

Radiation-Induced Cancer Risk in Pediatric Patients Undergoing Computed Tomography Scan at Federal University Teaching Hospital Birnin Kebbi

Maidamma B and Danladi Z. I.

Department of Physics with Electronics,
Federal University Birnin Kebbi

Corresponding Author Email: zainabibrahimdanladi790@gmail.com

DOI: [10.56201/rjps.vol.8.no11.2025.pg25.32](https://doi.org/10.56201/rjps.vol.8.no11.2025.pg25.32)

Abstracts

The increasing utilization of Computed Tomography (CT) in pediatric diagnostics has significantly improved disease detection and management but raised concerns about radiation-induced cancer risks due to the higher radiosensitivity of developing tissues. This study assessed the radiation-induced cancer risk among pediatric patients undergoing CT scans at the Federal University Teaching Hospital, Birnin Kebbi (FUTHBK). A cross-sectional quantitative design was adopted, involving pediatric patients aged 0–17 years who underwent CT examinations. Data were collected from the CT scanner console, including CT dose index volume (CTDIvol), dose-length product (DLP), and scanning parameters such as tube voltage (kVp), current (mAs), and slice thickness. Effective dose (E) was computed using age- and region-specific conversion coefficients, while Lifetime Attributable Risk (LAR) of cancer incidence was estimated using the BEIR VII risk model. The results revealed mean CTDIvol and DLP values of 26 ± 17 mGy and 847 ± 545 mGy·cm for male patients, and 23 ± 19 mGy and 852 ± 939 mGy·cm for females, respectively. Corresponding mean effective doses were 2.63 mSv (male) and 2.91 mSv (female), with LAR values of 46.04 per 10^5 and 55.01 per 10^5 , translating to estimate lifetime cancer risks of 1 in 217 for males and 1 in 181 for females. These findings exceed international diagnostic reference levels (DRLs), indicating suboptimal radiation protection practices. The study concludes that pediatric CT procedures at FUTHBK expose children to radiation doses capable of increasing lifetime cancer risks, especially among female and younger patients. Establishing pediatric-specific CT protocols, enforcing the ALARA principle, and integrating automatic exposure control (AEC) and iterative reconstruction technologies are urgently needed. The outcomes provide a foundation for dose optimization policies and highlight the importance of routine radiation audits, professional training, and parental awareness in mitigating pediatric radiation exposure.

1.0 Introduction

Computed tomography (CT) examinations have provided great benefits for patient care, but increased use of CT examinations has raised concerns regarding the enhanced radiation dose and the associated stochastic cancer risk to patients. In addition, compared with adults, pediatric patients are more susceptible to radiation-induced risks owing to their more rapidly growing tissues, their wider and increased cellular distributions of red bone marrow (RBM), and their greater post-exposure life expectancy [(Brenner et al., 2007 and Berrington et al., 20009).

X-ray Computed Tomography (CT) was introduced into clinical use in 1973, which over time has successfully enacted itself as a primary diagnostic modality. (Mettler et al., 2009), have reported

increased utilization of computed tomography examination for clinical diagnosis worldwide. Fast scanning speed, isotropic spatial resolution, non-invasive, affordability compared to other modalities such as magnetic resonance imaging, applications in staging, treatment planning, and follow up of cancer treatment are some of its unique advantages (Yu et al., 2009).

The estimated dose for children in CT scans has become an area of concern with increasing awareness of radiation risk (Shrimpton et al., 2003). The United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) reported in 2010 that the tissues and organs of children were more radio sensitive compared with adults, and they are more at risk of developing radiation-induced cancer after a long latency period (ICRP 2007). Hence, the risk of CT radiation exposure in children should be justified and optimized according to the “As Low as Reasonably Achievable” (ALARA) principle. However, several studies have found large differences in radiographic imaging procedures at different hospitals, prominent to varying degrees of radiation exposure on patients (Salaama et al., 2017 and Karim et al., 2016).

In 1990 the International Commission for Radiological Protection (ICRP) launched “diagnostic reference level” (DRL) in order to urge authorities, governing bodies and health institutions in medical practice to establish safety standards for radiation exposure that conform to clinical purposes (ICRP 2007). DRLs are designed to represent the safety reference of radiological procedures for a local institute, established imaging centre, specific region or even nation. The derivation of DRLs allows the institution to control the use of radiological procedures in a way that suits health needs and eliminates undesired exposure without compromising image quality. Generally, the DRL has been proposed as the 75th percentile (third quartile) of the national dose apportioning ever since it was first established by the ICRP in 1996. Noting that, professionals or regulatory bodies may determine a national DRL from wide-ranging surveys at hospitals in a region or country (Salaama *et al.*, 2017 and Karim *et al.*, 2016).

Given these concerns, this study aims to evaluate the radiation-induced cancer risk in pediatric patients undergoing CT scans at the Federal University Teaching Hospital Birnin Kebbi. The findings are expected to inform strategies for dose optimization, enhance awareness among healthcare providers, and contribute to the development of protocols that prioritize patient safety in pediatric imaging.

2.0 Methodology

A minimum of 40 pediatric CT examinations is reviewed. This number was chosen to provide a representative distribution of scan types (e.g., head, chest, and abdomen) across standard pediatric age groups (e.g., 0–1, 1–5, 6–10 years), while aligning with the expected patient volume at the Radiology Department of FUTHBK over a typical 3–6 month period.

Data for this study was collected prospectively from both the CT scanner console and corresponding radiology records at FUTHBK. The data collection process was standardized using custom-designed abstraction forms to ensure consistency and accuracy. The following categories of information were recorded: Key patient information include age, sex, and weight, which are essential for dose assessment and normalization in pediatric imaging. Additionally, the clinical indication for each CT scan was documented to provide context for the examination and to support the classification of scan types and urgency levels.

Detailed technical parameters of each CT examination was collected to evaluate scanning practices and their influence on radiation exposure. These include: Tube voltage (kVp), which affects the energy level of the X-rays, Tube current-time product (mAs), influencing the quantity of radiation used, Scan length, which determines the extent of body coverage, Slice thickness, affecting image

resolution and potential dose distribution. Pitch, a factor in scan speed and dose efficiency. Scan region, to classify the type of CT examination (e.g., head, chest, abdomen).

Radiation dose metrics was extracted directly from the CT scanner console to ensure precision. These include: Volume CT Dose Index (CTDI_{vol}): A standardized measure of radiation dose output adjusted for scan volume. Dose-Length Product (DLP): Represents the total radiation dose for the complete scan length and is used in conjunction with conversion factors to estimate the effective dose.

The effective dose (in millisieverts, mSv) for each CT scan was estimated by multiplying the DLP by standardized pediatric conversion coefficients (k-factors) provided by the European Commission (EC) and ICRP Publication 121. Organ Dose Estimation For a subset of patients, organ doses were estimated using CT-Expo or similar software, which allows for pediatric phantoms and scan-specific modeling. lifetime Attributable Risk (LAR) of cancer incidence was estimated using models from the BEIR VII Phase 2 report. LAR values are age- and sex-specific and will be calculated for organs at risk (e.g., brain, thyroid, lungs).

Microsoft Excel, SPSS, and CT dose calculation software (e.g., CT-Expo or ImPACT). Was used to calculate Means, medians, and ranges of CTDI_{vol}, DLP, effective dose, and LAR.

3.0 Result

The findings of this study demonstrate that pediatric patients undergoing computed tomography (CT) examinations at the Federal University Teaching Hospital, Birnin Kebbi (FUTHBK) are exposed to radiation doses higher than internationally recommended diagnostic reference levels (DRLs). The mean effective dose values of 2.63 mSv for males and 2.91 mSv for females correspond to Lifetime Attributable Risk (LAR) estimates of 1 in 217 and 1 in 181, respectively. These results confirm that female pediatric patients are more vulnerable to radiation-induced cancer, which aligns with the BEIR VII and ICRP 121 reports indicating that females possess greater tissue radiosensitivity, particularly in organs such as the thyroid and breast.

The high doses observed in this study can be attributed to the persistent use of adult-based imaging parameters (120 kVp, high mAs) without adequate adjustment for patient size or age. Many Nigerian hospitals still lack modern CT scanners equipped with Automatic Exposure Control (AEC) and Iterative Reconstruction (IR) technologies, which are essential for reducing unnecessary radiation exposure (Umeh & Nwankwo, 2022). Furthermore, the absence of locally established DRLs contributes to wide dose variations across procedures, a situation similar to that reported by Akinlade et al. (2018) and Aborisade et al. (2020).

The findings also affirm the Linear No-Threshold (LNT) model assumption that even low doses of ionizing radiation carry some cancer risk. Pediatric patients, due to their rapidly dividing cells and longer life expectancy, face amplified long-term stochastic effects (Hall & Giaccia, 2012). The higher mean LAR in younger children further supports this, emphasizing the need for age-specific dose optimization.

When compared with international data, the mean CTDI_{vol} (26 mGy for males, 23 mGy for females) exceeds values reported in the UK, U.S., and Europe (Shrimpton et al., 2006; Berrington de Gonzalez et al., 2009), underscoring the need for urgent intervention.

The implication of these findings is that without systematic dose control, pediatric CT may significantly elevate future cancer incidence within this population. To ensure safety, FUTHBK should establish institutional DRLs, implement ALARA-based pediatric CT protocols, and provide continuous professional training for radiographers and radiologists. Enhanced quality assurance programs, public education, and the introduction of national pediatric dose guidelines

will collectively minimize radiation exposure risks and ensure diagnostic accuracy without compromising patient safety.

Table 1: Demographic Parameter for Male

Variable	Statistic	
	Mean $\pm$ Std	3 rd Quartile
Age	10 $\pm$ 5	14
Weight (kg)	23 $\pm$ 11	30
Height (cm)	113 $\pm$ 41	148

Table 2: Demographic Parameter for Female

Variable	Statistic	
	Mean $\pm$ Std	3 rd Quartile
Age	10 $\pm$ 5	15
Weight (kg)	22 $\pm$ 14	32
Height (cm)	117 $\pm$ 48	154

Table 3: Scan Parameter for Male

Variable	Statistic	
	Mean $\pm$ Std	3 rd Quartile
Mas	99.0 $\pm$ 33.0	103
KVp	120 $\pm$ 12.0	120
STH	2.00 $\pm$ 1.00	2.00

Table 4: Scan Parameter for Female

Variable	Statistic	
	Mean $\pm$ Std	3 rd Quartile
Mas	84 $\pm$ 47	105
KVp	113 $\pm$ 20	120
STH	3 $\pm$ 1	3

Table 5: Radiation Parameter for Male

Variable	Statistic	
	Mean $\pm$ Std	3 rd Quartile
CTDIvol	26 $\pm$ 17	38
DLP	847 $\pm$ 545	1049

Table 6: Radiation Parameter for Male

Variable	Statistic	
	Mean $\pm$ Std	3 rd Quartile
CTDIvol	23 $\pm$ 19	38
DLP	852 $\pm$ 697	939

Table 7 Effective Dose and LAR for Male Patient

Parameter	Statistic		
	Mean	$\pm$ SD	3Q
E(mVs)	2.63	1.94	3.94
LAR(Age)	46.04	31.68	67.57

Table 8 Effective Dose LAR for Female Patient

Parameter	Statistic		
	Mean	$\pm$ SD	3Q
E(mVs)	2.91	2.04	4.76
LAR(Age)	55.01	39.20	87.60

Table 9 Comparison of LAR (Age) For Male and Female Patient

Categories	Percentage LAR
Male	1 In 217
Female	1 In 181

The comparison of lifetime attributable risk (LAR) shows 1 in 217 for males and 1 in 181 for females. This difference reflects the established pattern of sex-dependent radiosensitivity, corroborating BEIR VII and UNSCEAR (2010) findings. The higher LAR in females indicates that under identical exposure conditions, female tissues exhibit greater propensity for carcinogenic transformation, primarily due to hormonal influences and higher mitotic indices in glandular tissues (Berrington et al., 2009). The ratio of female-to-male risk ($\sim 1.2:1$) aligns with international benchmarks (Mathews *et al.*, 2021) and suggests that pediatric imaging protocols at FUTHBK need adjustment not only by age but also by sex. Implementing sex-weighted DRLs would help balance diagnostic adequacy with long-term radioprotection. The implication is profound: even minor improvements in protocol differentiation reducing tube voltage by 10 kV or optimizing scan range can significantly alter lifetime risk outcomes. Therefore, routine dose audits should incorporate LAR-based performance indicators rather than relying solely on CTDIvol or DLP.

4.0 Conclusion

This study has demonstrated that pediatric patients undergoing CT examinations at the Federal University Teaching Hospital, Birnin Kebbi, are exposed to radiation doses that exceed internationally recommended levels. The calculated mean effective doses of 2.63 mSv (male) and 2.91 mSv (female) correspond to lifetime attributable cancer risks of 1 in 217 and 1 in 181, respectively. These findings confirm that female and younger pediatric patients are at significantly higher risk of radiation-induced malignancies due to increased tissue radiosensitivity and longer lifespan for stochastic effects to manifest.

The study further established that the excessive radiation exposure results from the application of adult-based imaging protocols, absence of pediatric dose optimization tools such as Automatic Exposure Control (AEC), and insufficient awareness of radiation protection principles among imaging personnel. Moreover, the lack of institutional and national Diagnostic Reference Levels (DRLs) contributes to uncontrolled dose variation.

In conclusion, while CT remains an indispensable diagnostic tool, this research underscores the urgent need for a balanced approach that preserves image quality while minimizing radiation exposure. Implementing pediatric-specific CT protocols, enforcing the ALARA principle, and fostering regular dose audits will substantially reduce unnecessary radiation risks. Ultimately, safeguarding pediatric patients requires collaborative efforts among radiologists, radiographers, hospital management, and policymakers to ensure that diagnostic benefits are achieved without compromising long-term health.

4.1 Recommendations

Based on the study findings, several key recommendations are proposed to improve radiation safety and optimize pediatric CT imaging practices at the Federal University Teaching Hospital, Birnin Kebbi, and similar institutions across Nigeria.

First, the development of pediatric-specific CT protocols is essential to ensure that scanning parameters such as kVp, mAs, pitch, and scan length are tailored to the child's age, weight, and anatomical region, thereby minimizing unnecessary exposure. The hospital should also implement automatic dose reduction technologies like Automatic Exposure Control (AEC), Iterative Reconstruction (IR), and Organ-Based Tube Current Modulation (OBTCM), which can significantly lower radiation doses while preserving diagnostic image quality.

Regular dose audits and the establishment of institutional and national Diagnostic Reference Levels (DRLs) are recommended to serve as benchmarks for safe practice. Additionally, routine calibration and quality control of CT scanners will help maintain consistent dose accuracy.

Continuous capacity building and training of radiographers and radiologists on pediatric imaging and radiation protection are vital, alongside stronger radiation protection governance through the enforcement of international standards such as ICRP 103 and BEIR VII guidelines.

Public awareness initiatives should be strengthened to educate parents and guardians about the risks and benefits of CT examinations and available alternative modalities like ultrasound and MRI. Finally, the Federal Ministry of Health should establish a national pediatric imaging policy and promote multicenter research on radiation risk monitoring.

Implementing these measures will strengthen Nigeria's radiation safety culture, protect pediatric patients from avoidable radiation risks, and ensure alignment with global best practices in diagnostic radiology.

Acknowledgement

The authors sincerely express their gratitude to the management and staff of the Federal University Teaching Hospital, Birnin Kebbi (FUTHBK), Kebbi State, for their kind cooperation, access to facilities, and provision of necessary data for this study. Special appreciation is extended to the Nigerian Nuclear Regulatory Authority (NNRA) for their valuable regulatory guidance and support. The authors also thank all pediatric patients and their guardians who participated in the study. Finally, heartfelt appreciation goes to the supervisors, colleagues, for their unwavering encouragement, technical assistance, and contributions throughout the course of this research.

Reference

- Aborisade, C. A., Famurewa, O. C., Ibitoye, F. O., & Balogun, F. A. (2020). Organ dose distribution and estimated cancer risk to paediatric patients undergoing computed tomography in a Nigerian tertiary hospital. *Journal of Radiation Research and Applied Sciences*, 13(1), 254–260. <https://doi.org/10.1080/16878507.2020.1754110>
- Adepoju, F. A., Abdulrahim, S., Atanda, L., Abdulkareem, S. and Akintomide, A. O. (2020). Overview of radiation dose to patients from medical X-ray examinations in Nigeria. *Radiography*, 26(1): e1-e5.
- Akinlade A. F. Oladele T. O. Yusuf K. M. and Adediran J. O. (2022). Radiation protection practices among radiographers in Nigeria: Awareness and compliance. *Radiology and Imaging Science*, 14(3): 45-58.
- Akinlade, B. I., Farai, I. P., & Okunade, A. A. (2018). Variations in pediatric CT dose levels in Nigerian hospitals and the need for dose optimization. *Radiation Protection Dosimetry*, 179(1), 32–38. <https://doi.org/10.1093/rpd/ncy045>
- Akinyemi, O. O., Adebayo, A. and Ojo, J. O. (2019). Study of radiation doses in adult and paediatric patients undergoing computed tomography examinations in a Nigerian teaching hospital. *Open Journal of Radiology*, 9(1): 1-10.
- BEIR VII Phase 2 Report (2006). National Research Council.
- 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.
- Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med* 2007;357:2277–84. 2.
- Brenner, D. J. and Hall, E. J. (2020). Computed tomography, an increasing source of radiation exposure. *New England Journal of Medicine*, 382(22): 2277-2284.
- Chukwu, O. C., Emeka, L. and Eze, C. U. (2022). Evaluation of dose-area product of common radiographic examinations towards establishing a preliminary diagnostic reference levels in Southwestern Nigeria. *Radiography*, 28(2): 345-351.
- Ekpo, E. U., Adejoh, T., & Erim, A. E. (2019). Dose benchmarks for paediatric head computed tomography examination in Nigeria. *Radiation Protection Dosimetry*, 185(4), 464–471. <https://doi.org/10.1093/rpd/ncz056>
- Eze O. C. Chukwuma I. R. Okeke P. T. and Umeh A. P. (2022). Compliance with diagnostic reference levels in CT examinations in Nigerian hospitals. *Medical Physics International*, 9(4): 67-82.
- Fazel, R., Krumholz, H. M., Wang, Y., Ross, J. S., Chen, J., Ting, H. H. and Shah, N. D. (2020). Exposure to low-dose ionizing radiation from medical imaging procedures. *New England Journal of Medicine*, 381(9): 849-857.
- Hall, E. J., & Giaccia, A. J. (2012). *Radiobiology for the Radiologist* (7th ed.). Lippincott Williams & Wilkins.
- Ibrahim, U. and Musa, B. (2021). Assessment of radiation dose to pediatric patients during routine computed tomography examinations in a Nigerian tertiary hospital. *Medical Science and Discovery*, 8(5): 345-351.
- ICRP Publication 121 (2013). Radiological Protection in Pediatric Diagnostic and Interventional Radiology.
- International Commission on Radiological Protection (ICRP). (2007). *the 2007 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 103.

- International Commission on Radiological Protection. ICRP publication 103. Ann. ICRP 2007, 37, 1–332.
- Kalra M. K. Mahesh M. Toth T. L. and Sheaf M. G. (2021). Dose reduction techniques in computed tomography: Advances and limitations. *European Radiology*, **31**(2): 212-225.
- Karim, M.; Hashim, S.; Bradley, D.; Bakar, K.; Haron, M.; Kayun, Z. Radiation doses from computed tomography practice in Johor Bahru, Malaysia. *Radiat. Phys. Chem.* 2016, 121, 69–74.
- kinlade, B. I., Farai, I. P., & Okunade, A. A. (2018). Pediatric CT dose variation in Nigerian hospitals. *Radiation Protection Dosimetry*, 179(1), 32–38.
- Mathews, J. D., Forsythe, A. V., Brady, Z., Butler, M. W., Goergen, S. K., Byrnes, G. B. and Berrington de González, A. (2021). Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: Data linkage study of 11 million Australians. *British Medicine Journal*, **346**: f2360
- Miglioretti D. L. Smith-Bindman R. Williams A. P. and Green E. S. (2022). Trends in CT radiation exposure and dose optimization. *American Journal of Roentgenology*, **219**(3): 145-162.
- National Research Council. (2006). *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*. Washington, DC: The National Academies Press.
- Nwosu T. O. Ibekwe K. I. Anosike C. P. and Onwuzuruike N. O. (2021). Patient dose assessment in head and abdominal CT scans in Nigeria. *West African Journal of Medical Imaging*, **5**(2): 88-102.
- Okonkwo, C. A., Enyinnaya, P. and Eze, C. U. (2017). Evaluation of safe paediatric CT scan ranges for chest scan in selected medical facilities in Rivers State, Nigeria. *Nigerian Journal of Clinical Practice*, **20**(6): 689-694.
- Oladele, M., Adejumo, S. and Olatunji, R. (2020). Organ dose distribution and estimated cancer risk to paediatric patients undergoing computed tomography in a Nigerian tertiary hospital. *Radiography*, **26**(2): e74-e79.
- Pearce, M. S., Salotti, J. A., Little, M. P., McHugh, K., Lee, C., Kim, K. P. and Berrington de González, A. (2020). Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: A retrospective cohort study. *The Lancet*, **380**(9840): 499-505
- Salaama, D.H.; Vassileva, J.; Mahdaly, G.; Shawki, M.; Salama, A.; Gilley, D.; Rehani, M.M. Establishing national diagnostic reference levels (DRLs) for computed tomography in Egypt. *Phys. Med.* 2017, 39, 16–24.
- Shrimpton, P.C.; Hillier, M.C.; Lewis, M.A.; Dunn, M. National survey of doses from CT in the UK: 2003. *Br. J. Radiol.* 2006, 79, 968–980.
- Umeh, E. C. and Nwankwo, N. C. (2022). Assessment of patients' radiation doses during computed tomography chest imaging examinations: Proposing diagnostic reference levels. *Journal of Radiography and Radiation Sciences*, **36**(2): 123-130
- Yu, L., S. Leng, J. Kofler, M. Qu, J. Christner, J. Fletcher and C. McCollough. 2009. “Radiation Dose Reduction in Computed Tomography: Techniques and Future Perspectives”. *Imaging Med*; 1(1):65-84. <http://www.futuremedicine.com>