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Establishing Local Diagnostic Reference Levels for Common X-ray Examinations at the Federal Neuro-Psychiatric Hospital Maiduguri, Nigeria

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Abstract: Medical exposure in Nigeria is increasing due to the rise in the number of radiological centers and the use of X-rays for diagnostic and therapeutic purposes. In Maiduguri, Borno State, the number of patients undergoing diagnostic X-ray examinations is particularly high due to injuries from road traffic accidents, building collapses, and battlefield incidents caused by insurgency. These factors pose a significant risk of ionizing radiation to patients. Ensuring patient safety and optimizing doses without compromising diagnostic information necessitates establishing local diagnostic reference levels (LDRLs) to adhere to the ALARA (As Low As Reasonably Achievable) principle. This study determined the entrance surface dose (ESD) of patients at the Federal Neuro-Psychiatric Hospital Maiduguri using the indirect method. A total of 392 adult patients, randomly selected, were assessed: 100 patients each for skull, chest, and pelvis examinations, and 92 patients for abdominal radiological examinations. Demographic information such as sex, weight, age, organ thickness, and exposure parameters (tube voltage (kVp), tube current time product (mAs), focus to skin distance (FSD), and backscatter factor (BSF)) was recorded, and used to estimate the ESDs and establish LDRLs. The results indicate that the local diagnostic reference levels are 3.7 mGy for skull AP/PA, 0.3 mGy for chest PA, 5.4 mGy for abdomen AP, and 3.6 mGy for pelvis. When compared with national and international values, the 75th percentile of the results was comparable with national studies and similar studies but slightly higher than international values. This discrepancy highlights the need for practice optimization to reduce radiation doses in common X-ray radiography, thereby minimizing stochastic effects.

Keywords: Ionizing Radiation, X-rays, Entrance Surface Dose, Radiography.

1 Introduction

Ionizing radiation has been utilized for decades in healthcare services for medical imaging and therapy in Maiduguri, Borno State, Nigeria. This widespread use necessitates enhanced monitoring of ionizing and non-ionizing radiation applications to ensure the safety of patients, medical personnel, and the general public from the harmful effects of high radiation levels. The Nigerian Nuclear Regulatory Authority (NNRA) was established by an act in 1995 [1] with a mission of radiological protection, nuclear safety, and compliance with international best practices. To ensure patient safety during X-ray examinations and to monitor practice for radiation levels beyond permissible limits, the NNRA recommends continuous dose measurements of patients [2].

Optimizing patient protection and setting standards for good practice worldwide require accurate knowledge of the entrance surface dose (ESD) of patients undergoing X-ray examinations, which is critical for quality control and assurance in radiological procedures. Due to wide variations in patient dose levels for the same examination, the International Commission on Radiological Protection (ICRP) first conceptualized Diagnostic Reference Levels (DRLs) in 1996. DRLs serve as a simple test for detecting and identifying abnormally high dose levels by setting an upper threshold. When this threshold is exceeded, the imaging technique must be optimized to reduce radiation exposure to patients. The 75th percentile, or third quartile, of dose distributions for each examination type is typically used as the acceptable yardstick for DRLs. Due to variations in equipment, population, and region-specific training of radiographers, the use of local and regional DRLs is advised [3].

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To adhere to the "As Low As Reasonably Achievable" (ALARA) principle, the ICRP recommends dose optimization as a radiation protection guideline. DRLs are used to optimize patient radiation protection for both interventional and diagnostic procedures and are particularly useful for frequently performed radiography such as head, chest, abdomen, and pelvis X-ray examinations [4,5].

2 Materials and methods

2.1 Study Area

This prospective research was carried out at the Federal Neuro-Psychiatric Hospital (FNPH) Maiduguri, Borno State, from February 2nd to December 23rd, 2022. Patient anthropometric data such as height, weight, sex, and age were obtained at the time of examination and recorded. Corresponding exposure parameters such as tube potential (*kVp*), focus to skin distance (*FSD*), tube current time product (*mAs*), filtration of the machine (inherent and added), thickness of the irradiated part of the patient's body, and exposure projections (*AP*, *PA*) were also recorded during routine examinations.

2.2 Ethical Clearance

Ethical approval for the study was obtained from the ethical board of the hospital and oral consent was obtained from all subjects recruited into the study. After collecting all the readings of exposure parameters and demographic information of patients, the obtained values were computed using the equation applied by Tung and Tsai (2014) to determine the entrance surface dose (ESD) [6]:

$$ESD\ (mGy) = OP \times \left(\frac{kVp}{80}\right)^2 \times \left(\frac{100}{FSD}\right)^2 \times mAs \times BSF \quad (1)$$

where *OP* is tube output, *Kvp* is peak tube voltage applied, *FSD* is focused to skin distance (*cm*) (distance between the X-ray tube and patient skin), *mAs* is exposure current and time product and BSF is back scatter factor. The data obtained was analyzed using Microsoft Excel 2019.

The diagnostic reference level (DRL), which represents the 3rd quartile or 75th percentile of the ESD distribution values, was obtained by arranging the values in ascending order and applying the following equation:

$$Q_3 = 3 \times \frac{(N+1)}{4} \quad (2)$$

where Q_3 is the 3rd quartile or 75th percentile of the ESD distribution, and *N* is the number of terms in the ESD distribution.

2.3 Statistical Analysis

The results were analyzed by analysis of variance (ANOVA) at $P \leq 0.05$ using the SPSS statistical package.

2.4 Sample Size

The research assessed a total of 392 adult patients, comprising 100 patients for each organ (skull, chest, and pelvis) and 92 abdominal radiological examinations. Table 1 and Table 2 present the results obtained, including the gender distribution of the research participants, mean entrance surface dose (ESDs), and projections used in the study. The study group consisted of 205 (52%) males and 187 (48%) females. Table 3 illustrates the mean, minimum, and maximum ESDs, as well as the 25th and 75th percentiles.

Table 4 presents the Diagnostic Reference Levels (DRLs) for head, chest, abdomen, and pelvic radiographic examinations in the study. Our results were compared with DRLs reported by the National Radiological Protection Board (NRPB) for the UK in 2000, the European Commission, as well as National Diagnostic Reference Levels (NDRLs) obtained in other similar research studies by Joseph et al. (2017) in Nigeria and Zarghani *et al*. (2018) in Iran [7,8].

Table 1: Shows Gender Distribution of the Research Participants.

Sex	Frequency	Percentage (%)
Male	205	52
Female	187	48
Total	392	100

Table 2: Mean Entrance Surface Dose (ESDs) obtained.

Radiograph	Projections	Mean ESD (*mGy*)
Head	AP/PA	3.5
Chest	PA	0.3
Abdomen	AP	4.9
Pelvis	AP	3.5

Table 3: Local Diagnostic Reference Level.

Radiograph	Projection	Mean ESD (mGy)	1st quartile (mGy)	3rd quartile (mGy)
Head	AP/PA	4.5	4.3	3.7
Chest	PA	0.3	0.3	0.3
Abdomen	AP	4.9	5.2	5.4
Pelvis	AP	3.5	3.2	3.6

Table 4: Comparison of LDRLs for radiographic examination in this work with European Commission, United Kingdom, NRPB, and other similar Studies.

Examination	Zarghani *et al.*, 2018 [7]	Joseph *et al.*, 2017 [8]	EU DRL (mGY)	UK DRL (mGY)	NRPB DRL (mGY)	Present Study
Head	1.22	1.02	0.7	1.8	3.0	3.7
Chest	0.54	0.59	0.3	0.2	0.2	0.3
Abdomen	2.15	1.01	3.0	4.4	6.0	5.4
Pelvis	1.47	0.82	4.0	4.0	4.0	3.6

3 Results and Discussion

The results reveal that the 3rd quartile of the measured ESDs for chest, abdomen, and pelvic radiography in our study are in line with other results presented in other studies and previously established DRLs. However, it was found that the 3rd quartile of the measured ESD for head AP/PA radiography is slightly higher than those reported in other studies. This indicates that the Local Diagnostic Reference Levels (LDRLs) obtained in our study for chest, abdomen, and pelvis examinations did not exceed the DRL values reported in other studies and internationally recommended values. Conversely, slightly higher values were obtained for the head AP/PA examination. It appears that the reasons for the discrepancy may be due to differences in patient exposure parameters and techniques used in our study compared to those in Western countries.

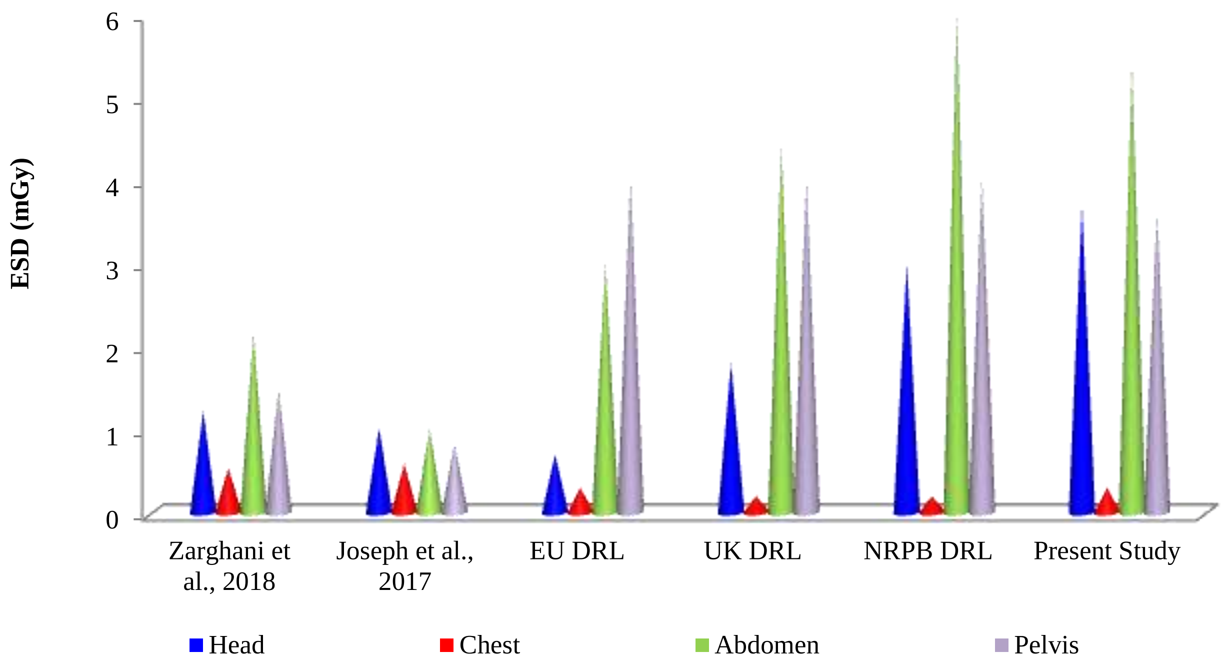

Fig.1: Comparison of LDRLs for radiographic examination in this work with European Commission, United Kingdom, NRPB, and other similar Studies

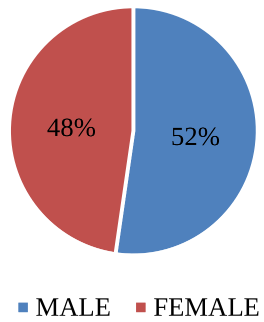

Fig. 2: Gender Distribution of the Research Participants.

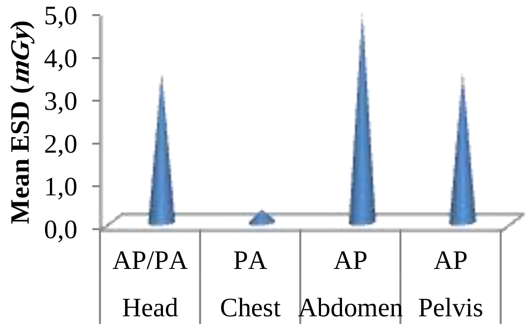

Fig. 3: Mean Entrance Surface Dose (ESDs) obtained.

As an initial step towards optimizing diagnostic radiography and ensuring patient safety, the International Commission on Radiological Protection (ICRP) has recommended the utilization of Diagnostic Reference Levels (DRLs) in its publications (ICRP, 1996). DRLs represent values derived from population dose surveys, indicating the third quartile in the range of observed doses. The guidance dose level corresponds to the 75th percentile, signifying that 75% of individuals receive doses below this value. This suggests that dose reduction is feasible for the 25% of individuals whose doses exceed the guidance value [9].

Diagnostic reference levels serve as “trigger levels” to instigate quality improvement initiatives. The following parameters are commonly adopted for establishing DRLs: entrance surface dose (ESD) and dose-area product (DAP) for radiography and fluoroscopy, and Weighted Computed Tomography Dose Index (CTDIw) per slice for CT scans. In our study, the 75th percentile of the entrance surface dose was used as the local diagnostic reference level (LDRL). These LDRLs for routine head, chest, abdomen, and pelvis diagnostic X-ray examinations were determined as follows: 3.7 *mGy*, 0.3 *mGy*, 5.4 *mGy*, and 3.6 *mGy*, respectively. These values were comparable with national and other similar studies but were slightly higher than international values.

It’s important to note that the 75th percentile dose values reported in our study are not threshold doses or penalizing limits. Instead, they serve as benchmarks for the study center to compare their dose values with national and international standards. Such comparisons can enable the identification of outliers in dose values, uncover other contributing factors, and trigger optimization strategies [10-12]. By continually assessing and optimizing radiographic practices based on these reference levels, healthcare facilities can enhance patient safety and minimize radiation exposure.

4 Conclusions

The research findings indicate that the 3rd quartile, or local diagnostic reference levels (LDRLs), for head AP/PA, chest PA, abdomen AP, and pelvis AP examinations align with national and other similar research studies. However, these LDRLs are slightly higher than the international reference guidance values. This suggests the necessity for optimization of practice to reduce radiation doses for patients undergoing common X-ray radiography in all projections, thereby minimizing stochastic effects. By optimizing radiographic practices and adhering to established diagnostic reference levels, healthcare facilities can enhance patient safety and mitigate the risks associated with ionizing radiation exposure. Continuous monitoring and evaluation of dose values, along with implementation of optimization strategies, are crucial steps towards ensuring the highest standards of radiological safety for patients and healthcare professionals alike.

5 Recommendations

Based on the findings of the research, it is recommended to develop local optimization protocols tailored to the specific patient population and equipment characteristics of the healthcare facility, aiming to reduce radiation doses while maintaining diagnostic quality. Implementing a robust system for monitoring patient radiation doses during X-ray examinations and conducting regular quality assurance assessments will ensure compliance with established diagnostic reference levels and optimization protocols. Providing ongoing education and training for radiographers and healthcare professionals involved in radiographic procedures is crucial, emphasizing the importance of dose optimization techniques and adherence to established protocols. Investing in modern radiographic equipment with advanced dose-reduction features, and ensuring regular maintenance and calibration, is essential to optimize performance and minimize radiation exposure. Educating patients about the risks and benefits of X-ray examinations, encouraging shared decision-making, and obtaining informed consent for procedures while emphasizing efforts to minimize radiation exposure is imperative. Working closely with regulatory authorities, such as the Nigerian Nuclear Regulatory Authority (NNRA), to ensure compliance with national and international radiation safety standards is vital. Encouraging further research and development initiatives aimed at optimizing radiographic practices and reducing radiation doses, as well as fostering a culture of continuous improvement within the healthcare facility through regular reviews of practices and dose monitoring data, will contribute to enhanced radiological safety practices, minimize radiation exposure for patients, and improved overall healthcare quality in Maiduguri and beyond.

Conflict of interest

The authors declare that they have no conflict of interest.

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