Research Article
Open Access

Development of local diagnostic reference levels for conventional X-ray examinations in Kebbi state

Abstract

Diagnostic Reference Levels (DRLs) serve as benchmarks for evaluating the quality of radiological equipment and procedures by assessing patient radiation doses and identifying the need for corrective actions when necessary. This study aims to encourage healthcare professionals to monitor patient radiation doses and ensure compliance with radiation protection principles, ultimately reducing exposure while maintaining diagnostic effectiveness. Radiation doses were assessed for various radiological procedures across two major Hospitals in Kebbi State, focusing on chest (PA, AP, LAT), abdomen (AP), pelvis (AP), cervical spine (AP), lumbar spine (AP, LAT), hip (AP), and thoracic spine (AP, LAT) examinations. Data collection included both patient and equipment parameters, which were analysed using Cal Dose X-5.0 software to estimate entrance skin dose (ESD) and effective dose (ED) for 1000 patients. Statistical analysis was conducted to determine the mean, standard deviation, Relationship (t-test) and third quartile values, which were compared with international DRL recommendations. The mean ESD ranged from 1.07 mGy to 7.39 mGy, while ED values ranged from 0.09 mSv/year to 0.87 mSv/year. ESD values for most examinations exceeded the thresholds established by ARPNSA (2017), NRPB (2000), and other studies, while ED values remained below the Nigeria Nuclear Regulatory Agency's limit of 1.0 mSv/year. The 75th percentile DRLs for Abdomen AP, Chest AP, Chest LAT, Cervical AP, Cervical LAT, Skull AP, Skull PA, Skull LAT, Paranasal AP, Shoulder AP, Femur AP, Lumbar AP, Lumbar Sacral AP, Thoraco-lumbar AP, Pelvis AP, and Hip Joint AP were 8.07, 2.59, 1.63, 2.84, 4.79, 4.64, 6.46, 5.62, 6.09, 2.49, 5.75, 4.59, 9.15, 5.56, 2.68, 6.12, and 8.07 mGy, respectively. Abdomen AP, Hip Joint AP, Lumbar Spine AP, and Pelvis AP examinations aligned with DRL values from the European Commission (1999) and IAEA (1996). However, DRLs for other examinations exceeded these benchmarks. Variability in doses between centres was attributed to factors such as outdated X-ray machines, suboptimal radiographic techniques, and insufficiently documented radiation protection practices. These findings highlight the urgent need for the development of standardized dose measurement protocols, implementation of quality assurance programs, and dose optimization strategies in Kebbi State to enhance patient safety and compliance with international radiation safety standards.

Keywords: entrance skin dose, effective dose, diagnostic reference levels, X-ray and Kebbi

Volume 9 Issue 2 - 2025

B Samaila,[1] MD Rilwanu,[2] B Maidamma[1]

[1]Department of Physics with Electronics, Federal University, Nigeria

[2]Department of Radiology, Federal University Teaching Hospital, Nigeria

Correspondence: Buhari Samaila, Department of physics with electronics, Federal University Birnin Kebbi, P.M.B 1157, Nigeria, Tel +234 906 622 9957

Received: November 22, 2025 | **Published:** December 4, 2025

Introduction

Diagnostic X-rays represent the major portion of radiation exposure from artificial origin to the population. According to the World Health Organization (WHO), more than 3.6 billion diagnostic radiology exams are performed every year around the world. Diagnostic imaging is a cornerstone of modern medicine, aiding in the diagnosis, treatment, and monitoring of various medical conditions. Among the modalities, conventional X-ray remains the most widely utilized due to its accessibility, cost-effectiveness, and ability to provide essential diagnostic information. However, the use of ionizing radiation in X-ray imaging raises concerns about patient safety, necessitating measures to minimize radiation exposure while ensuring diagnostic efficacy. One such measure is the establishment of Diagnostic Reference Levels (DRLs), which serve as benchmarks for optimizing radiation doses during medical imaging procedures.[1,2] The stochastic effects of low-dose ionizing radiation are not fully understood, underscoring the importance of monitoring patient doses during diagnostic procedures. As noted by Diop et al.,[3] a robust culture of radiation protection is essential to ensuring patient safety. However, in many regions, including Senegal, practices related to patient radiation protection are inadequately documented, highlighting a gap in healthcare practices and research. This situation necessitates detailed investigations to assess the existing standards and identify areas for improvement.

The concept of DRLs was first introduced by the International Commission on Radiological Protection[4] (ICRP) in 1996 to standardize radiation dose management in medical imaging. DRLs are typically defined as the 75th percentile of the dose distribution for a specific examination and patient group, providing a threshold above which dose optimization should be considered. The application of DRLs helps identify outliers, promote adherence to best practices, and guide improvements in radiological techniques.[4] Despite their critical role, the development of DRLs requires region-specific data due to variations in equipment, imaging protocols, and patient demographics.[5,6] In many developing countries, including Nigeria, the establishment of DRLs is still in its early stages. Local DRLs are essential to account for variations in imaging equipment, protocols, and patient demographics, which often differ significantly from those in developed countries where international DRLs are typically established.[7] Without these local benchmarks, healthcare providers may rely on international DRLs, which may not adequately reflect the specific practices and challenges of the local context. In Nigeria, efforts to establish DRLs have gained momentum in recent years, with studies highlighting significant disparities in radiation doses across healthcare facilities. These differences are often attributed to outdated equipment, lack of standardization in imaging protocols, and inadequate training of radiographers.[8,9]

Kebbi State, like other regions in Nigeria, has seen a growing demand for conventional X-ray examinations, driven by increasing healthcare needs. However, there is limited information on the radiation doses patients receive during these procedures. Recent studies have highlighted the need for localized dose optimization efforts to enhance patient safety while maintaining diagnostic efficacy.[9,10] Developing local DRLs personalized to Kebbi State's healthcare facilities will not only bridge this knowledge gap but also align with international recommendations to ensure safe and effective radiological practices. This study represents the first comprehensive effort to evaluate radiation doses as well as the establishment of diagnostic reference levels (DRLs) for adult patients undergoing conventional X-rays in public hospitals in Kebbi State. By comparing the measured doses with the requirements of the Basic Safety Standards (BSS), this research aims to determine whether current practices align with international guidelines. Ultimately, the study seeks to enhance radiological practices, promote a culture of radiation protection, and minimize patient radiation exposure, thereby contributing to improved healthcare outcomes in Kebbi State. The findings will provide a framework for dose optimization, enhance compliance with international radiation safety standards, and contribute to the broader efforts to establish national DRLs in Nigeria.

Material and Method

This study began after the reception of permission from the Ministry of Health Kebbi State and Federal Medical Centres Birnin Kebbi ethical research committee. The scope of the radiation dose assessment was limited to the most frequent X-ray examinations that give a large contribution to the entrance skin doses and effective dose. The following nine routine types of X-ray examinations are included in the investigations: chest (PA), abdomen (AP), pelvis (AP), hip (AP), cervical spine (AP), thoracic spine (AP), thoracic spine (LAT), lumbar spine (AP), and lumbar spine (LAT). Chest (PA), Abdomen (AP), and cervical spine (AP) examinations were acquired in a standing position while the other examinations were taken in the supine position. The patients that underwent AP/PA and LAT projection were considered as separate cases to estimate the dose for each projection. The data were collected prospectively in two x-ray rooms in Sir Yahaya Memorial Hospital and FTHB. The exposure parameters displayed on the console of the X-ray unit during the examination were recorded.

Study area

The study was carried out in two selected centres in Kebbi State. The selected centre is comprised of Sir Yahaya Memorial Hospital (SYMH) and Federal Teaching Hospital Birnin Kebbi (FTHB) Kebbi. Kebbi State is located in the northwestern part of Nigeria. It is situated between latitudes 10° 8′ N – 13° 15′ N, and longitudes 3° 30′ E – 6° 02′ E. The State is bordered by Sokoto and Zamfara States to the east, Niger State to the south, the Benin Republic to the west, and the Niger Republic to the north. The population of the State was projected to be 5,026,111 (https://www.nigeriagalleria.com/Nigeria/States). Kebbi State occupies 36,800 square kilometers of land.

Sample size and data collection

The data of 1000 patients (for both female and male) were collected prospectively from two selected centres in Kebbi State. The collected data were divided into two different parts. The first Part involves Patient demographic data such as Name, Age, and Gender, while the second part involves exposure parameters such as tube kilovoltage (kV), exposure time product (mAs), Focus on skin distance (FSD), and Focus on Film Distance (FFD) from the X-ray tube.

Data analysis

After the data had been collected prospectively from the centres, it was automatically transferred to CAL Dose_X 5.0, software for Entrance Surface Air Kerma, Incidence Air Kerma, backscattered factor, and weighted doses (effective doses) as shown in figure below (Figure 1).[11,12]

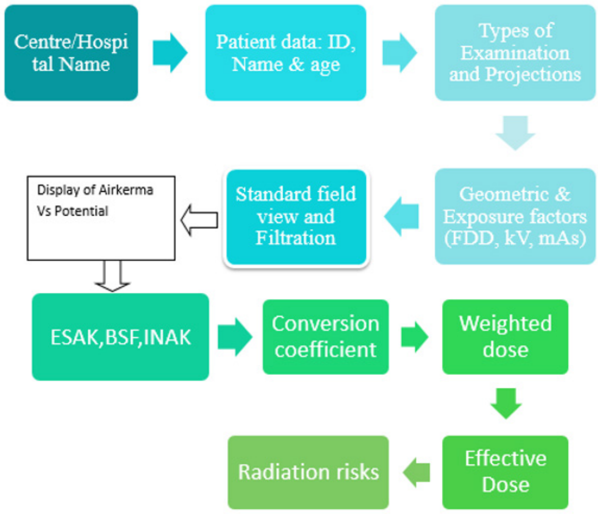

Figure 1 Cal Dose X_5.0 data analysis flow chart.

The tube output of each x-ray machine was deduced from the graph of INAK (mGy) against mAs Plotted by software which yielded a slope (k) in mGy/mAs given as

$$\text{Slope}(K) = 0.0419 \times V^{0.2771} \quad (1)$$

The Entrance Surface Air Kerma was converted using equation (2) below:

$$ESD = ESAK \times BSF \quad (2)$$

The weighted Fash (F) /Mash (M) dose determined by the software was also converted into effective dose using equation (3) below[13]

$$\text{Effective Dose} = \frac{1}{2}[F + M] \quad (3)$$

Diagnostic reference level determination

There are three main steps involved in the determination of DRLs (Figure 2).

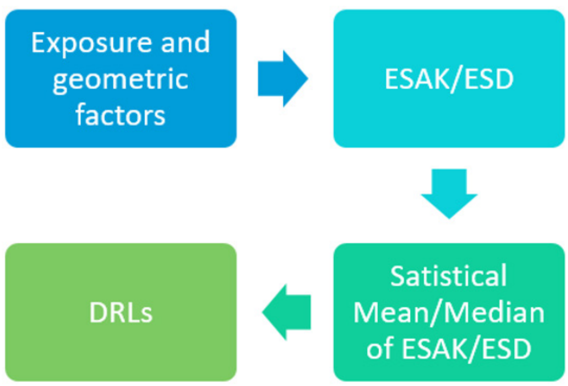

Figure 2 DRL Estimation flow chart.

Citation: Samaila B, Rilwanu, Maidamma B. Development of local diagnostic reference levels for conventional X-ray examinations in Kebbi state. *Material Sci & Eng.* 2025;9(2):78‒87. DOI: 10.15406/mseij.2025.09.00257

Ethical clearance

The ethical clearance for conducting this research work was obtained from the Ministry of Health Kebbi State and Federal University Teaching Hospital Birnin Kebbi.

Result and discussion

The results in Table 1 indicate that FTHB generally employs higher kV and mAs for high-attenuation regions such as the abdomen, lumbar, and thoracolumbar spine, leading to higher ESD and ED compared to SYMH. For example, the mean ED for abdomen erect AP at FTHB was nearly double that at SYMH (1.32 ± 0.49 mSv vs. 0.68 ± 0.09 mSv), with a corresponding DRL of 1.65 mSv. Conversely, for low-attenuation projections such as chest PA, neck lateral, and skull imaging, ED values were lower or comparable at FTHB, reflecting optimized exposure protocols for these regions. Derived DRLs (75th percentile) highlight areas with potential for dose reduction. Abdomen and lumbar projections exhibited the highest DRLs, indicating a need for protocol standardization and equipment quality control. In contrast, DRLs for chest, neck, and skull projections were relatively low, demonstrating effective dose management practices in routine imaging. Patient-specific factors, including age and anatomical size, influenced exposure settings, as evidenced by higher kV, mAs, and ESD in larger patients at FTHB. Additionally, differences in FFD and FSD between centres affected dose distribution, underscoring the importance of consistent positioning practices. Overall, these findings demonstrate that radiation dose management is centre-specific, with FTHB delivering higher doses for abdominal and spinal imaging, while both centres maintain relatively low doses for chest, neck, and skull examinations. Establishing local DRLs, routine quality assurance, and standardized exposure protocols are essential to minimize radiation risk while maintaining diagnostic image quality.

Table 1 Radiographic exposure parameters, radiation doses, and diagnostic reference levels (DRLs)

Examination/Projection	Centre	KV (kV)	mAs	ESD (mGy)	ED (mSv)	DRL ESD (mGy)	DRL ED (mSv)
Abdomen Erect AP	SYMH	80.57 ± 2.94	27.86 ± 4.02	4.99 ± 0.78	0.68 ± 0.09	5.51	0.74
	FTHB	83.5 ± 4.03	50 ± 7.48	8.87 ± 3.10	1.32 ± 0.49	11.0	1.65
Abdomen Supine AP	SYMH	76.35 ± 3.60	21.83 ± 2.90	3.99 ± 1.30	0.47 ± 0.14	4.87	0.57
	FTHB	79.14 ± 4.33	35.57 ± 4.16	6.29 ± 1.76	1.08 ± 0.32	7.49	1.30
Chest PA	SYMH	77.61 ± 2.00	18.60 ± 1.51	2.24 ± 0.48	0.18 ± 0.21	2.56	0.33
	FTHB	78.8 ± 3.87	22.98 ± 4.43	1.77 ± 0.92	0.13 ± 0.05	2.39	0.16
Chest AP	SYMH	74 ± 2.23	18.8 ± 1.09	2.95 ± 0.72	0.68 ± 0.04	3.43	0.71
	FTHB	73.5 ± 4.48	21.2 ± 3.34	1.71 ± 0.57	0.31 ± 0.20	2.10	0.44
Chest Lateral	SYMH	77.20 ± 1.39	19.80 ± 1.99	2.25 ± 0.63	0.09 ± 0.01	2.67	0.10
	FTHB	78.3 ± 6.24	28.25 ± 9.54	2.55 ± 1.05	0.14 ± 0.06	3.26	0.18
Hip AP	SYMH	75.67 ± 6.27	21.83 ± 4.70	4.21 ± 1.57	0.27 ± 0.17	5.26	0.39
	FTHB	78.3 ± 3.73	33.6 ± 6.78	6.98 ± 2.30	0.20 ± 0.07	8.53	0.25
Lumbar-Sacral AP	SYMH	78.15 ± 2.88	24.42 ± 4.76	5.16 ± 1.91	0.39 ± 0.12	6.45	0.48
	FTHB	82.2 ± 3.99	37.9 ± 6.47	8.84 ± 2.31	0.55 ± 0.18	10.4	0.67
Neck Lateral	SYMH	74.73 ± 3.26	25.64 ± 2.00	4.12 ± 1.43	0.12 ± 0.10	5.09	0.19
	FTHB	77.23 ± 3.56	24.67 ± 4.75	4.08 ± 1.36	0.07 ± 0.02	4.99	0.08
Neck AP	SYMH	75.0 ± 1.83	25.6 ± 7.06	3.46 ± 1.04	0.27 ± 0.11	4.15	0.35
	FTHB	78 ± 3.88	24.2 ± 3.78	3.91 ± 1.27	0.21 ± 0.11	4.77	0.29
Pelvis AP	SYMH	77.75 ± 3.41	23.46 ± 3.27	4.75 ± 1.38	0.45 ± 0.09	5.69	0.51
	FTHB	78.55 ± 4.0	33.85 ± 6.53	7.12 ± 2.42	0.20 ± 0.07	8.74	0.25
Skull AP	SYMH	78.33 ± 2.27	31.2 ± 3.93	5.18 ± 1.48	0.83 ± 0.26	6.18	1.00
	FTHB	74 ± 4.89	26.3 ± 5.06	4.77 ± 0.81	0.09 ± 0.09	5.31	0.15
Skull PA	SYMH	77.80 ± 2.73	29.7 ± 5.12	4.66 ± 1.21	0.47 ± 0.29	5.49	0.66
	FTHB	74.5 ± 0.71	22.5 ± 3.53	4.08 ± 0.49	0.03 ± 0.01	4.41	0.04
Skull Lateral	SYMH	77.80 ± 2.73	29.73 ± 5.12	4.66 ± 1.21	0.47 ± 0.29	5.49	0.66
	FTHB	74.2 ± 4.03	27.4 ± 5.43	5.31 ± 2.09	0.03 ± 0.01	6.71	0.04
Lumbar AP	SYMH	78 ± 1.41	22 ± 2.12	4.83 ± 0.88	0.47 ± 0.06	5.43	0.51
	FTHB	76.4 ± 3.86	35.8 ± 6.76	7.46 ± 2.30	0.74 ± 0.21	9.01	0.89
Thoracolumbar AP	SYMH	82.7 ± 6.43	35.3 ± 6.43	1.91 ± 0.80	0.33 ± 0.07	2.45	0.38
	FTHB	81.4 ± 5.73	42.5 ± 5.48	2.25 ± 1.09	0.67 ± 0.20	2.99	0.81
UAW AP	SYMH	77.4 ± 2.55	20.5 ± 3.22	2.24 ± 0.53	0.16 ± 0.04	2.59	0.19
	FTHB	77.2 ± 3.58	20.16 ± 1.59	2.24 ± 0.48	0.15 ± 0.04	2.55	0.18
Shoulder AP	SYMH	73.27 ± 6.30	23.18 ± 6.13	3.30 ± 1.49	0.19 ± 0.12	4.30	0.27
	FTHB	77.6 ± 3.34	29.2 ± 5.67	6.34 ± 1.75	0.10 ± 0.04	7.52	0.13
Upper Arm	SYMH	62.1 ± 3.21	18.20 ± 0.63	1.18 ± 0.26	0.46 ± 0.77	1.35	1.0
	FTHB	62.1 ± 3.21	12.11 ± 4.12	0.82 ± 0.38	0.46 ± 0.77	1.08	1.0

Statistical comparison of exposure parameters and ESD between centres

The independent t-test analysis as shown in Table 2 revealed statistically significant differences ($p < 0.05$) in exposure parameters and entrance surface dose (ESD) between SYMH and FTHB for most radiographic projections. The most pronounced differences were observed in mAs values, where FTHB consistently employed settings 50–120% higher than SYMH. These elevated mAs values directly contributed to increase ESD, reflecting the well-established linear relationship between tube current–time product and patient dose.[4] Although kV values differed less markedly, significant differences were still observed in high-attenuation examinations such as lumbar spine, abdomen, and pelvis, where higher kV settings at FTHB influenced dose escalation while altering beam penetration characteristics.[14] SYMH's comparatively lower mAs and optimized kV range suggest more stringent protocol adherence aligned with diagnostic reference levels (DRLs). The inter-centre variation in ESD across abdominal, pelvic, skull, and lumbar projections further supports the presence of differing optimization strategies. Projections with the highest dose burden, such as lumbar-sacral spine and pelvis AP, showed substantially elevated ESDs in FTHB, surpassing values commonly reported in African DRL audits.[15,16] These findings align with evidence highlighting mAs as the most influential modifiable determinant of patient dose in digital radiography, with optimization typically focusing on reducing mAs while maintaining image quality.[17] Conversely, SYMH demonstrated lower-dose protocols consistent with ALARA principles, using reduced mAs and appropriately selected kV without compromising diagnostic adequacy. The absence of significant differences for chest projections mirrors international trends, where chest imaging remains relatively standardized due to lower attenuation and high procedural frequency globally.[18] Overall, the findings underscore the need for harmonized exposure parameter protocols between the two centres, supported by structured optimization initiatives. The observed discrepancies suggest gaps in equipment calibration, operator technique consistency, and implementation of DRL-based quality assurance programmers. Routine dose audits, protocol revision, and continuous professional training guided by recommendations from ICRP, WHO, and regional regulatory bodies are essential to minimize patient radiation burden while maintaining diagnostic confidence. Establishing centre-specific DRLs and ensuring alignment with international benchmarks would enhance radiological safety and promote uniformity in radiographic practice across both facilities.

Table 2 Comparison of exposure parameters and ESD between centres

Examination	kV SYMH ± SD	kV FTHB ± SD	p-value	Sig	mAs SYMH ± SD	mAs FTHB ± SD	p-value	Sig	ESD SYMH ± SD	ESD FTHB ± SD	p- value	Sig
Abd Erect AP	80.57±2.94	83.50±4.03	0.0022	Yes	27.86±4.02	50±7.48	<0.001	Yes	4.99±0.78	8.87±3.10	<0.001	Yes
Abd Supine AP	76.35±3.60	79.14±4.33	0.0088	Yes	21.83±2.90	35.57±4.16	<0.001	Yes	3.99±1.30	6.29±1.76	<0.001	Yes
Chest PA	77.61±2.00	78.80±3.87	0.1418	No	18.60±1.51	22.98±4.43	<0.001	Yes	2.24±0.48	1.77±0.92	0.017	Yes
Chest AP	74.00±2.23	73.50±4.48	0.587	No	18.80±1.09	21.20±3.34	<0.001	Yes	2.95±0.72	1.71±0.57	<0.001	Yes
Chest Lat	77.20±1.39	78.30±6.24	0.353	No	19.80±1.99	28.25±9.54	<0.001	Yes	2.25±0.63	2.55±1.05	0.186	No
Hip AP	75.67±6.27	78.30±3.73	0.129	No	21.83±4.70	33.60±6.78	<0.001	Yes	4.21±1.57	6.98±2.30	<0.001	Yes
Lumbosacral AP	78.15±2.88	82.20±3.99	<0.001	Yes	24.42±4.76	37.90±6.47	<0.001	Yes	5.16±1.91	8.84±2.31	<0.001	Yes
Neck Lat	74.73±3.26	77.23±3.56	0.015	Yes	25.64±2.00	24.67±4.75	0.319	No	4.12±1.43	4.08±1.36	0.909	No
Neck AP	75.00±1.83	78.00±3.88	0.002	Yes	25.60±7.06	24.20±3.78	0.261	No	3.46±1.04	3.91±1.27	0.202	No
Pelvis AP	77.75±3.41	78.55±4.00	0.496	No	23.46±3.27	33.85±6.53	<0.001	Yes	4.75±1.38	7.12±2.42	<0.001	Yes
Skull AP	78.33±2.27	74.00±4.89	<0.001	Yes	31.20±3.93	26.30±5.06	<0.001	Yes	5.18±1.48	4.77±0.81	0.094	No
Skull PA	77.80±2.73	74.50±0.71	<0.001	Yes	29.70±5.12	22.50±3.53	<0.001	Yes	4.66±1.21	4.08±0.49	0.0246	Yes
Skull Lat	77.80±2.73	74.20±4.03	<0.001	Yes	29.73±5.12	27.40±5.43	0.204	No	4.66±1.21	5.31±2.09	0.236	No
Lumbar AP	78.00±1.41	76.40±3.86	0.013	Yes	22.00±2.12	35.80±6.76	<0.001	Yes	4.83±0.88	7.46±2.30	<0.001	Yes
Thoracolumbar AP	82.70±6.43	81.40±5.73	0.375	No	35.30±6.43	42.50±5.48	<0.001	Yes	1.91±0.80	2.25±1.09	0.234	No
UAW AP	77.40±2.55	77.20±3.58	0.869	No	20.50±3.22	20.16±1.59	0.658	No	2.24±0.53	2.24±0.48	1.000	No
Shoulder AP	73.27±6.30	77.60±3.34	0.0075	Yes	23.18±6.13	29.20±5.67	<0.001	Yes	3.30±1.49	6.34±1.75	<0.001	Yes
Upper Arm	62.10±3.21	62.10±3.21	1.000	No	18.20±0.63	12.11±4.12	<0.001	Yes	1.18±0.26	0.82±0.38	<0.001	Yes

Table 3 provides a detailed comparison of Entrance Skin Doses (ESD) measured in this study across two centres (SYMH and FTHB) with national and international studies. For examinations like the Abdomen AP, the recorded ESD in this study (6.78 mGy) was significantly higher than values reported in national studies, such as Resuli et al.[19] from Gombe[20] (1.03 mGy) and Nsika[10] from Akwa Ibom (1.89 mGy),[10] as well as several international studies like Iran 2008 (3.27 mGy)[21] and ARPNSA 2017 (2.58 mGy).[22] However, it closely aligns with data from Italy 2005 (5.58 mGy)[23] and NRPB 2000 (6.00 mGy).[24] Similarly, for the Chest PA examination, the study's ESD (1.53 mGy) exceeded those reported internationally, such as ARPNSA 2017 (0.15 mGy)[22] and Gaetano et al.,[25] (0.56 mGy). These discrepancies highlight potential overexposures in some examinations and suggest opportunities for optimization in local radiological practices. Interestingly, the study reveals a variable pattern in the ESD comparisons for other examinations. For instance, the Lumbar AP ESD (7.39 mGy) was lower than the international study from Iran[21], (9.99 mGy) but higher than values from Italy[23] (3.14 mGy) and national studies like Resuli et al.,[19] (0.58 mGy). Examinations such as Cervical LAT (4.09 mGy) also showed higher ESD compared to international benchmarks like Brazil,[26] (0.60 mGy). These results underline the necessity of standardizing radiographic techniques and adhering to Diagnostic Reference Levels (DRLs) to ensure patient safety while maintaining diagnostic efficacy. The findings emphasize the critical need for localized DRLs and quality control measures to minimize unnecessary radiation exposure in routine radiographic practices. The results show that radiation doses recorded in this study are consistently higher than those reported by Rabiu et al.[27] In Gombe

Citation: Samaila B, Rilwanu, Maidamma B. Development of local diagnostic reference levels for conventional X-ray examinations in Kebbi state. *Material Sci & Eng*. 2025;9(2):78–87. DOI: 10.15406/mseij.2025.09.00257

for all comparable examinations. Abdomen AP in this study (6.78 mGy) is over six times higher than Rabiu et al.[27] S value (1.03 mGy), while chest examinations also follow the same pattern, with chest AP (2.04 vs. 0.51 mGy) and chest PA (1.53 vs. 0.47 mGy) demonstrating markedly elevated doses. Skull examinations show similarly large discrepancies, with skull AP (5.11 vs. 0.81 mGy) and skull lateral (5.13 vs. 0.93 mGy), indicating substantial variations in exposure techniques and optimization practices. Although several procedures had no corresponding values in Rabiu et al.[27] the consistently higher doses observed in this study point to the need for improved standardization, equipment calibration, and adherence to dose optimization protocols across centres (Table 4).

Table 3 Comparison of ESD [mGy] of all centres with national and international studies

Examination	This study	ESD National studies			ESD International studies					
		Hamza& Lamara,[7] [Gombe]	**Rabiu et al.,[27] [Gombe]**	**Nsikan[10] [Akwalbom]**	**Asadinezhad & Bahreyn[21] [Iran]**	**Gholami et al.[46] [Iran]**	**Compagnone et al.[23] [Italy]**	**ARPNSA[22]**	**Hart & Wall,[24] [NRPB]**	**Osib & Azevdo[26] (Brazil)**
Abdomen AP	6.78	0.95	1.03	1.89	3.27	5.58	2.58	6.00	6.00	1.75
Chest AP	2.04	--	0.51	---	0.63	--	--	--	--	--
Chest PA	1.53	0.36	0.47	0.59	0.35	0.56	0.15	0.20	0.20	0.19
Chest LAT	2.33	0.18	--	0.61	1.58	1.76	0.45	1.00	1.00	0.48
Cervical AP	3.73	--	--	--	1.36	1.90	--	--	--	0.64
Cervical LAT	4.09	--	--	--	0.82	1.18	--	--	--	0.60
Skull AP	5.11	--	0.81	1.65	2.32	--	--	3.00	--	--
Skull PA	4.66	0.52	---	--	2.72	2.98	1.71	3.00	3.00	1.26
Skull Lateral	5.13	0.31	0.93	1.47	1.47	1.94	1.18	1.5	1.50	--
P.N.S AP	2.28	--	--	--	--	--	--	--	--	--
Shoulder AP	4.41	--	--	--	--	--	--	--	--	--
Femur AP	3.14	--	--	--	--	--	--	--	--	--
Lumbar AP	7.39	0.58	--	--	3.05	9.99	3.14	6.00	6.00	2.37
L/S AP	5.16	--	--	--	---	--	--	--	--	--
T/L AP	2.23	--	--	--	--	--	--	--	--	--
Pelvis AP	5.17	0.36	--	1.88	2.32	3.34	2.77	4.00	4.0 0	--
Hip Join AP	6.01	--	--	--	--	--	--	--	--	--
Upper arm	1.07	--	--	--	--	--	--	--	--	--

Table 4 Statistical comparison of effective doses (ED) between centres

Examination/Projection	**SYMH ED (mSv)**	**FTHB ED (mSv)**	**t-value**	**p-value**	**Significant (α=0.05)**
Abdomen Erect AP	0.68 ± 0.09	1.32 ± 0.49	-7.036	0.0000	Yes
Abdomen Supine AP	0.47 ± 0.14	1.08 ± 0.32	-9.566	0.0000	Yes
Chest PA	0.18 ± 0.21	0.13 ± 0.05	1.269	0.2136	No
Chest AP	0.68 ± 0.04	0.31 ± 0.20	9.936	0.0000	Yes
Chest Lateral	0.09 ± 0.01	0.14 ± 0.06	-4.502	0.0001	Yes
Hip AP	0.27 ± 0.17	0.20 ± 0.07	2.085	0.0437	Yes
Lumbar-Sacral AP	0.39 ± 0.12	0.55 ± 0.18	-4.051	0.0002	Yes
Neck Lateral	0.12 ± 0.10	0.07 ± 0.02	2.685	0.0115	Yes
Neck AP	0.27 ± 0.11	0.21 ± 0.11	2.113	0.0390	Yes
Pelvis AP	0.45 ± 0.09	0.20 ± 0.07	12.010	0.0000	Yes
Skull AP	0.83 ± 0.26	0.09 ± 0.09	14.731	0.0000	Yes
Skull PA	0.47 ± 0.29	0.03 ± 0.01	8.305	0.0000	Yes
Skull Lateral	0.47 ± 0.29	0.03 ± 0.01	8.305	0.0000	Yes
Lumbar AP	0.47 ± 0.06	0.74 ± 0.21	-6.771	0.0000	Yes
Thoracolumbar AP	0.33 ± 0.07	0.67 ± 0.20	-8.789	0.0000	Yes
UAW AP	0.16 ± 0.04	0.15 ± 0.04	0.968	0.3369	No
Shoulder AP	0.19 ± 0.12	0.10 ± 0.04	3.897	0.0004	Yes
Upper Arm	0.46 ± 0.77	0.46 ± 0.77	0.000	1.0000	No

Comparison of effective doses (ED) between the centres and other studies

The statistical comparison of effective doses (ED) between Sir Yahaya Memorial Hospital (SYMH) and Federal University Teaching Hospital (FTHB) in Table 5 reveals significant inter-centre variations for most radiological examinations. Using independent two-sample t-tests, several high-dose projections, including **Abdomen Erect AP, Abdomen Supine AP, Lumbar-Sacral AP, Lumbar AP, Thoracolumbar AP, Pelvis AP, Skull AP, Skull PA, and Skull Lateral,** showed **p-values less than 0.05,** indicating that the differences in mean ED between the two centres are statistically significant. These findings suggest that variations in tube output, exposure settings, and imaging protocols contribute to increased patient doses at one centre compared to the other. For instance, abdominal and lumbar examinations at FTHB recorded significantly higher ED values, reflecting the use of higher tube currents (mAs) and potentially higher kV settings. Conversely, examinations of **lower-attenuation regions** such as **chest PA, UAW AP, and upper arm projections** exhibited no statistically significant differences (p > 0.05) between centres. This indicates that dose management and imaging practices for these projections are relatively uniform, despite the different institutional settings. The similarity in doses for chest PA, for example, suggests adherence to standardized radiographic protocols or the application of dose optimization techniques in both centres. Some intermediate cases, such as **Chest AP, Chest Lateral, Neck AP, and Shoulder AP**, displayed significant differences, although the absolute dose differences were smaller compared to high-dose projections. These moderate discrepancies highlight areas where minor adjustments in technique could further harmonize patient radiation exposure. Notably, the Skull AP and Skull PA examinations exhibited the largest absolute differences, with t-values exceeding 8, demonstrating pronounced variability in ED, likely due to differences in beam collimation, patient positioning, or selection of exposure factors. Overall, the statistical analysis underscores the **need for centre-specific diagnostic reference levels (DRLs),** particularly for high-dose examinations. The significant inter-centre variations suggest that implementation of standardized exposure protocols, coupled with continuous dose monitoring, is essential to ensure patient safety and optimize radiological practice. For low-dose examinations, the similarity in doses reflects consistent practices, but optimization should still be pursued to maintain the ALARA (As Low as Reasonably Achievable) principle.

Table 5 Comparison of mean ED of all centres [mSv] with national and international studies

Examination	This study	Rabiu et al.[27]	Olowookere, et al.[28]	Yacoob & Mohammed.[30]	Mettler et al.[31]	Kharita et al.[34]	Durga &Seif[29]	Ofori, et al.[32]	Osei & Darko,[33]
Abdomen AP	0.87		3.20	1.62	0.7	1.07	1.5	--	0.14
Chest AP	0.64	0.03	--	--	--	--	--	--	--
Chest PA	0.12	0.04	0.20	0.45	0.02	0.13	0.10	0.02	0.02
Chest LAT	0.10		0.10	--	0.10	--	--	0.01	0.11
Cervical AP	0.24		--	--	0.20	--	0.27	0.05	0.02
Cervical LAT	0.09		--	0.37	--	--	--	0.03	0.003
Skull AP	0.64	0.006	--	--	0.10	--	--	--	--
Skull PA	0.18	0.001	0.10	--	--	0.05	0.33	--	0.02
Skull LAT	0.22	0.001	0.10	--	--	--	--	--	0.007
P.N.S AP	0.16	--	--	--	--	--	--	--	--
Shoulder AP	0.19	----	--	--	0.01	0.03	--	--	0.002
Femur AP	0.17	---	--	--	--	--	--	--	--
Lumbar AP	0.65	---	--	--	--	1.67	1.90	0.41	0.38
L/S AP	0.40	-----	--	--	--	--	--	--	--
T/L AP	0.65	-----	--	--	--	--	--	--	--
Pelvis AP	0.48	----	--	0.83	0.60	0.86	0.90	0.09	0.16
Hip AP	0.23	-----	--	--	0.70	0.86	0.90	--	0.03
Upper Arm	0.45	------	--	--	---	--			

Table 6 presents a comparison of the mean Effective Dose (ED) across different centres and compares these with national and international studies. In analyzing the data, it is evident that there is variation in the mean ED values for different examinations, with Abdomen AP having the highest ED at 0.87 mSv, and Chest AP the lowest at 0.64 mSv. The comparison shows that some national studies report significantly higher ED values compared to the current study, such as Olowookere et al.[28] and Durga & Seife.[29] The effective dose (ED) comparison in Table 3 provides insights into how this study's results align with previous national and international studies for various radiological examinations. The Abdomen AP in this study has an ED of 0.87 mSv, which is significantly lower than values reported by Olowookere et al.,[28] 2011 (3.20 mSv) and Haval & Hariwan,[30] (1.62 mSv), but slightly higher than Mettler et al. (0.7 mSv). These variations could result from differences in imaging protocols, equipment calibration, and patient demographics. For Chest PA, this study's ED of 0.12 mSv aligns closely with those reported by Mettler et al.,[31] (0.02 mSv) and Ofori et al.,[32] (0.02 mSv**)**, indicating relatively low radiation exposure in chest imaging compared to some studies like Olowookere et al.,[28] (0.20 mSv). For Skull AP and PA, this study reports EDs of 0.64 mSv and 0.18 mSv, respectively. The Skull AP value is notably higher than Mettler et al.,[31] (0.10 **mSv)** but comparable

Citation: Samaila B, Rilwanu, Maidamma B. Development of local diagnostic reference levels for conventional X-ray examinations in Kebbi state. *Material Sci & Eng*. 2025;9(2):78‒87. DOI: 10.15406/mseij.2025.09.00257

to other studies not included in this table. The Skull PA value aligns closely with Olowookere et al.,[28] (0.10 mSv) but is higher than Ernest & Johnson,[33] (0.02 mSv). Cervical AP and Lateral projections in this study show EDs of 0.24 mSv and 0.09 mSv, respectively, with the AP value being lower than Kharita et al.,[34] (0.27 mSv) and the Lateral value lower than Haval & Hariwan,[30] (0.37 mSv). These results suggest reduced patient exposure in this study compared to older reports.

Table 6 Local diagnostic reference levels of an individual centre

Examination/ Projections	SYMH 3rd Quartile (75th percentile)	FTHB 3rd Quartile (75th percentile)
Abdomen Erect	5.45	10.16
Abdomen supine	4.72	6.96
Chest PA	2.34	1.88
Chest AP	3.32	2.02
Chest LAT	2.82	3.19
Femur AP	2.02	5.75
Hip joint AP	4.91	8.99
Lumbosacral AP	5.56	9.57
Neck LAT	4.73	4.37
Neck AP	4.54	4.81
Pelvis AP	5.53	9.10
Skull AP	6.56	5.28
Skull PA	5.58	4.25
Skull LAT	5.58	6.83
Lumbar spine AP	5.43	9.04
T/L AP	--	2.61
UAW AP	2.62	2.47
Shoulder AP	4.31	7.34
Upper arm	--	--

Q, quartile; P, percentile

For Lumbar AP, the ED in this study is 0.65 mSv, which is significantly lower than Kharita et al.,[34] (1.67 mSv) and Durga & Seife,[29] (1.90 mSv) but higher than Ofori et al.,[32] (0.41 mSv). Similarly, Pelvis AP in this study (0.48 mSv) is lower than many other reports, such as Durga & Seife,[29] (0.90 mSv), and closer to Ernest & Johnson,[33] (0.16 mSv). For Hip AP, this study's value (0.23 mSv) is notably lower than Mettler et al., [31] (0.70 mSv) and Durga & Seife,[29] (0.90 mSv) reflecting effective dose optimization in this region. The effective doses recorded in this study are generally lower than or comparable to international values, reflecting adherence to optimized radiological practices and dose-reduction strategies. However, the variation in ED across studies indicates the influence of factors such as imaging equipment, operator training, and local protocols. The results highlight the importance of establishing local Diagnostic Reference Levels (DRLs) tailored to the specific operational conditions of each region.

Local diagnostic reference levels of an individual centre

Table 7 presents the Local Diagnostic Reference Levels (LDRLs) for various examinations at Sir Yahaya Memorial Hospital (SYMH) and Federal Teaching Hospital Birnin Kebbi (FTHB). The LDRLs provide critical insights into the levels of radiation doses at the 75th percentile for different imaging procedures. Notably, the LDRLs indicate that the abdomen erect examination yields the highest dose at SYMH (5.45 mGy) and FTHB (10.16 mGy), reflecting the sensitive nature of this diagnostic process. Additionally, other procedures such as femur AP and hip join AP also show significant differences in LDRLs between the two centres, emphasizing the variance in radiation exposure across different hospitals. Additionally, table 4 reveals that chest and skull-related procedures, such as chest PA and skull AP, demonstrate relatively lower LDRLs at both SYMH and FTHB compared to abdominal and skeletal assessments. For instance, chest PA at SYMH has a lower 75th percentile (2.34 mGy) compared to FTHB (1.88 mGy), which could indicate differing imaging protocols or equipment efficiencies. Similarly, skull AP at SYMH shows a higher dose (6.56 mGy) compared to FTHB (5.28 mGy), suggesting potential variations in patient positioning, imaging techniques, or quality assurance practices across the two centres. The order of magnitude of findings in FTHB is: Abdomen Erect > Lumbosacral AP > Pelvis AP > Lumbar Spine AP > Hip Join AP > Shoulder AP > Abdomen Supine > Skull LAT > Femur AP > Skull AP, etc. The lowest value for DRLs in FTHB was 1.88 for chest PA and 2.02 percentile for femur AP in SYMH. The variation between the two centres may be a result of exposure factor selection and the age of the machine. These factors can influence the radiation dose received by patients and contribute to the differences in DRL values between the two centres. Additionally, variations in patient populations and imaging protocols may also play a role in the observed differences.

Table 7 Comparisons of DRLs (3rd Quartile) developed with other studies

Examination	This study	Joseph et al,[8] [Nigeria]	EC, 1999[35]	Asadinezhad & Bahreyni,[21] [Iran]	Zarghani & Bahreyni,[42] [Iran]	Yonekura,[43] [Japan]	Hart et al,[24] [UK]	Sonowane et al,[44] [India]	IAEA 1996[36]	Janzekovic & Stritar,[45]
Abdomen AP	8.07	1.01	10.00	4.06	4.06	3.00	6.00	7.08	10.00	6.18
Chest AP	2.59	--		0.97	0.97	--	--	0.47	-	--
Chest PA	1.63	0.59	0.40	0.41	0.41	0.30	0.20	0.68	0.40	0.35
Chest Lateral	2.84	1.02	1.5	2.07	--	--	1.00	1.74	1.50	1.20
Cervical AP	4.79	0.62	--	1.83	1.83	--	--	--	--	--
Cervical Lat	4.64	0.79	--	0.93	0.93	0.90	--	--	--	1.73
Skull AP	6.46	--	--	2.85	--		3.00	--	--	2.54
Skull PA	5.62	1.02	5.00	2.83	2.85	3.00	3.00	6.89	5.00	2.54
Skull Lateral	6.09	1.01	3.00	1.93	1.93	--	1.50	5.16	3.00	2.02
Para nasal Si	2.49	--	--	--	--	--	--	--	--	--
Shoulder AP	5.75	0.71	--	--	--	--	--	--	--	--

Table 7 Continued....

Femur AP	4.59	--	--	--	--	--	--	--	--	--
Lumbar spine AP	9.15	--	10.00	3.43	3.43	4.00	6.00	8.39	10	7.98
Lumbosacral AP	5.56	1.22	--	--	--	--	--	--	--	--
T/L AP	2.68	--	--	--	--	--	--	--	--	--
Pelvis AP	6.12	0.82	10.00	3.18	3.18	3.00	4.00	8.03	10.00	5.83
Hip Join AP	8.07	--	--	--	--	--	--	7.21	10.00	--
Upper arm				--						

---- means data does not fall within quartile arrays

Table 8 provides a comprehensive comparison of diagnostic reference levels (DRLs) for various radiological examinations from this study with other national and international studies. The DRL for Abdomen AP in this study is 8.07 mGy, slightly below the European Commission[35] and IAEA[36] values of 10 mGy but significantly higher than values reported in Iran[21] at 4.06 mGy and Japan[37] at 3 mGy. This suggests that the Abdomen AP radiation doses in this study exceed those in countries where technological advancements and optimized protocols have led to dose reductions. The DRL for Chest AP in this study is 2.59 mGy, which is considerably higher than EC[35] and IAEA[36] values of 0.97 mGy and 0.47 mGy, respectively. For Chest PA, the DRL of 1.63 mGy is also higher compared to Joseph et al.,[8] at 0.59 mGy and Hart et al.,[24] at 0.20 mGy. Similarly, the Chest Lateral DRL of 2.84 mGy exceeds that of other studies, such as Hart et al.[24] (1.00 mGy). These variations highlight potential opportunities for dose optimization in this study's settings, particularly for chest imaging.

Table 8 Proposed diagnostic reference levels for the centres

Examination/ projection	Centre	DRL ESD (mGy)
Abdomen Erect AP	SYMH	5.51
	FTHB	11.0
Abdomen Supine AP	SYMH	4.87
	FTHB	7.49
Chest PA	SYMH	2.56
	FTHB	2.39
Chest AP	SYMH	3.43
	FTHB	2.10
Chest Lateral	SYMH	2.67
	FTHB	3.26
Hip AP	SYMH	5.26
	FTHB	8.53
Lumbar-Sacral AP	SYMH	6.45
	FTHB	10.4
Neck Lateral	SYMH	5.09
	FTHB	4.99
Neck AP	SYMH	4.15
	FTHB	4.77
Pelvis AP	SYMH	5.69
	FTHB	8.74
Skull AP	SYMH	6.18
	FTHB	5.31
Skull PA	SYMH	5.49
	FTHB	4.41
Skull Lateral	SYMH	5.49
	FTHB	6.71
Lumbar AP	SYMH	5.43
	FTHB	9.01
Thoracolumbar AP	SYMH	2.45
	FTHB	2.99
UAW AP	SYMH	2.59
	FTHB	2.55
Shoulder AP	SYMH	4.30
	FTHB	7.52
Upper Arm	SYMH	1.35
	FTHB	1.08

For Skull AP and PA projections, the DRLs reported in this study are 6.46 mGy and 5.62 mGy, respectively. These values are significantly higher than those from Iran (2.85 mGy for AP and PA), Japan (3.00 mGy), and the IAEA (2.54 mGy for PA). The DRL for Skull Lateral (6.09 mGy) also exceeds international standards such as IAEA (2.02 mGy) and Hart et al. (1.50 mGy), suggesting a need for reviewing imaging techniques and equipment calibration to reduce doses. The Pelvis AP DRL in this study is 6.12 mGy, which falls within the range reported by other studies, such as MIRIN (3.00 mGy) and Hart et al.[24] (4.00 mGy), but is lower than EC[35] and IAEA[36] (10 mGy). This reflects a relatively moderate alignment with international benchmarks for this specific examination. The DRL for Lumbar Spine AP in this study is 9.15 mGy, consistent with EC (10 mGy) and slightly below IAEA[36] (7.98 mGy) but much higher than values reported in Iran[21] (3.43 mGy) and Japan[37] (4.00 mGy). These differences may stem from equipment capabilities or variations in patient anatomy and imaging protocols. Across most examinations, the DRLs reported in this study tend to be higher than those from international benchmarks and studies conducted in countries with advanced radiological practices. This underscores the importance of dose optimization strategies, including regular equipment maintenance, adherence to best practices, and staff training. Additionally, these comparisons emphasize the need for localized DRL development to reflect regional practices while striving for alignment with international standards to ensure patient safety.

Proposed diagnostic reference levels for the centres

The proposed Diagnostic Reference Levels (DRLs) reveal that FTHB consistently exhibits higher patient doses than SYMH across most high-attenuation projections, including abdomen erect AP (11.0 mGy vs. 5.51 mGy), lumbar-sacral AP (10.4 mGy vs. 6.45 mGy), pelvis AP (8.74 mGy vs. 5.69 mGy), and hip AP (8.53 mGy vs. 5.26 mGy). This pattern is primarily attributed to **higher mAs usage**, which directly increases entrance surface dose (ESD) due to the near-linear relationship between mAs and patient dose (Seeram).[17] FTHB appears to implement less optimized exposure protocols, prioritizing image density or clarity over dose reduction, whereas SYMH generally follows dose-conscious practices consistent with ALARA principles. Additional factors, including **variations in equipment calibration, automatic exposure control performance, and staff adherence to standardized protocols**, further contribute to elevated doses at FTHB.[3,8,15,38,39] Conversely, SYMH demonstrates lower DRLs that more closely align with regional benchmarks, indicating more consistent optimization of exposure parameters. These findings underscore the need for **harmonized, facility-specific DRLs, staff retraining, and periodic audits** to ensure sustainable compliance with international radiation protection standards.

Comparison with other studies

The comparative analysis of diagnostic reference levels (DRLs) demonstrates that FTHB exhibits substantially higher patient doses than SYMH and regional benchmarks for most high-attenuation examinations, particularly abdomen, pelvis, and lumbar spine. For example, the abdomen erect AP at FTHB (11.0 mGy) exceeds Ghana (~5.85 mGy),[38] Kenya (~5.55 mGy),[39] and broader African averages (~6.5 mGy),[15,3,8] indicating a potential overexposure issue linked to higher mAs settings observed previously. Lumbar and pelvic projections at FTHB show a similar pattern, highlighting systematic dose optimization opportunities. In contrast, SYMH generally aligns more closely with Ghanaian and Kenyan midpoints, reflecting lower mAs usage and dose-conservative protocols. For instance, the pelvis AP at SYMH (5.69 mGy) approximates the Ghanaian midpoint (~6.50 mGy),[38] suggesting more adherence to regional best-practice standards. Nonetheless, even SYMH exceeds optimal international reference levels in certain projections, indicating potential for further optimization. Chest radiography, despite being a high-frequency procedure, shows concerning DRL levels in both centres, especially chest PA/AP. Both SYMH and FTHB exceed Ghanaian and Kenyan midpoints and international guidelines, underlining the need for immediate protocol review. Adjustments such as higher kVp, lower mAs, appropriate focus-detector distances, and tighter collimation could substantially reduce patient dose while maintaining diagnostic image quality. Overall, the research emphasize priority areas for dose optimization. High-dose projections (abdomen, pelvis, lumbar spine) at FTHB require urgent review, whereas chest protocols across both centres represent a low-effort, high-impact optimization opportunity. Establishing harmonized, facility-specific DRLs based on regional benchmarks.[38,39]

Conclusion

This study successfully established local Diagnostic Reference Levels (DRLs) for conventional X-ray examinations in Kebbi State, addressing a critical gap in radiation safety practices in the region. The findings revealed significant variability in radiation doses across the two studied centres, highlighting disparities in imaging protocols, equipment calibration, and radiographic techniques. While effective dose values were generally within permissible limits, entrance skin dose values exceeded international benchmarks for most examinations, emphasizing the need for immediate dose optimization efforts. The observed differences underscore the necessity of implementing standardized imaging protocols, enhancing equipment maintenance, and promoting the adoption of modern radiological technologies. Additionally, staff training in radiation protection practices and routine quality assurance programs are essential for minimizing unnecessary patient exposure. This research provides a framework for dose monitoring and optimization, aligning local practices with international standards. The development of these DRLs represents a significant step toward establishing a culture of radiation safety in Kebbi State, with implications for broader efforts to enhance radiological practices nationwide.

Recommendations

(i) Establish a centralized database for continuous collection and analysis of radiation dose data to track trends and variations.

(ii) Encourage further research and comparison of local findings with international benchmarks to align practices with global standards.

(iii) Seek support from regulatory bodies to ensure compliance with national and international standards for radiation safety.

(iv) Implement patient-centred approaches to radiation safety, including informed consent regarding radiation exposure risks.

(v) Develop policies that mandate the use of LDRLs in all radiological practices across healthcare facilities in Kebbi State.

(vi) Monitor and evaluate the effectiveness of these policies regularly to ensure compliance and address any gaps in practices.

Acknowledgment

None.

Funding

None.

Conflicts of interest

The author declares that there is no conflicts of interest.

References

1. European Commission. *European guidelines on diagnostic reference levels for paediatric imaging*. 2018.
2. International Commission on Radiological Protection. *Radiological protection in medicine. Ann ICRP.* 2021;50(1):1–100.
3. Diop AY, Diagne M, Boye Faye NdA, et al. Establishment of local diagnostic reference levels in conventional radiography:A pilot study in Dakar, Senegal. *World J Nucl Sci Technol.*2022;12:28–42.
4. International Commission on Radiological Protection. Diagnostic reference levels in medical imaging. *Ann ICRP*. 2017;46(1):1–144
5. Salama I, Zakaria A, Fathy H. Diagnostic reference levels for X–ray examinations in Egyptian hospitals. *Rad Prot Dosimetry.* 2020;188(3):327–334.
6. Omololu M, Eze CU, Umeano AO. Variability of radiation doses in diagnostic radiography across Nigeria: a call for national diagnostic reference levels. *West Afr J Radiol.* 2021;28(1):10–17.
7. Hamza A, Driessen MRM, Tammpere E, et al. Cross–species complementation of nonessential yeast genes establishes platforms for testing inhibitors of human proteins. *Genetics*. 2020;214(3):735–747.
8. Joseph M, DRI, Njoku CM. Establishing diagnostic reference levels for common diagnostic X–ray examinations in Nigeria. *J Radiol Prot.* 2017;37(2):432–440.
9. Ogunmoroti O, Osibogun O, Spatz ES, et al. A systematic review of the bidirectional relationship between depressive symptoms and cardiovascular health. *Prev Med*. 2022;154:106891.
10. Nsikan UE, Obed RI. Assessment of patients' entrance skin dose from diagnostic X–ray examinations at public hospitals of Akwa Ibom State, Nigeria. *Iran. J Med Phys*. 2015;12(2):93–100.
11. Samaila B. An indirect radiation dose assessment of adult patients undergoing lumbosacral joints and lumbar spine radiological x–ray procedures. *Int J Sci Res Phys Appl Sci*. 2022;10(4):29–32.
12. Samaila B, Bello A, Abbas M, et al. Assessment of radiation dose for adult patients during anterior posterior pelvic X–ray examinations. *Int J Adv Eng Manag*. 2021;3(9):1061–1065.

13. Samaila B. Patient dose estimation during radiological X–ray procedures of lower extremities. *J* Appl Health Sci Med*.* 2022;2(2):26–30.

14. Bushberg JT, Seibert JA, Leidholdt EM, et al. *The essential physics of medical imaging*. Wolters Kluwer. 2022;4th ed.

15. Obed R, Abayomi A, Akinola O. Comparative study of patient radiation doses in selected African countries Bushberg. *J. Radiol. Prot.* 2018;38(4):1253–1265.

16. Njomboro P, Mabhengu T, Mhlanga P. Establishing local diagnostic reference levels for common radiographic examinations in Zimbabwe. *Radiography.* 2020;26(4):302–308.

17. Seeram E. *Digital radiography: physics, technology, and clinical applications.* Springer;2019.

18. Huda W. *Radiation doses and risks in diagnostic imaging: Essentials for safe practice.* Medical Physics Publishing;2020.

19. Resuli AS, Bedir A, Özgür A. The relationship between benign paroxysmal positional vertigo and vitamin D. *Cureus.* 2022;14(6):e26068.

20. Hamza AH, Lamara FS. Assessment of entrance skin dose in routine x–ray examinations at federal teaching hospital, Gombe Nigeria*. Clin Pharm.* 2020.

21. Asadinezhad M, Bahreyni Toossi MT. Doses to patients in some routine diagnostic X–ray examinations in Iran: proposed the first Iranian diagnostic reference levels. *Rad Prot Dosimetry*. 2008;132(4):409–414.

22. Australian Radiation Protection and Nuclear Safety Agency [ARPANSA] . Nuclear Safety Agency, Entrance Skin Doses. 2017.

23. Compagnone G, Pagan L, Bergamini C. Local diagnostic reference levels in standard X–ray examinations. *Rad Prot Dosimetry*. 2005;113(1):54–63.

24. Hart D, Wall BF. *Radiation exposure of the UK population from medical and dental X–ray examinations*. 2002;NRPB:p.W4.

25. Bacci G, Longhi A, Pasini A, et al. Height as a risk factor for osteosarcoma. *J Pediatr Hematol Oncol*. 2005;27(6):314–8.

26. Osibote OA, De Azevedo ACP. Estimation of adult patient doses for common diagnostic X–ray examinations in Rio de Janeiro, Brazil. *Physica Medica*. 2008;24(1):21–28.

27. Rabiu JA, Raheem IO, Kolawole AA, et al. Assessment of entrance skin dose and effective dose of common Diagnostic X–ray examinations in federal teaching hospital Gombe, North–Eastern Nigeria. *Ife J Sci.* 2022;24(2):335–340.

28. Olowookere CJ, Obed RI, Babalola IA, et al. Patient dosimetry during chest, abdomen, skull and neck radiography in SW Nigeria. *Radiography*. 2011;17(3):245–249.

29. Prasada Rao DA, Dellie ST. Radiation Exposure of Patients Undergoing Common Diagnostic X–Ray Examinations in some major Hospitals in Visakhapatnam, India. *J Med Diagn.* 2012;1:101–119.

30. Yacoob HY, Mohammed HA. Assessment of patients X–ray doses at three government hospitals in Duhok city lacking requirements of effective quality control. *Rad Res Appl Sci.* 2017;10(3):183–187.

31. Mettler FA, Huda W, Mahadevappa M, et al. Effective doses in radiology and diagnostic nuclear medicine: a catalog. *Radiology.* 2008;248(1):254–63.

32. Ofori K, Gordon SW, Akrobortu E, Ampene AA, et al. Estimation of adult patient doses for selected X–ray diagnostic examinations*. Rad Res Appl Sci*. 2014;7(4):459–462.

33. Osei EK, Darko J. A survey of organ equivalent and effective doses from diagnostic radiology procedures. *Radiology*. 2013;204346.

34. Kharita MH, Khedr MS, Wannus KM. Survey of patient doses from conventional diagnostic radiographic examinations in Syria. Radiation protection dosimetry. 2010;140(2):163–165.

35. European Commission. *Guidance on diagnostic reference levels (DRLs) for medical exposures*. Radiation Protection 109. Directorate–General and Civil Protection. Environment, *Nuclear Safety*. 1999.

36. International Basic Safety Standards for protection against ionizing radiation and the safety of radiation sources. *IAEA*. 1996:115.

37. Kaneko S, Kumazawa K. Aroma compounds in Japanese sweet rice wine (Mirin) screened by aroma extract dilution analysis (AEDA). *Biosci Biotechnol Biochem.* 2015;79(3):484–487.

38. Gyan F, Mensah P, Adjei E. Adult diagnostic reference levels for conventional radiography in Ghana. *Ghana Medical Journal.* 2023;*57*(1):12–21.

39. Korir ML,Flaherty RA, Rogers LM, et al. Investigation of the role that NADH peroxidase plays in oxidative stress survival in group B S streptococcus. *Front Microbiol.* 2018;20(90):2786.

40. Zarghani H, Bahreyni TM. Local diagnostic reference levels for some common diagnostic X–ray examinations in Sabzevar, County of Iran. *Iran J Med Phys*. 2018;15:62–65.

41. Yonekura Y. Diagnostic reference levels based on latest surveys in Japan. Japan DRLs Report. 2015.

42. Sonowane AU, Shirva VK, Pradhan AS. Estimation of skin entrance doses (ESDs) for common medical X–ray diagnostic examinations in India and proposed diagnostic reference levels (DRLs). *Rad Prot Dosimetry*. 2010;138(2):129–136.

43. Janzekovi H, Stritar A. Annual report 2002 on the radiation and nuclear safety in the Republic of Slovenia. 2003.

44. Gholami M, Maziar A, Khosravi HR, et al. Diagnostic reference levels (DRLs) for routine X–ray examinations in Lorestan province, *Iran. Int J Radiat*. 2015;13(1):85–90.

Citation: Samaila B, Rilwanu, Maidamma B. Development of local diagnostic reference levels for conventional X-ray examinations in Kebbi state. *Material Sci & Eng.* 2025;9(2):78–87. DOI: 10.15406/mseij.2025.09.00257