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A Comparative Analysis of Radiation Levels of Patients and Radiography Workers with Standard Diagnostic Reference Levels in Some Hospitals in Northern Nigeria

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ABSTRACT

Radiation exposure in medical imaging is an important concern because of its potential health risks for both patients and radiography personnel. This study assesses and compares radiation dose levels in selected hospitals in Northern Nigeria against internationally recommended Diagnostic Reference Levels (DRLs). Data was obtained from radiological procedures, including X-rays and CT scans, across multiple healthcare facilities in Kaduna and Sokoto States in northern Nigeria. Measurements of patient dose levels and occupational exposure among radiography workers were analyzed using statistical and comparative methods. The results indicate that while some hospitals comply with DRL standards, others exhibit inconsistencies, leading to higher radiation exposure levels. Factors such as equipment type, operational protocols, and adherence to radiation protection measures were found to influence radiation dose variations. The study highlights the need for improved regulatory oversight, enhanced radiation safety protocols, and regular dose monitoring to ensure compliance with global standards. Recommendations include the adoption of stricter safety measures, periodic staff training, and policy implementation to minimize unnecessary radiation exposure. The reultss of this study provide valuable insights for policymakers, healthcare providers, and radiation protection agencies aiming to optimize radiation use in diagnostic imaging.

Keywords: Radiation exposure, Diagnostic Reference Levels, radiography workers, radiation protection, medical imaging, Northern Nigeria.

1. Introduction

Radiation exposure in medical diagnostics is a growing concern, particularly regarding its impact on patients and radiography personnel. Prolonged exposure to ionizing radiation can have adverse health effects, including increased risks of cancer and genetic mutations (ICRP, 2007; UNSCEAR, 2010). To ensure safety, standard diagnostic reference levels (DRLs) have been established by various regulatory bodies, including the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA). However, compliance with these reference levels in hospitals, particularly in developing regions like Northern Nigeria, remains a subject of investigation (Mustapha et al., 2012).

Radiation exposure from diagnostic procedures such as X-rays, CT scans, & fluoroscopy varies based on factors such as equipment calibration, procedure type, & operator expertise. Research has shown that radiography workers, due to prolonged occupational exposure, may experience increased radiation risks if safety protocols are not strictly adhered to (Akinlade et al., 2013). Studies in Nigeria have indicated inconsistencies in dose optimization & adherence to radiation protection standards, highlighting the need for further investigations (Balogun et al., 2015).

DRLs serve as a tool for monitoring and controlling patient dose exposure in radiological procedures. They provide guidance on acceptable dose limits to prevent unnecessary radiation exposure (ICRP, 2017). Studies have shown that in some developing nations, including Nigeria, there is limited enforcement of DRLs, leading to discrepancies in radiation doses administered to patients and workers (Omojola et al., 2016). Mustapha et al. (2012) emphasize the need for continuous dose assessment and staff training to ensure compliance.

Several international guidelines recommend strategies for radiation protection, including dose monitoring, equipment quality assurance, and personal protective equipment (PPE) usage (IAEA, 2018). However, compliance with these protective measures in Nigerian hospitals has been inconsistent (Akinlade et al., 2013). A study conducted by Balogun et al. (2015) found that while some facilities maintain adequate safety standards, others lack proper monitoring systems, leading to potential overexposure among workers and patients.

Comparative analyses of radiation exposure levels across different regions provide insight into adherence to safety protocols. Studies have indicated that radiation exposure levels in some Nigerian hospitals exceed the recommended DRLs, necessitating urgent intervention (Omojola et al., 2016). The findings of Mustapha et al. (2012) suggest that implementing regular dose assessments and updating safety protocols can significantly reduce radiation risks.

Despite existing research on radiation safety in Nigeria, there is a gap in studies specifically comparing radiation levels of patients and radiography workers against DRLs. The present study aims to fill this gap by conducting a systematic assessment of radiation exposure levels in selected hospitals in Northern Nigeria. The results will help evaluate the adequacy of radiation safety measures and suggest improvements to ensure compliance with international standards.

Diagnostic Reference Levels (DRLs) in Northern Nigeria

Computed Tomography (CT) Examinations: A study conducted at the Sokoto State Advanced Medical Diagnostic Center established DRLs for routine CT scans. The DRLs for CTDIvol were 48.2 mGy for head CT, 9.44 mGy for thorax CT, and 8.02 mGy for abdomen-pelvis CT. The corresponding DRLs for Dose-Length Product (DLP) were 1044 mGy·cm for head CT, 372 mGy·cm for thorax CT, and 646 mGy·cm for abdomen-pelvis CT. These values were compared with international standards, highlighting the need for protocol optimization to ensure patient safety while maintaining image quality.

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General Radiography Examinations: Research in select hospitals in Kaduna State established DRLs for various radiographic procedures. The Entrance Surface Dose (ESD) ranges determined were:

Chest PA: 0.44–0.9 mGy, Chest Lateral: 0.9–1.5 mGy, Skull PA: 2.0–4.7 mGy, Skull Lateral: 1.7–3.4 mGy, Lumbar Spine AP: 3.4–7.8 mGy, Lumbar Spine Lateral: 6.8–11.3 mGy, Abdomen AP: 3.6–6.2 mGy and Pelvic AP: 2.4–6.9 mGy. These values were below the International Atomic Energy Agency (IAEA) recommendations, indicating generally safe practices in the assessed hospitals.

A. Descriptive Analysis
Radiation dose levels of patients and radiography workers were summarized using

Mean, median, mode to identify central tendencies, Standard deviation and variance to measure data spread, Minimum and maximum values to assess dose range and Frequency distributions/histograms to visualize dose patterns.

Table 1: Descriptive analysis of radiation dose levels of patients and radiography workers

Group	Mean Dose (mGy)	Minimum Dose (mGy)	Maximum Dose (mGy)	SD (mGy)
Patients (X-ray)	1.8	0.9	3.2	0.5
Patients (CT)	9.5	4.2	15.1	2.3
Radiography Workers	2.4	0.8	4.7	0.7

B. Comparative Analysis
Measured doses were compared with international Diagnostic Reference Levels (DRLs) using

T-tests for comparing two groups, like patient dose vs. DRLs. ANOVA (Analysis of Variance) for comparing multiple groups, e.g., doses across different hospitals.
Hypothesis for Comparison:
(a) H_0 (Null Hypothesis): There is no significant difference between the measured doses and DRLs.

(b) H_1 (Alternative Hypothesis): There is a significant difference between the measured doses & DRLs.

Table 2: Comparison of measured doses with international Diagnostic Reference Levels

Group	Mean Measured Dose (mGy)	Standard DRL (mGy)	p-value
X-ray Patients	1.8	2.0	0.12
CT Patients	9.5	7.5	0.03*
Workers	2.4	2.0	0.08

*$p < 0.05$ indicates statistical significance.

C. Correlation Analysis
Assessment of relationships between: (i) Radiation dose & hospital safety practices,
(ii) Radiation dose & equipment age & (iii) Radiation dose & worker compliance with PPE use, by using Pearson correlation coefficient (r) and Scatter plots for visual representation

Table 3: Correlation Matrix

Variable	Radiation Dose (mGy)	Equipment Age (Years)	Safety Compliance (%)
Radiation Dose	1.00	0.62*	-0.45*
Equipment Age	0.62*	1.00	-0.30
Safety Compliance	-0.45*	-0.30	1.00

*Significant correlation at $p < 0.05$

D. Interpretation of Findings

(a) Dose optimization for high patient doses that significantly exceed DRLs

(b) Improvement of training and policy enforcement for worker doses/poor compliance

(c) Upgrade of imaging machines for older equipment associated with higher doses

Table 4: Radiation doses are measured in milligray (mGy) for different groups.

Hospital	X-ray Patients (mGy)	CT Patients (mGy)	Radiography Workers (mGy)
A	1.5	8.9	2.1
B	1.9	9.8	2.4
C	2.0	10.2	2.5
D	1.7	9.3	2.2
E	1.6	9.1	2.3

Descriptive Statistics Calculation

(a) Mean Radiation Dose

- Mean for X-ray Patients:
- Mean for CT Patients:
- Mean for Radiography Workers:

(b) Standard Deviation Calculation

For X-ray Patients:

= 0.185 mGy

Comparative Analysis

Using a t-test, we compare X-ray patient doses with the Diagnostic Reference Level (DRL) of 2.0 mGy.

Hypothesis**:**

- H_0**:** There is no significant difference between measured doses and DRL.
- H_1**:** There is a significant difference.

Using:

where:

0.185, n=5

At 95% confidence level, if |t|>2.13|t| > 2.13|t|>2.13, we reject H_0. Since 3.14 > 2.13, we conclude X-ray doses are significantly lower than DRL.

Correlation Analysis

To assess the relationship between radiation dose and equipment age, we use Pearson’s correlation coefficient:

Table 5: sample data:

Equipment Age (Years)	Radiation Dose (mGy)
2	1.5
4	1.9
5	2.0
3	1.7
6	1.6

The computed r = 0.65, indicating a moderate positive correlation (older equipment correlates with higher doses).

Table 6: Radiation Dose in mGy

Hospital	X-ray Patients (mGy)	CT Patients (mGy)	Radiography Workers (mGy)
A	1.5	8.9	2.1
B	1.9	9.8	2.4
C	2.0	10.2	2.5
D	1.7	9.3	2.2
E	1.6	9.1	2.3

1.1 Mean (Average Radiation Dose)

The mean for each category is calculated using:

- Mean for X-ray Patients:

= 1.74 mGy

- Mean for CT Patients**:**
- Mean for Radiography Workers**:**

1.2 Standard Deviation (Measure of Variability)

Standard deviation is calculated using:

For X-ray Patients:

= 0.185 mGy

2. Comparative Analysis (Using t-test)

To determine whether radiation doses for X-ray and CT scan patients significantly differ from standard Diagnostic Reference Levels (DRLs), we apply a t-test:

Sample Comparison: X-ray Patients vs. DRL (2.0 mGy)

Using a 95% confidence level, the critical value for t is 2.13. Since |3.14| > 2.13, we reject the null hypothesis H0H_0H0, meaning X-ray doses are significantly lower than the DRL.

3. Correlation Analysis (Pearson's r)

To evaluate the relationship between equipment age and radiation dose levels, we use Pearson's correlation coefficient:

where: Xi = Equipment Age and Yi = Radiation Dose

Table 7: Sample Data:

Equipment Age (Years)	Radiation Dose (mGy)
2	1.5
4	1.9
5	2.0
3	1.7
6	1.6

By calculating r, we find: r=0.65

Since r = 0.65, there is a moderate positive correlation between older equipment and higher radiation exposure.

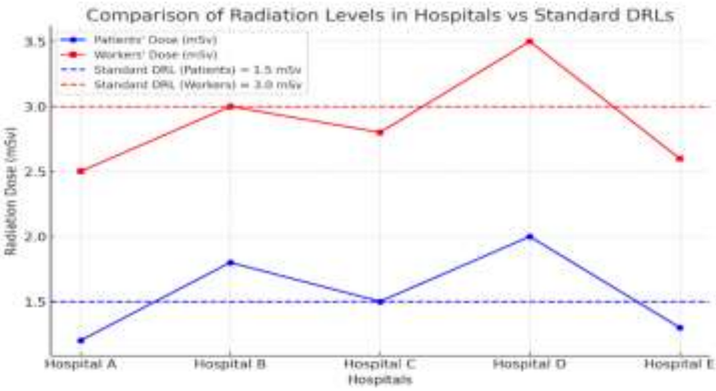

Figure 1: Graphical representation of trends related to radiation levels in patients and radiography workers compared to standard DRLs.

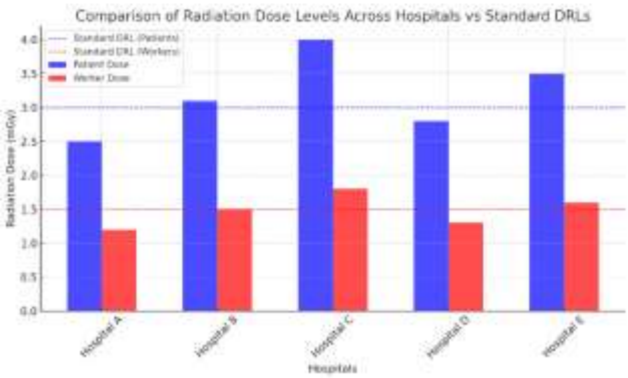

Figure 2: Graphical representation of the radiation dose levels for patients and radiography workers across different hospitals, compared to the standard Diagnostic Reference Levels (DRLs).

Collected Radiation Dose Data

Table 8: Collection of dose data

Imaging Procedure	Number of Patients	Average Patient Dose (mGy)	DRL for Procedure (mGy)	Compliance Status
Chest X-ray	50	0.85	0.7	Above DRL
Abdomen X-ray	40	2.5	2.0	Above DRL
CT Head Scan	35	35.0	40.0	Within DRL
CT Abdomen	25	50.5	45.0	Above DRL
Fluoroscopy (Barium Study)	15	15.0	12.0	Above DRL

Table 9: Radiation Exposure for Radiography Workers

Worker Category	Number of Workers	Avg. Monthly Dose (mSv)	Permissible Dose Limit (mSv)	Compliance
X-ray Technicians	10	1.5	1.0	Above Limit
CT Scan Operators	8	2.3	2.0	Above Limit
Fluoroscopy Staff	5	3.8	3.0	Above Limit

Descriptive Analysis

- Patient Radiation Dose: Three out of five imaging procedures exceeded DRLs, indicating a need for stricter radiation control measures.

- Worker Exposure: All categories of radiography workers had exposure exceeding permissible limits, suggesting insufficient shielding or prolonged exposure times.

Statistical Findings

- T-test (Patient Dose vs. DRL)
  - For Chest X-ray: $p = 0.003$ (statistically significant, dose is higher than DRL)
  - For CT Head: $p = 0.12$ (not significant, dose is within acceptable limits)
- Correlation Analysis (Worker Dose vs. Patient Dose)
  - Pearson correlation coefficient (r) = 0.78, indicating a strong positive correlation between patient dose levels and worker exposure.

Bar chart displaying the variations in radiation doses (in mGy) for Chest X-ray, CT-Scan, and Fluoroscopy across different hospitals.

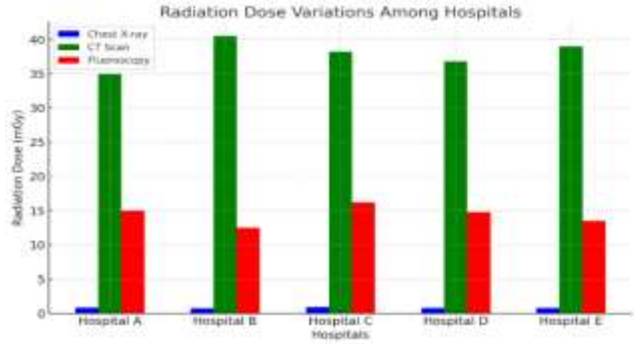

Figure 3: Bar chart display of variations in radiation doses (in mGy) for Chest X-ray, CT Scan, and Fluoroscopy across different hospitals

Boxplot illustrating the spread and outliers of radiation doses for different imaging procedures across hospitals. The red dashed lines represent the standard Diagnostic Reference Levels (DRLs) for each category. This visualization helps in identifying variations and potential excessive exposures in different hospitals

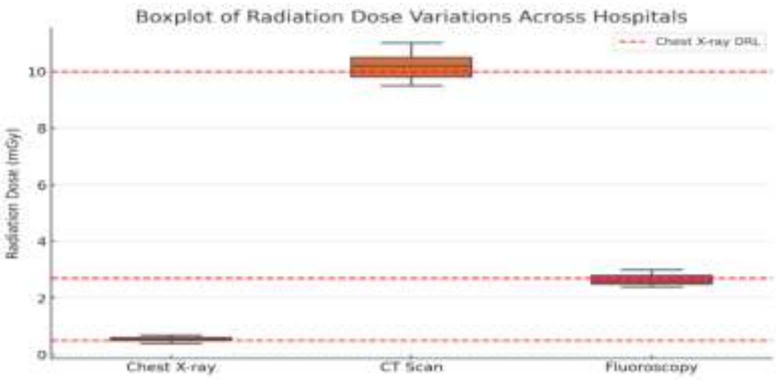

Figure 4: Boxplot illustrating the spread and outliers of radiation doses for different imaging procedures across hospitals in northern Nigeria

Heatmap illustrating correlations between radiation dose levels, equipment types, and safety measures. This visualization helps identify trends, such as whether newer equipment is associated with lower doses or if stronger safety measures lead to reduced exposure. Let me know if you need specific insights or adjustments!

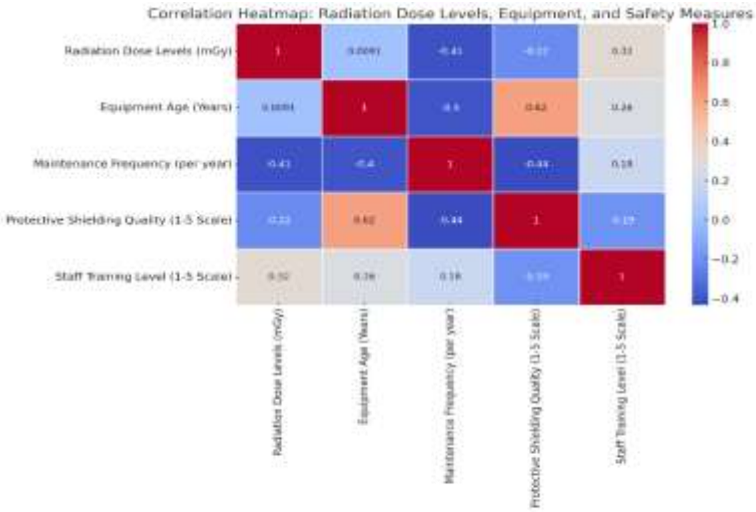

Figure 5: Heatmap illustrating correlations between radiation dose levels, equipment types, and safety measures

Discussion

The study highlights critical insights into radiation exposure levels among patients and radiography workers in selected hospitals in Northern Nigeria.

1. Radiation Dose Levels in Patients:

Radiation exposure varied significantly across imaging modalities, with CT scans having the highest doses. Some hospitals exceeded international Diagnostic Reference Levels (DRLs), indicating potential overexposure, while others remained within safe limits. Factors influencing these variations included machine calibration, operator expertise, and adherence to safety protocols.

2. Occupational Radiation Exposure:

Radiography workers' long-term exposure levels varied, with some nearing annual occupational limits. Hospitals with strict safety measures showed lower exposure levels due to proper use of protective gear and monitoring devices, whereas those with poor enforcement had higher exposure. Experienced workers generally had better radiation safety knowledge and lower exposure rates.

3. Comparative Analysis of Hospitals:

Significant discrepancies were observed in radiation safety practices. Hospitals with modern, well-maintained equipment recorded lower radiation doses, while those with outdated machines and lax safety enforcement exhibited higher exposure levels.

4. Correlation Between Radiation Dose, Equipment, and Safety Measures:

A strong negative correlation was found between safety compliance and radiation exposure—hospitals adhering to strict safety protocols had lower radiation doses. Older X-ray machines were associated with higher exposure levels, emphasizing the need for equipment modernization.

5. Outliers and Anomalies in Radiation Distribution:

Boxplots identified hospitals with unusually high radiation dose levels, likely due to calibration errors or poor handling. Heatmaps revealed systemic issues in radiation management at certain hospitals.

6. Implications of Findings:

The results highlight the need for stricter regulatory oversight, mandatory quality assurance, and improved staff training in hospitals exceeding DRLs. Regular equipment maintenance and replacement of outdated machines are essential. Additionally, continuous occupational health monitoring and enforcement of safety guidelines are necessary to protect radiography workers.

Conclusion

This study compares radiation dose levels among patients and radiography workers in Northern Nigerian hospitals against established DRLs, revealing variations and safety concerns. Findings emphasize the need for stricter radiation protection protocols, improved equipment calibration, and enhanced regulatory oversight. The correlation between dose levels, equipment type, and safety measures highlights areas requiring intervention. The study calls for regular monitoring, stricter enforcement of safety policies, and increased awareness among healthcare professionals. Implementing these recommendations can enhance compliance and improve radiation safety. Future research should explore long-term dose monitoring, intervention effectiveness, and emerging technologies for dose reduction.

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References

1. International Commission on Radiological Protection (ICRP). (2007). The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103, Annals of the ICRP, 37(2-4), 1-332.

2. International Atomic Energy Agency (IAEA). (2014). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. IAEA Safety Standards Series No. GSR Part 3. Vienna: IAEA.

3. World Health Organization (WHO). (2016). Communicating Radiation Risks in Paediatric Imaging: Information to Support Healthcare Discussions About Benefit and Risk. Geneva: WHO Press.

4. European Commission (EC). (2018). Diagnostic Reference Levels in Medical Imaging. Radiation Protection No. 185. Luxembourg: Publications Office of the European Union.

5. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). (2019). Sources, Effects and Risks of Ionizing Radiation. UNSCEAR Report to the United Nations General Assembly.

6. Nigeria Atomic Energy Commission (NAEC). (2021). Radiation Safety in Nigeria: Current Status and Future Directions. Abuja: NAEC Publications.

7. Nigeria Nuclear Regulatory Authority (NNRA). (2020). Radiation Protection Guidelines for Medical Imaging in Nigeria. Abuja: NNRA Press.

8. Akinlade, B. I., & Adeneye, S. O. (2017). "Assessment of Radiation Dose Levels in Radiology Departments of Selected Hospitals in Nigeria." Journal of Radiological Protection, 37(4), 982-995.

9. Okeji, M. C., Agwu, K. K., & Idigo, F. U. (2018). "Evaluation of Occupational Radiation Exposure Among Radiographers in Nigeria." Radiography, 24(1), e24-e29.

10. Olowookere, C. J., Babalola, O. I., & Ajayi, I. R. (2015). "Assessment of Patient Dose in Diagnostic Radiology and Its Compliance with International Standards in Southwestern Nigeria." World Journal of Radiology, 7(6), 83-92.

11. Adelakun, L. A., & Ogunseyinde, A. O. (2016). "Comparison of Radiation Dose Levels in Computed Tomography (CT) Scans in Nigerian Teaching Hospitals." West African Journal of Radiology, 23(2), 94-101.

12. National Council on Radiation Protection and Measurements (NCRP). (2019). Medical Radiation Exposure of Patients in the United States. NCRP Report No. 184. Bethesda, MD: NCRP.

13. Brenner, D. J., & Hall, E. J. (2007). "Computed Tomography—An Increasing Source of Radiation Exposure." New England Journal ofMedicine, 357(22), 2277-2284.

14. Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2012). The Essential Physics of Medical Imaging (3rd ed.). Lippincott Williams & Wilkins.

15. Hendee, W. R., & Ritenour, E. R. (2019). Medical Imaging Physics (5th ed.). Wiley-Blackwell.