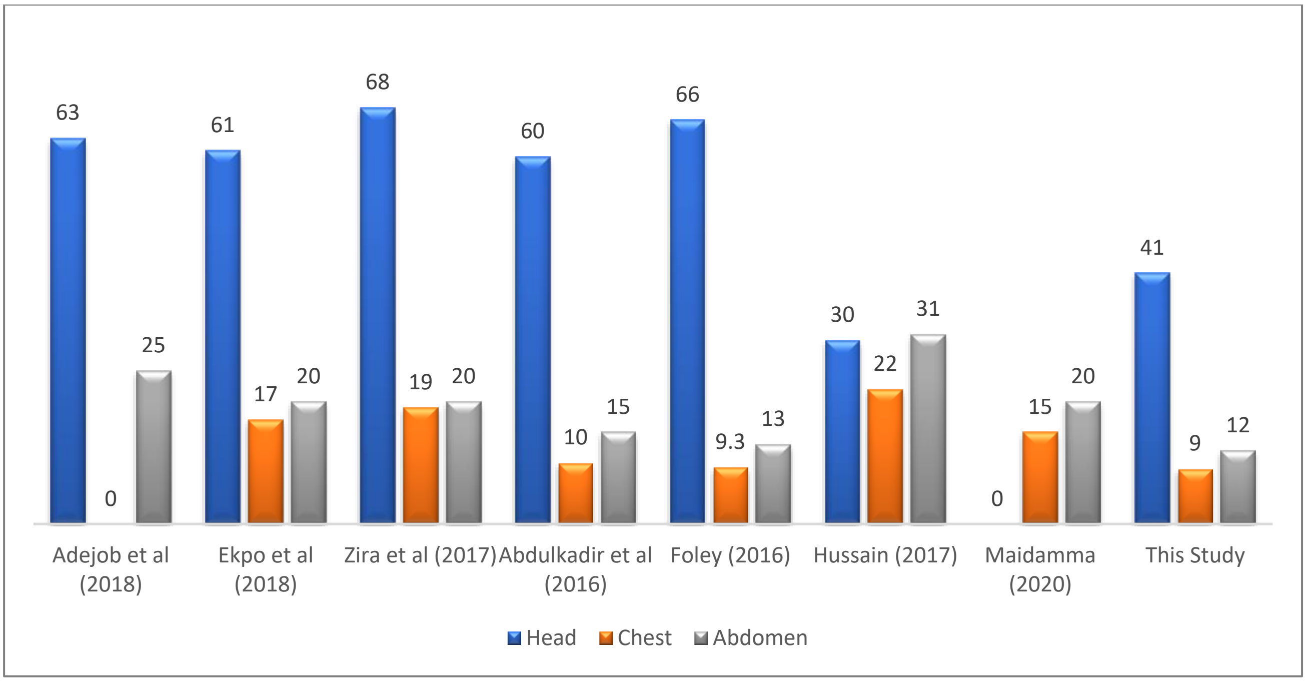

Figure 4: Comparison of Mean CTDIvol (mGy) with Literature

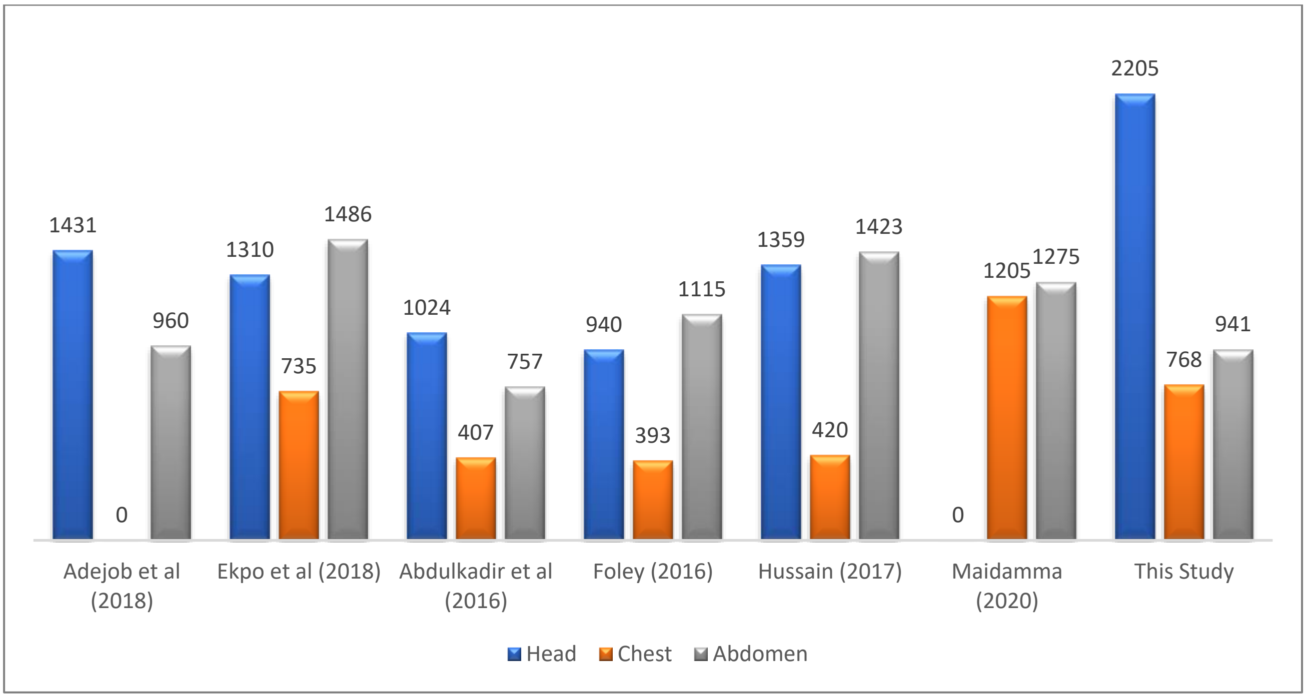

Figure 5: Comparison of Mean DLP (mGy.cm) with Literature

Comparison of Scan Parameters with Literature

Figure 2 illustrates the comparison of tube voltage (kV) values used at FTHBK with those reported in national and international literature. The mean values from this study were 126 kV for head CT scans and 120 kV for both chest and abdominal CT scans. When compared with the UK (2003) DRL study, Foley et al. (2016) Canada, and Nigerian studies such as Maidamma (2020), Hussain (2017), and Garba (2014), the kV settings at FTHBK are within the accepted international range of 100–140 kV. This indicates that the hospital follows standard practice in selecting tube voltage, ensuring that images are acquired with sufficient penetration and contrast. The alignment with global values also implies that kV is not a major contributor to the slightly higher radiation doses observed in this study compared to some literature. The implication is that dose variations at FTHBK may be more strongly influenced by other technical factors, such as tube current (mA), scan length, and the use of dose modulation techniques, rather than tube voltage settings.

Figure 3 further confirms the consistency of kV selection across head, chest, and abdominal CT examinations when compared with multiple reference studies. The kV values used at FTHBK closely match those reported in

Maidamma (2020), Hussain (2017), earlier Nigerian studies, and international benchmarks from the UK and Canada. The lack of significant deviation suggests a standardized practice of using 120–126 kV across different scan regions, which is in line with ALARA principles since it avoids unnecessary escalation of voltage that could increase patient dose. These finding highlights that the higher dose indices recorded in the present study are unlikely to originate from tube voltage but rather from higher mA values or extended scan lengths applied during examinations. The implication is that optimization strategies at FTHBK should maintain the current kV protocols but focus more on regulating tube current and, where possible, reducing scan length.

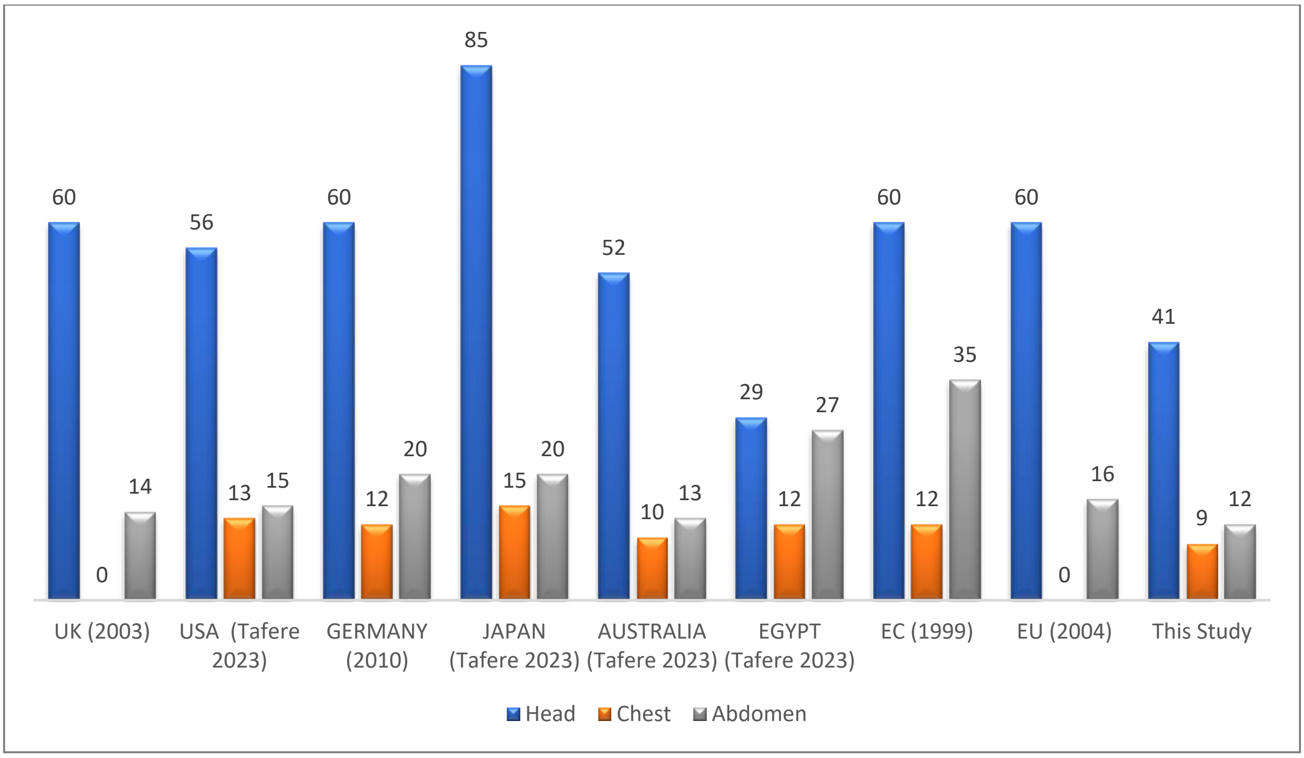

Figure 6: Comparison of Mean CTDIvol (mGy.cm) with Country's Established DRLs

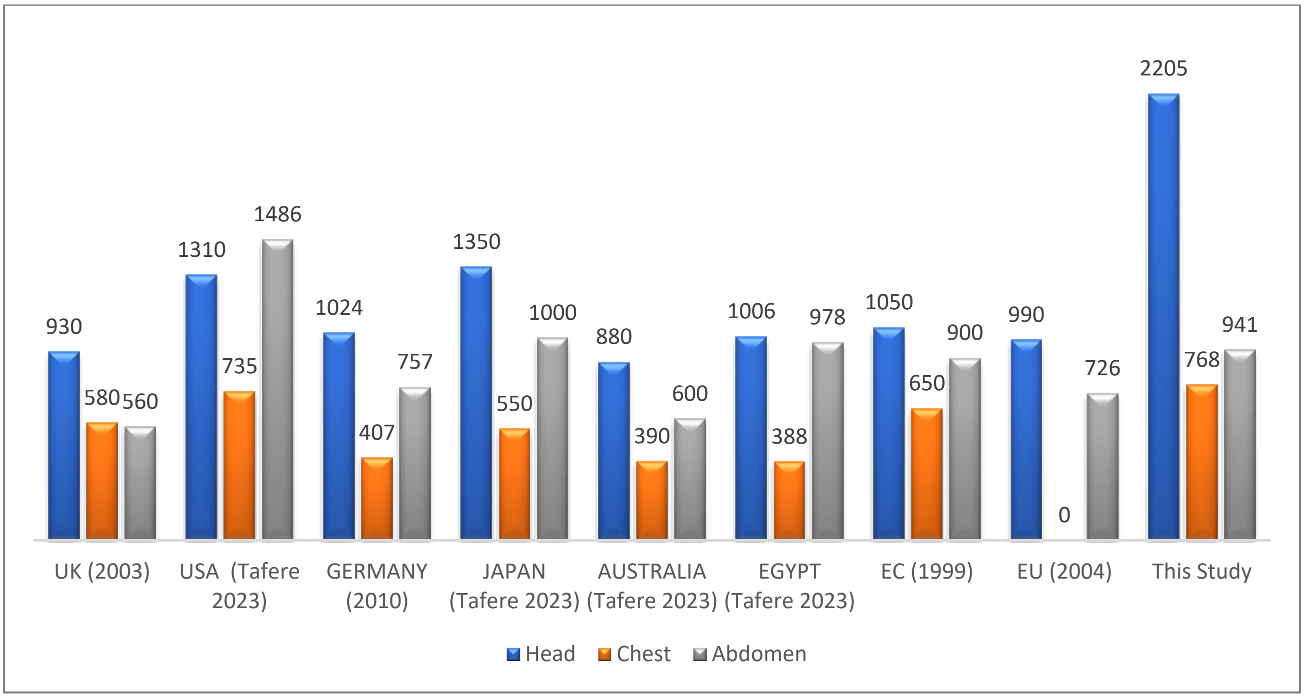

Figure 7: Comparison of Mean DLP (mGy.cm) with Country's with Established DRLs

Table 3: Mean Radiation Dose

Parameters	Scan Region					
	Head	No. Patient	Chest	No. Patient	Abdomen	No. Patient
CTDIvol (mGy)	41	45	9.0	10	12	45
DLP (mGy.cm)	2205	45	768	10	941	45

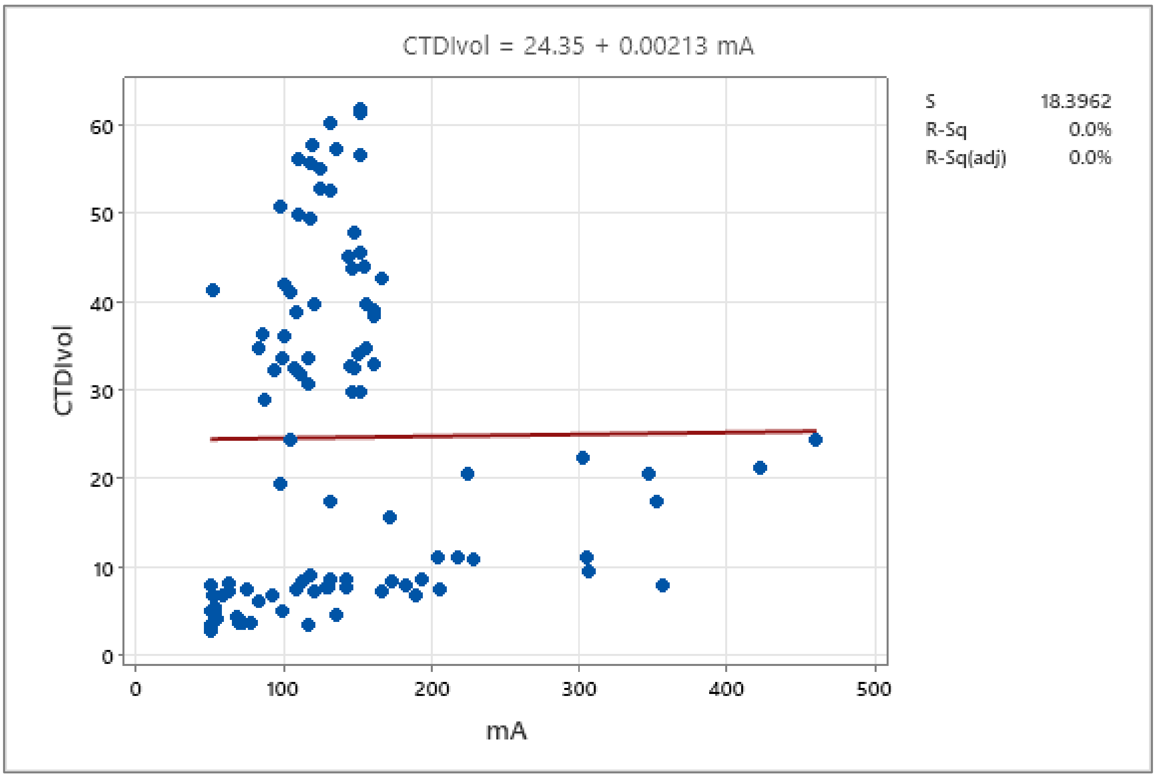

Figure 8: Comparison of CTDIvol with mA in the centre

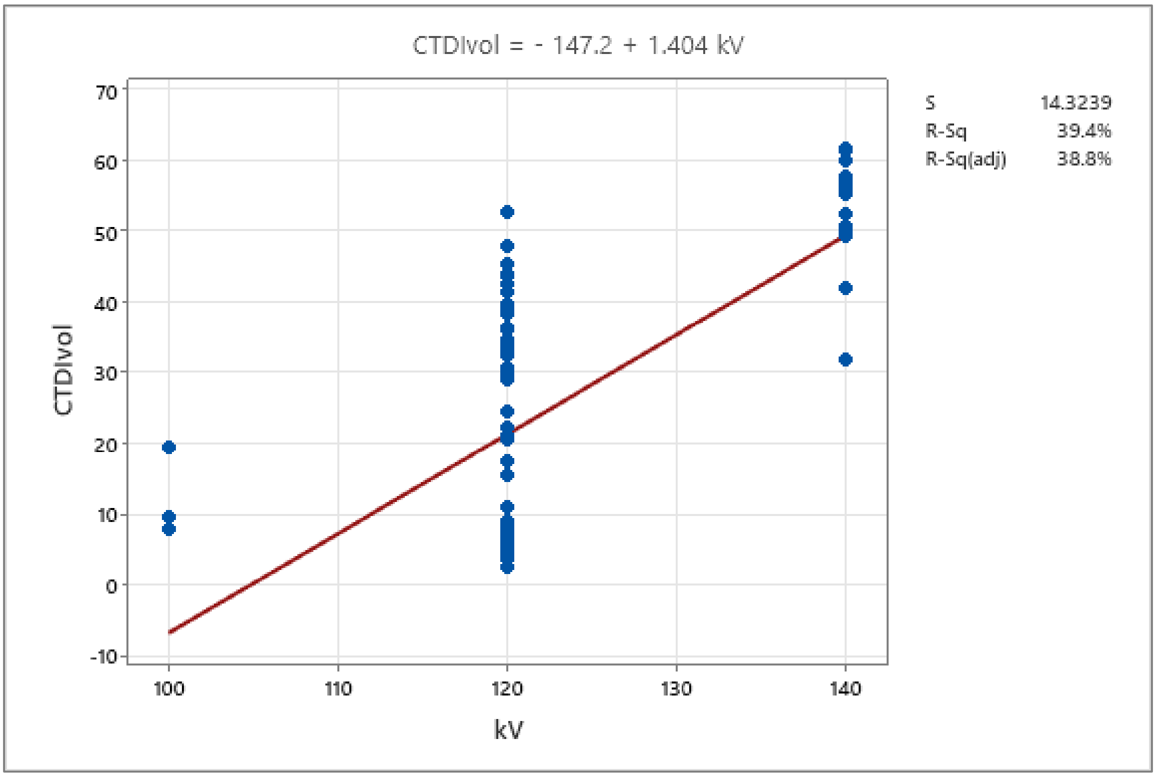

Figure 9: Comparison of CTDIvol with kV in the centre

Radiation Dose

Dose parameters, including CTDIvol and DLP, were determined and represent the dose procedure indicators used in the FTHBK and are presented in Table 3.

Table 3 presents the mean CTDIvol and DLP values for head, chest, and abdominal CT scans performed at FTHBK. The results show that the head CT recorded a CTDIvol of 41 mGy and a DLP of 2205 mGy·cm, while the chest CT had a CTDIvol of 9.0 mGy and a DLP of 768 mGy·cm, and the abdominal CT demonstrated a CTDIvol of 12 mGy and a DLP of 941 mGy·cm. These outcomes reveal clear variation in dose distribution across anatomical regions, with head CT examinations delivering the highest doses, consistent with global patterns, as head CTs often require higher exposure for adequate image quality. However, the DLP for head CT is considerably elevated when compared with reference data, raising concerns about potential overexposure. The relatively moderate CTDIvol values for chest and abdomen suggest reasonable compliance with safety benchmarks, though the DLP values indicate possible extension of scan lengths beyond optimal ranges. The implication is that while tube output levels are acceptable, protocol review—especially for head CT—is necessary to reduce cumulative exposure without sacrificing diagnostic accuracy.

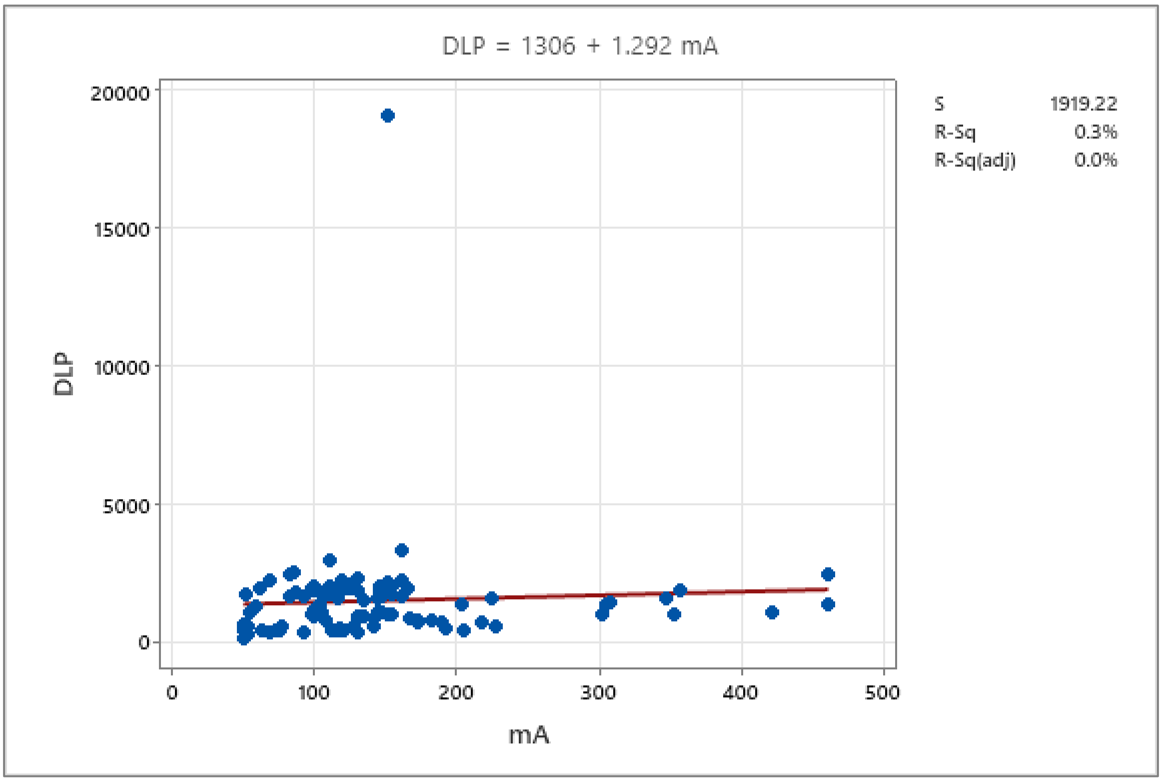

Figure 10: Comparison of DLP with mA in the centre

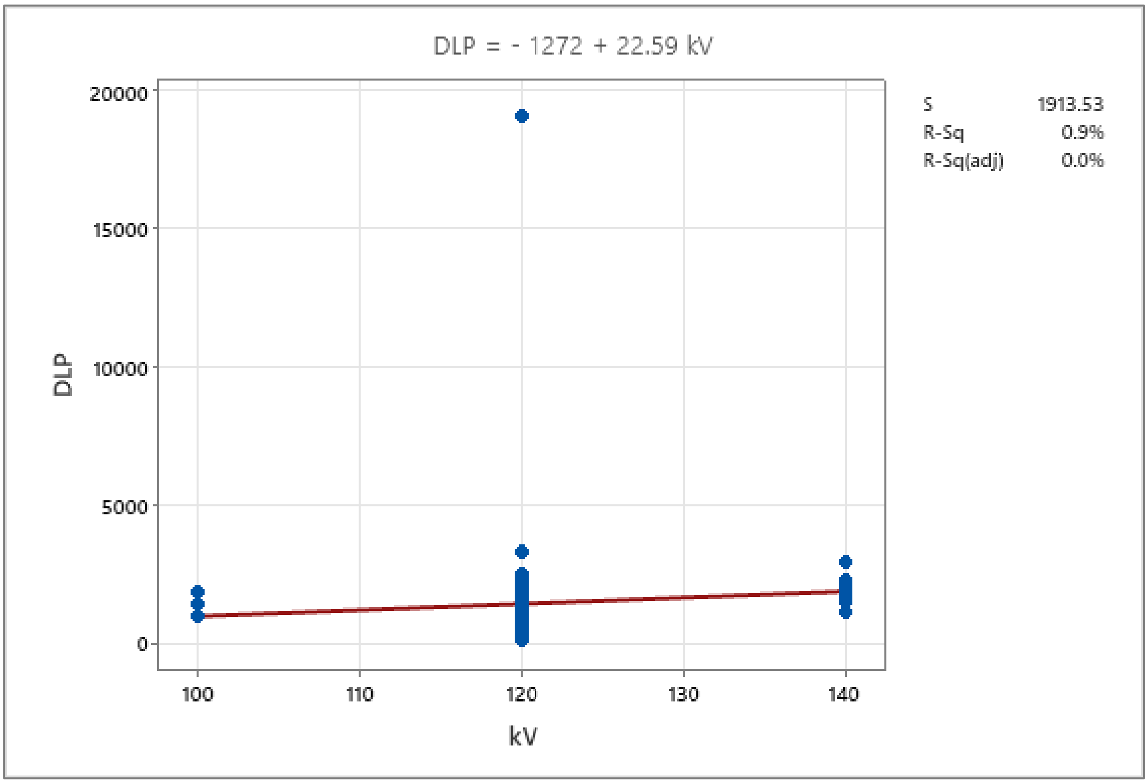

Figure 11: Comparison of DLP with kV in the centre

Comparison of Radiation Dose Levels with Literature

Figure 4 compares the CTDIvol values from FTHBK with those reported in Nigerian and international literature. The study's mean CTDIvol of 41 mGy for head, 9.0 mGy for chest, and 12 mGy for abdomen lies within the international practice range, but the head CTDIvol is relatively higher than those reported by Maidamma (2020), Hussain (2017), and Garba (2014).

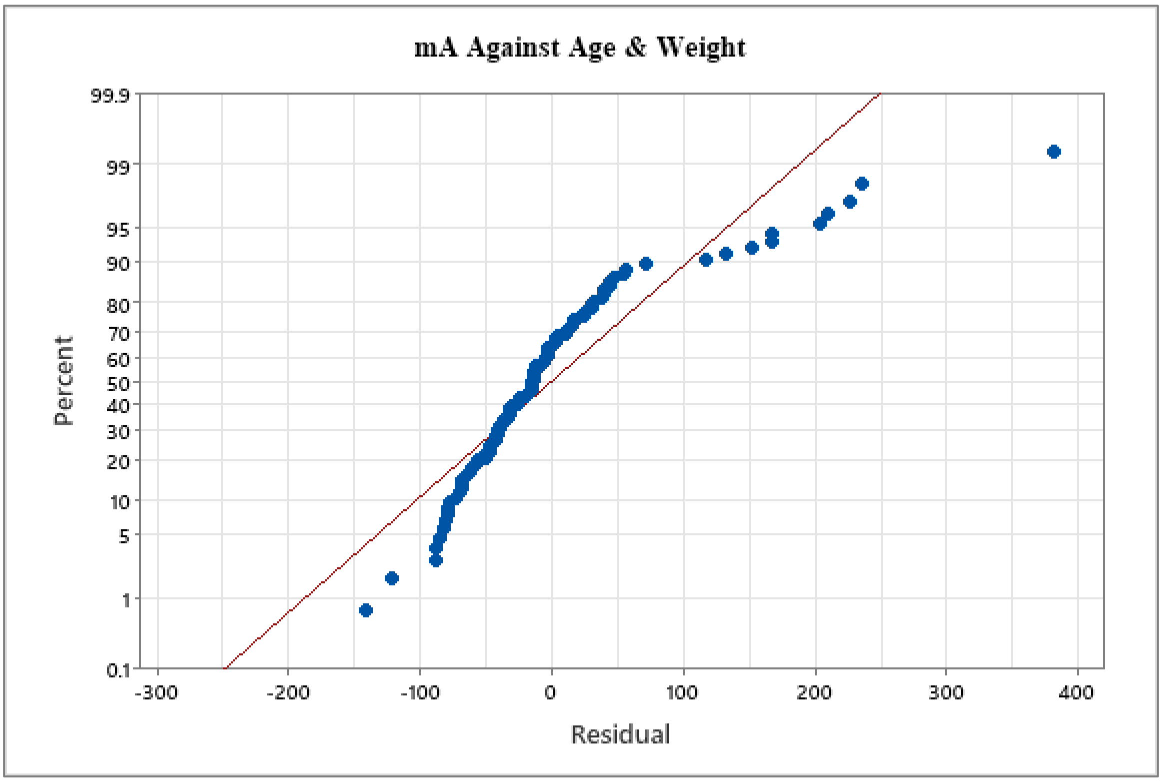

Figure 12: Comparison of mA with Age & Weight in the center

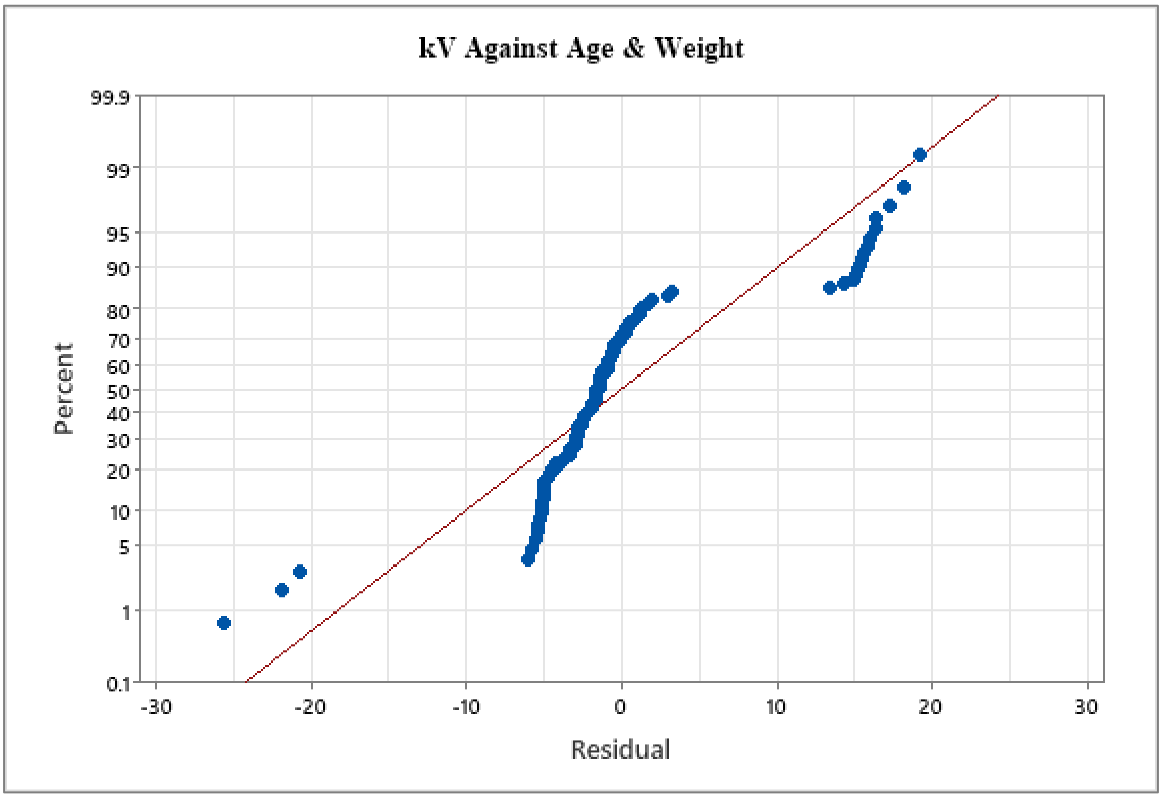

Figure 13: Comparison of kV with Age & Weight in the center

In contrast, chest and abdominal CTDIvol values are lower or comparable to those reported previously, indicating closer alignment with global standards. The relatively higher head CTDIvol suggests that local protocols may not yet be fully optimized, potentially due to higher tube current settings or limited use of dose-reduction features. The implication is that dose-optimization efforts at FTHBK should particularly focus on head CT protocols to bring CTDIvol levels into closer compliance with international DRLs, while maintaining image quality.

Figure 5 compares DLP values between FTHBK and reference studies. The results demonstrate that the head CT DLP of 2205 mGy·cm is substantially higher than values reported in Adejoh et al. (2018), Ekpo et al. (2018), and Hussain (2017), and also exceeds benchmarks from Foley (2016) and other international DRLs.

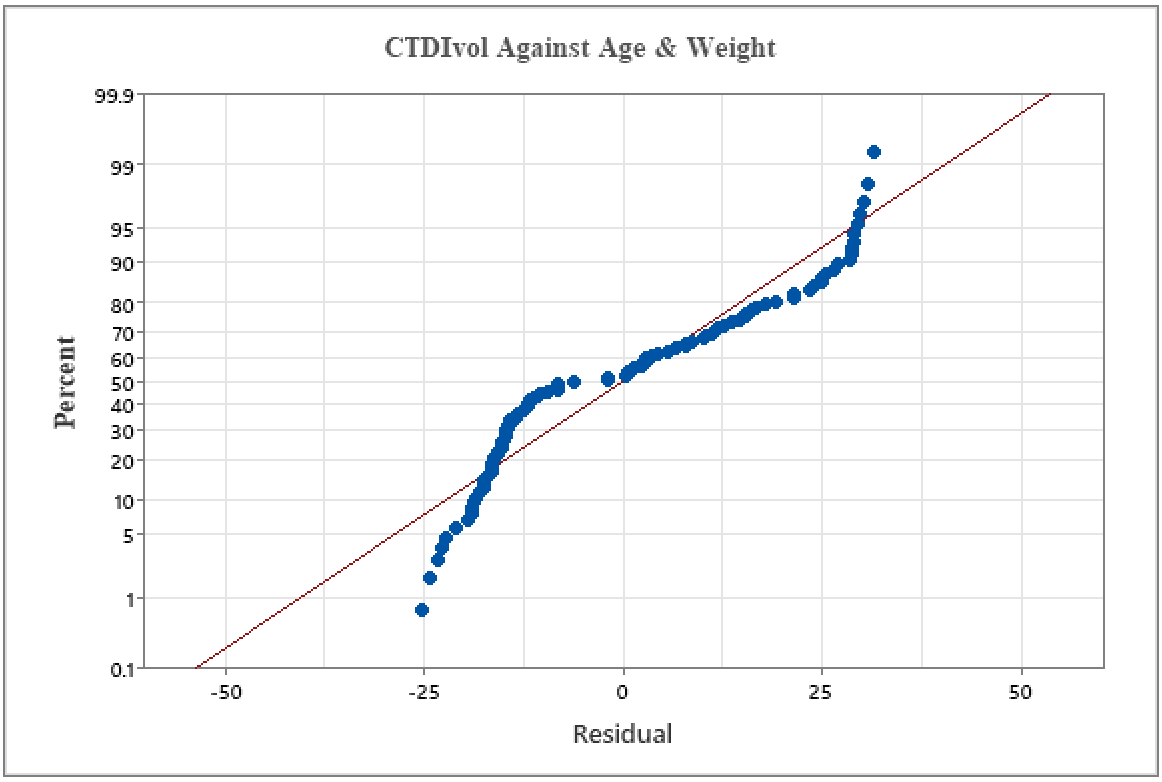

Figure 14: Comparison of CTDIvol with Age & Weight in the centre

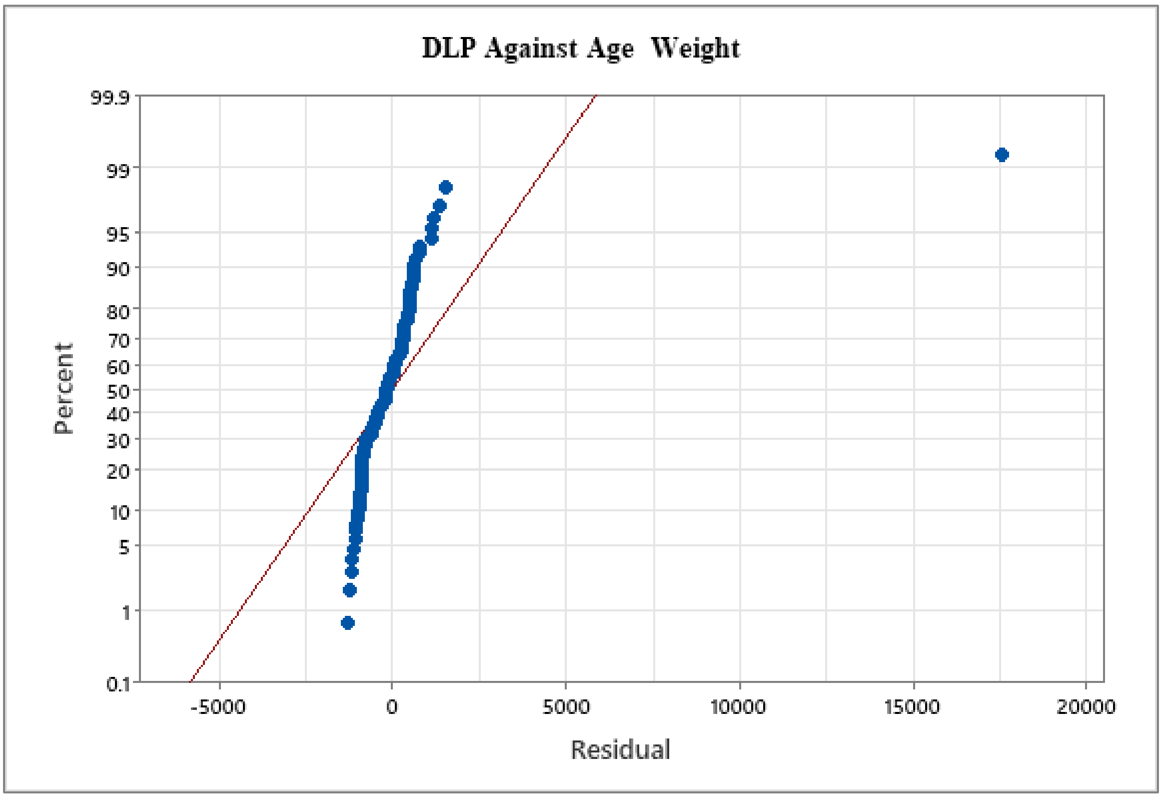

Figure 15: Comparison of DLP with Age & Weight in the center

Conversely, the chest DLP (768 mGy·cm) and abdominal DLP (941 mGy·cm), although moderately high, remain within ranges reported in Nigerian studies and approach international DRL thresholds. The elevated head DLP is most likely due to longer scan lengths, since DLP is directly proportional to scan length, rather than an unusually high CTDIvol. The implication is that FTHBK should critically evaluate collimation practices and scan range limits during head CT examinations to minimize unnecessary exposure. Optimizing scan length could substantially reduce DLP values, ensuring compliance with the ALARA principle without compromising clinical outcomes.

Figure 6 compares the CTDIvol values recorded at FTHBK with established Diagnostic Reference Levels (DRLs) from various countries, including the UK, USA, Germany, Japan, Australia, Egypt, and the European

Commission (EC). The mean head CTDIvol of 41 mGy observed in this study is higher than the DRLs reported in Japan, Germany, and Australia, but remains within the broader DRL ranges established in the UK and USA. For chest CT (9.0 mGy) and abdominal CT (12 mGy), the FTHBK values fall within or slightly below most international DRLs, suggesting relatively good compliance. These findings imply that head CT examinations at FTHBK deliver higher-than-recommended radiation doses, warranting closer scrutiny of technical parameters, particularly mA and exposure time. Conversely, the chest and abdomen CTDIvol values demonstrate encouraging alignment with established DRLs, indicating that protocols for these regions are reasonably optimized.

Figure 7 compares the DLP outcomes at FTHBK with established DRLs from the UK, USA, Japan, Germany, Australia, Egypt, and the EU. The head DLP of 2205 mGy·cm is markedly higher than most international benchmarks, which generally report values below 1400 mGy·cm. This suggests that scan length for head CT examinations at FTHBK is excessive and may contribute substantially to patient overexposure. For the chest CT (768 mGy·cm) and abdominal CT (941 mGy·cm), the values are generally within the DRL ranges reported in Europe, Japan, and Egypt, though still higher than those reported in some Australian and German studies. The implications are twofold: first, that head CT protocols at FTHBK require urgent review to reduce the scan range and optimize exposure; and second, that while chest and abdominal protocols demonstrate acceptable compliance, further fine-tuning could reduce DLPs further, thereby enhancing patient safety.

Figure 8 (CTDIvol vs mA) shows a strong positive correlation, indicating that increases in tube current are associated with proportional increases in CTDIvol. The regression line demonstrates a close fit, with the coefficient of determination (r^2) confirming that changes in mA explain a significant proportion of the variation in CTDIvol. This finding is consistent with radiation physics principles: higher mA levels produce more X-ray photons, thereby increasing patient dose. The implication is that mA is the dominant technical factor influencing radiation dose at FTHBK. This result underscores the importance of implementing automatic tube current modulation (ATCM) or adjusting mA protocols based on patient size to minimize unnecessary dose while maintaining diagnostic image quality.

Figure 9 (CTDIvol vs kV) reveals a weaker but still positive correlation. While CTDIvol increases with higher kV, the relationship is less pronounced than with mA. This outcome is expected, since kV adjustments are usually applied within a narrow range (120–126 kV at FTHBK) to balance dose and image contrast. Although raising kV increases photon energy and dose approximately by the square of voltage, the relatively standardized use of kV at FTHBK explains the weaker correlation. Importantly, higher kV can reduce image contrast, meaning any attempt to reduce dose via kV adjustment must be carefully weighed against diagnostic image requirements.

These results demonstrate that mA is the primary driver of radiation dose variations, while kV plays a secondary but more controlled role. Dose optimization strategies at FTHBK should therefore prioritize the regulation of tube current, particularly through ATCM and protocol tailoring based on patient size and clinical indication. Maintaining kV within international standards while controlling mA will allow the center to align more closely with established DRLs and uphold the ALARA principle.

Figure 10 (DLP vs mA) demonstrates a strong positive correlation, with DLP increasing significantly as mA increases. The regression line shows a clear upward trend, and the coefficient of determination (r^2) indicates that a large proportion of the variance in DLP is attributable to changes in mA. This is expected, since higher mA increases photon flux and thus patient exposure, while DLP reflects both CTDIvol and scan length. The implication is that mA is a key determinant of cumulative dose in CT examinations at FTHBK, and that regulating tube current would have the greatest impact on reducing patient exposure, particularly for head CT scans, where DLP values were found to be elevated.

Figure 11 (DLP vs kV) shows a weaker correlation than mA. Although increasing kV raises DLP, the effect is less pronounced because kV values at FTHBK vary little (mostly 120–126 kV). Unlike mA, which directly scales photon quantity, kV alters photon energy and tissue penetration, thereby indirectly affecting dose. The regression analysis confirms that while kV contributes to dose, its role in explaining DLP variation is relatively minor. Clinically, this suggests that adjusting kV alone is not sufficient for meaningful dose reduction and should be modified only in specific scenarios, such as pediatric imaging or low-dose chest protocols, where image contrast and patient size allow.

These findings emphasize that mA is the dominant factor influencing both CTDIvol and DLP, while kV plays a secondary role, largely controlled by standardized practice. Dose optimization strategies should therefore prioritize tube current modulation and careful control of scan length, since both directly impact DLP. By maintaining kV within standard diagnostic ranges and focusing on mA regulation, FTHBK can reduce cumulative patient dose while preserving diagnostic image quality, thereby ensuring compliance with international DRLs and the ALARA principle.

Figure 12 shows the relationship between tube current (mA) and patient demographic factors, specifically age and weight. The regression analysis shows a clear positive correlation between mA and patient weight, meaning that as patient body size increases, higher tube currents are applied. This finding is expected since larger patients require more photons to penetrate tissues and achieve acceptable image quality. The relationship with age, however, appears less consistent, suggesting that mA selection at FTHBK is more strongly driven by patient size than by chronological age. This aligns with best practice, as dose adjustments should be tailored to patient thickness or weight rather than age alone. The implication is that the hospital demonstrates awareness of patient-specific dose tailoring, but the strength of correlation also highlights the importance of avoiding excessive mA escalation in heavier patients, where automatic exposure control (AEC) could help maintain balance between dose and image quality.

Figure 13 presents the regression analyses of tube voltage (kV) on patient age and weight. Unlike mA, the correlation between kV and both age and weight is weak to negligible. The kV values remain relatively constant across all patient categories, typically within the standardized range of 120–126 kV. This stability reflects common CT practice, where voltage is generally fixed for adult protocols and varied only in specific situations (e.g., pediatric scans, low-dose chest imaging). The weak association also implies that patient size at FTHBK does not influence kV selection, and the hospital relies on a uniform kV protocol for all routine examinations. While this ensures consistency and image quality, it may overlook opportunities for further optimization within subgroups, such as smaller or younger patients, where reducing to 100–110 kV could lower dose without compromising diagnostic value.

Figures 12 and 13 confirm that mA is adjusted according to patient weight, while kV is maintained at a fixed level irrespective of patient demographics. This practice aligns with global standards, since mA modulation is the most effective method for personalizing dose. However, relying on fixed kV settings may limit opportunities for additional optimization, particularly in lighter patients. The findings suggest that FTHBK is applying some level of patient-specific dose management, but further refinement—such as incorporating AEC for mA adjustment and selectively lowering kV for smaller patients—would enhance compliance with the ALARA principle and reduce unnecessary radiation burden.

Figure 14 shows the relationship between CTDIvol and patient demographics (age and weight). The regression analysis indicates a positive correlation between CTDIvol and patient weight, suggesting that heavier patients receive higher radiation doses. This is expected, as increased body mass requires higher tube current and, sometimes, longer scan ranges to achieve diagnostic image quality. The relationship with age, however, is less defined, reflecting the fact that age itself is not a technical parameter; rather, weight and body habitus drive dose adjustments. The implication is that patient weight is the dominant demographic factor influencing CTDIvol, and careful regulation of tube current in heavier patients is crucial to prevent unnecessary exposure.

Figure 15 demonstrates the correlation between DLP and patient age and weight. The findings reveal a strong positive correlation with weight, even more pronounced than with CTDIvol, since DLP incorporates both dose per slice and scan length. Heavier patients not only require higher mA but also sometimes longer scan coverage, leading to elevated DLP values. Once again, the relationship with age is weaker, confirming that dose management is primarily dependent on physical body size rather than chronological age. The high DLP values observed in heavier patients highlight the importance of using strict collimation and avoiding unnecessary scan extension to keep exposures within acceptable limits.

Together, Figures 14 and 15 confirm that weight is the critical determinant of patient dose outcomes (CTDIvol and DLP) at FTHBK, while age plays only a secondary role. This aligns with international best practice, which emphasizes dose optimization based on patient size rather than age alone. However, the strength of these correlations suggests that heavier patients are at increased risk of higher radiation burdens, making optimization strategies such as:

The regression analyses presented in Figures 12 through 15 explore the influence of patient demographics, specifically age and weight, on tube current (mA), tube voltage (kV), and radiation dose outcomes (CTDIvol and DLP). Figure 12 (mA vs Age and Weight) shows a clear positive correlation between mA and patient weight, indicating that heavier patients required higher mA to achieve acceptable image quality. This reflects appropriate clinical practice, since patient body size directly influences photon penetration. The relationship with age, however, was less consistent, confirming that weight rather than age is the primary determinant of tube current selection at FTHBK. Figure 13 (kV vs Age and Weight) reveals only a weak association between kV and both age and weight. Tube voltage remained relatively constant at 120–126 kV across all examinations, indicating the use of standardized kV protocols regardless of patient size. While this ensures image quality consistency, it also suggests that opportunities for further optimization, such as lowering kV for smaller or younger patients, are currently underutilized.

Figure 14 (CTDIvol vs Age and Weight) demonstrates a positive correlation between CTDIvol and patient weight, with heavier patients receiving higher radiation doses. The effect of age was less pronounced, further reinforcing the dominant role of body mass in dose variation. Figure 15 (DLP vs Age and Weight) reveals an even stronger positive correlation with weight, reflecting the combined influence of higher mA requirements and potentially extended scan lengths in larger patients. Once again, age played a minimal role in dose determination. Collectively, these findings confirm that patient weight is the strongest demographic factor influencing radiation dose outcomes at FTHBK, while age alone has little direct effect. This pattern is consistent with international best practices, which emphasize tailoring dose to patient size rather than age. However, the strength of the correlations highlights the potential for overexposure in heavier patients, underscoring the need for further optimization. Strategies such as implementing automatic tube current modulation (ATCM), adopting weight-based protocol adjustments, and ensuring strict scan length collimation would significantly improve dose compliance with international DRLs. In contrast, the weak association of kV with patient size suggests that current standardized voltage protocols are adequate for most adult patients, though selective reduction of kV for smaller or pediatric patients could further enhance adherence to the ALARA principle.

CONCLUSION

This study assessed radiation dose compliance at the Federal Teaching Hospital, Birnin-Kebbi, providing vital baseline data for a newly established radiology center in Nigeria. The findings show that while tube voltage (kV) practices are standardized and consistent with international values, higher tube current (mA) values and longer scan lengths significantly elevate patient dose levels, particularly for head CT scans. Chest and abdominal CT protocols, however, generally demonstrated compliance with international DRLs. Regression analyses confirmed that tube current is the strongest technical predictor of radiation dose, while kV has a weaker effect because it is standardized. Furthermore, patient weight, rather than age, was identified as the primary demographic factor influencing dose variation, reinforcing the need for weight-based adjustments in clinical practice.

The implications of these findings are substantial. Firstly, optimization strategies such as automatic tube current modulation (ATCM), strict scan length collimation, and weight-adjusted protocols should be prioritized to reduce unnecessary radiation exposure. Secondly, the elevated head CT dose levels highlight the importance of protocol review and continuous quality assurance in dose management. Beyond FTHBK, this study provides a foundation for establishing localized DRLs in Nigeria, which will enhance patient safety, guide radiation protection policy, and support evidence-based training in radiology. By aligning clinical practice with the ALARA principle and international safety standards, Nigeria can ensure that advances in diagnostic imaging continue to benefit patients without increasing long-term health risks.

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