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Comparative Analysis of Personnel Radiation Dose Across Diagnostic and Radiotherapy Departments in Selected Tertiary Hospitals in Abuja and Sokoto, Nigeria.

Jibrin Job Enemona[1*], Idris M. Mustapha[1], Abdulahi A. Mundi[1]

[1]Department of Physics (Radiation and Medical Physics), Nasarawa State University, Keffi, Nigeria.

ABSTRACT

Occupational exposure to ionizing radiation remains a significant concern for healthcare personnel working in diagnostic and radiotherapy departments. This study investigates a comparative analysis of personnel radiation dose across diagnostic and radiotherapy departments in selected tertiary hospitals in Abuja and Sokoto, Nigeria. The data for this study were obtained using optically stimulated luminescence dosimeters (OSLDs), which were assigned to radiation workers in both departments across three selected hospitals. Each participant wore an OSLD at chest level during routine daily clinical activities. The dosimeters were read using an OSLD reader, and the dosimetric data obtained were analyzed using Microsoft Excel to determine the annual effective doses and the associated excess lifetime cancer risk for staff in both departments. The results showed that personnel in the diagnostic departments received annual effective doses of 0.2004 mSv, 0.190 mSv, and 0.185 mSv, while those in the radiotherapy departments received 0.158 mSv, 0.140 mSv, and 0.145 mSv. The calculated excess lifetime cancer risk was 0.00041, 0.00038, and 0.00037 for diagnostic personnel and 0.00032, 0.00028, and 0.00029 for radiotherapy personnel, all of which are below the recommended standard value of 0.05. The findings indicate that although personnel in the diagnostic departments received slightly higher radiation doses and associated cancer risk compared to those in radiotherapy, the exposure levels in both departments remain within internationally recommended limits. Continuous personnel dose monitoring, strict adherence to radiation protection principles, and regular training of radiation workers are therefore recommended to further minimize occupational exposure and associated health risks.

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***Corresponding Author**

Jibrin Job Enemona

Department of Physics (Radiation and Medical Physics), Nasarawa State University, Keffi, Nigeria

E-mail: *jobenemona1@gmail.com*

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1. INTRODUCTION

Ionizing radiation is central to modern medical practice, from conventional X-ray and computed tomography (CT) in diagnostic departments to megavoltage photon and electron beams in radiotherapy. Its use also results in occupational exposure of healthcare workers. International guidelines require exposures to be kept as low as reasonably achievable (ALARA) and set an effective dose limit of 20 mSv per year averaged over five years, with no more than 50 mSv in any single year (ICRP, 2007; IAEA, 2014; UNSCEAR, 2020).

Diagnostic and radiotherapy departments share the purpose of patient care but have very different radiation work profiles. Diagnostic imaging involves many short procedures with scattered radiation, whereas radiotherapy involves fewer patients, high-energy sources and exposure that depends strongly on task, such as quality assurance, source handling and patient set-up. Geometry, energy spectra, work practices and shielding therefore differ substantially between the two specialties (Gbetchedji et al., 2020). In diagnostic departments, repeated proximity to the source during imaging can produce higher cumulative staff doses despite lower per-procedure radiation intensity (Aliyu et al., 2020), while in radiotherapy remote delivery, heavy shielding and interlocks generally limit staff exposure (Olobatoke & Mothiba, 2021).

In Nigeria, occupational monitoring and protection practices vary widely, and many facilities lack routine personnel monitoring or complete dose records (Akinlade et al., 2020; Badejo et al., 2023). Reported annual doses from single-department studies are generally low: 0.03–0.32 mSv among radiology personnel in four teaching hospitals in Southern Nigeria (Nwokeoji & Ononugbo, 2019), 0.2442–0.2732 mSv among radiographers in Port Harcourt (Okawele et al., 2024), and a mean of 0.31 mSv at diagnostic centres in South West Nigeria (Oyeyemi et al., 2022). However, most Nigerian studies have examined individual departments, and few have compared diagnostic and radiotherapy personnel directly within the same institutional setting. This study addresses that gap.

The aim was to compare personnel radiation dose across diagnostic and radiotherapy departments in three tertiary hospitals in Abuja and Sokoto. The objectives were to (i) determine the effective dose received by diagnostic personnel and (ii) by radiotherapy personnel, (iii) calculate annual effective dose and compare it with the recommended limit, and (iv) calculate excess lifetime cancer risk and compare it with the reference value.

2. MATERIALS AND METHODS

2.1 Study area and participants

The study was conducted in the diagnostic radiology and radiotherapy departments of three tertiary hospitals with established imaging and cancer-management services: the National Hospital Abuja, the Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, and the Africa Medical Centre of Excellence (AMCE), Abuja. The hospitals are coded A, B and C in the results. Total population sampling was used: all 112 occupationally exposed personnel were included, comprising 53 in diagnostic departments (19 radiographers, 9 radiologists, 12 nurses, 13 technical assistants) and 59 in radiotherapy departments (9 radiation oncologists, 13 oncology nurses, 9 medical physicists, 10 brachytherapists, 9 radiation therapists, 9 radiation protection officers). Hospital A contributed 23 diagnostic and 25 radiotherapy staff, Hospital B 15 and 19, and Hospital C 15 and 15. Eligible staff were directly involved in diagnostic or radiotherapy procedures, were consistently monitored with OSLDs, had complete records and gave informed consent. Administrative staff, temporary or visiting staff and those with incomplete records were excluded.

2.2 Dosimetry

OSLDs (aluminium oxide doped with carbon, Al_2O_3:C) were worn at chest level during routine daily clinical activities, and read with an OSLD reader. Weekly dose records were the primary data and were extrapolated to monthly and annual values over a 12-month monitoring period. Data were organised in Microsoft Excel, and descriptive statistics (mean, minimum and maximum) were used to summarise doses by staff category and department.

2.3 Dose and risk calculations

The annual effective dose was calculated as AED (mSv/y) = Dm × 12, where Dm is the monthly dose (mSv). The dose ratio (DR = AED / 20) and the percentage of the ICRP limit (%ICRP = AED / 20 × 100) were used to compare AED with the ICRP occupational limit of 20 mSv/y. The excess lifetime cancer risk was calculated as ELCR = AED × DL × RF, where DL is the duration of occupational exposure (40 years) and RF is the fatal cancer risk factor (0.05 Sv^{-1}), with AED expressed in Sv. Mean doses are reported per person within each staff category; departmental values are the mean of the staff-category means.

3. RESULTS

3.1 Diagnostic departments

Individual annual effective doses in the diagnostic departments ranged from 0.10 to 0.34 mSv. Radiographers consistently recorded the highest mean doses and ELCR in all three hospitals, reflecting their

direct operation of X-ray equipment and frequent presence in examination rooms. Radiologists and technical assistants received intermediate doses, and nurses the lowest (Table 1, Figure 1).

Table 1. Mean annual effective dose (AED, mSv) and excess lifetime cancer risk (ELCR) by diagnostic staff category in Hospitals A, B and C. ICRP limit: 20 mSv/y.

Staff category	n (A/B/C)	AED A	AED B	AED C	ELCR A ($\times10^{-4}$)	ELCR B ($\times10^{-4}$)	ELCR C ($\times10^{-4}$)
Radiographers	8 / 5 / 6	0.321	0.294	0.310	6.4	5.9	6.1
Radiologists	5 / 2 / 2	0.178	0.175	0.150	3.6	3.5	3.0
Nurses	4 / 4 / 4	0.138	0.115	0.130	2.8	2.3	2.6
Technical assistants	6 / 4 / 3	0.165	0.175	0.150	3.3	3.5	3.0

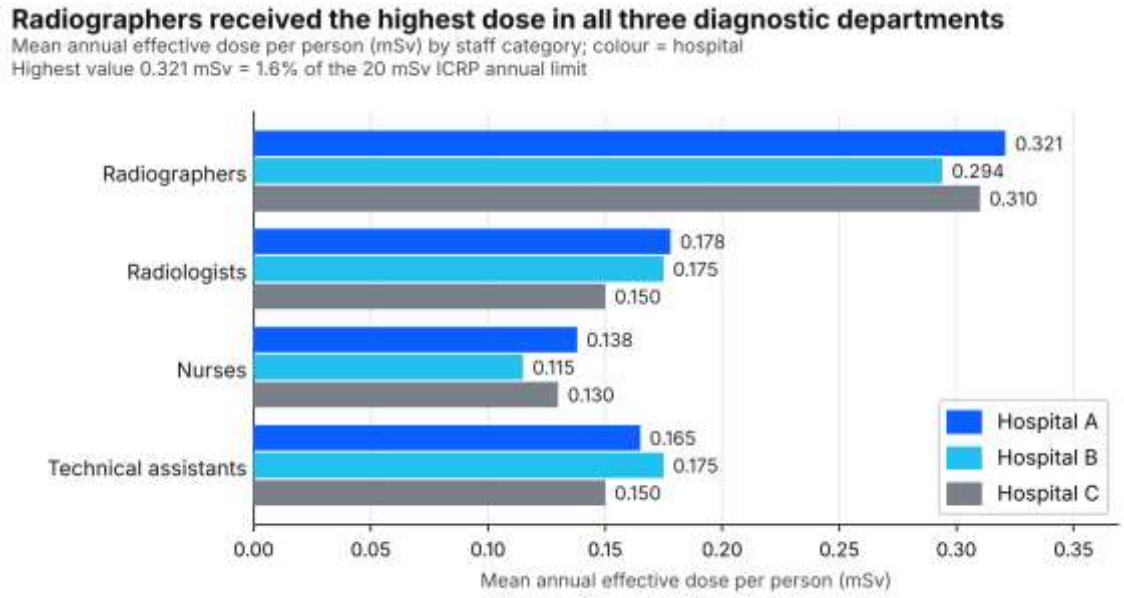


Figure 1. Mean annual effective dose per person by diagnostic staff category and hospital.

3.2 Radiotherapy departments

Individual annual effective doses in the radiotherapy departments ranged from 0.03 to 0.30 mSv. Radiation therapists and brachytherapists recorded the highest doses, reflecting close involvement in treatment delivery and handling of radioactive sources. Medical physicists, oncology nurses and radiation oncologists received moderate doses, and radiation protection officers the lowest, consistent with their supervisory and monitoring roles (Table 2, Figure 2). Radiation therapists in Hospital A had the highest mean dose (0.280 mSv; ELCR 0.00056), whereas brachytherapists were most exposed in Hospital C (0.205 mSv).

Table 2. Mean annual effective dose (AED, mSv) and excess lifetime cancer risk (ELCR) by radiotherapy staff category in Hospitals A, B and C. ICRP limit: 20 mSv/y.

Staff category	n (A/B/C)	AED A	AED B	AED C	ELCR A ($\times10^{-4}$)	ELCR B ($\times10^{-4}$)	ELCR C ($\times10^{-4}$)
Radiation oncologists	3 / 3 / 3	0.120	0.120	0.140	2.4	2.4	2.8
Oncology nurses	5 / 4 / 4	0.132	0.130	0.133	2.6	2.6	2.7
Medical physicists	4 / 3 / 2	0.150	0.150	0.165	3.0	3.0	3.3
Brachytherapists	5 / 3 / 2	0.228	0.200	0.205	4.6	4.0	4.1
Radiation therapists	4 / 3 / 2	0.280	0.210	0.180	5.6	4.3	3.6
Radiation protection officers	4 / 3 / 2	0.040	0.030	0.045	0.8	0.67	0.9

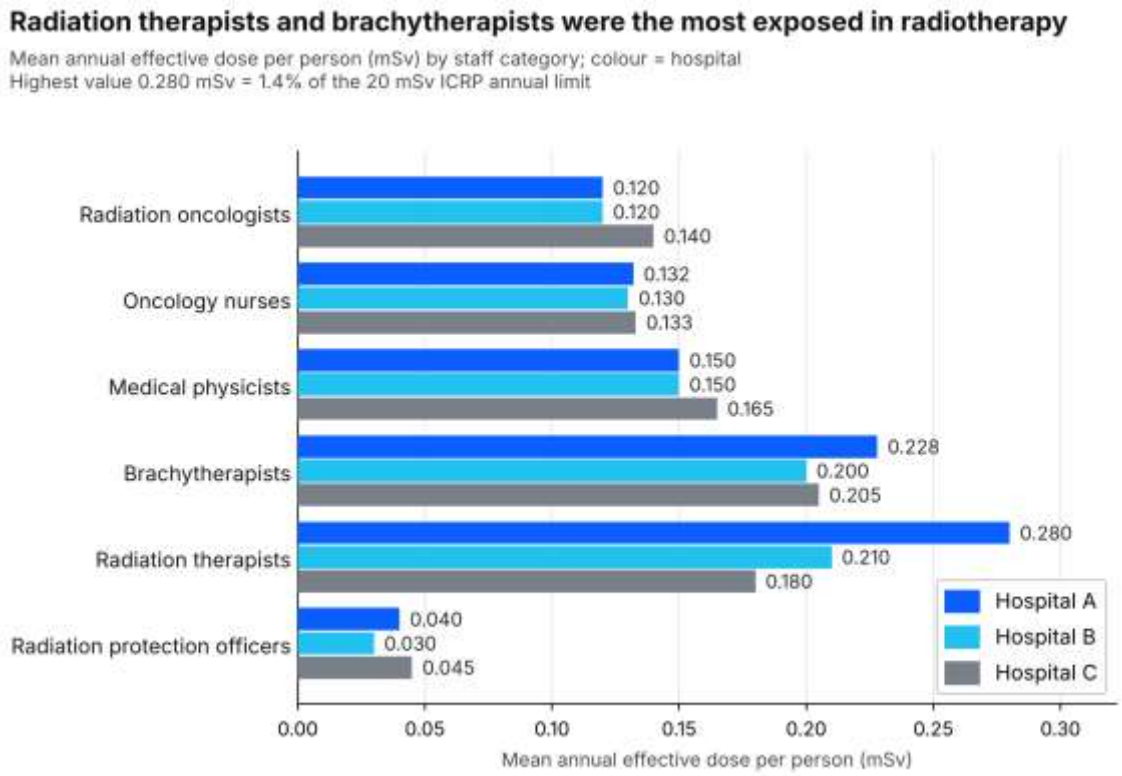


Figure 2. Mean annual effective dose per person by radiotherapy staff category and hospital.

4. DISCUSSION

This study compared occupational dose and excess lifetime cancer risk between diagnostic and radiotherapy personnel in three tertiary hospitals. Diagnostic staff received higher mean annual effective doses and ELCR than radiotherapy staff in every hospital, with the highest values in Hospital A diagnostic (0.2004 mSv; ELCR 0.00041) and the lowest in Hospital B radiotherapy (0.140 mSv; ELCR 0.00028). This agrees with reports that diagnostic radiology workers accumulate higher doses because of frequent imaging procedures and proximity to the source (Bushberg et al., 2012; Aliyu et al., 2020). In radiotherapy, remote beam delivery, heavy shielding and interlock systems keep staff away from the source during irradiation (Olobatoke & Mothiba, 2021), which plausibly explains the lower values.

Within departments, dose followed job role. Radiographers were the most exposed diagnostic group (0.294–0.321 mSv), and radiation therapists and brachytherapists the most exposed in radiotherapy, in line with UNSCEAR (2020), which identifies radiographers and radiation therapy personnel as relatively highly exposed groups, and with Alotaibi et al. (2020). Radiation protection officers recorded the lowest doses (0.030–0.045 mSv), consistent with limited time in radiation areas and strict application of time, distance and shielding (ICRP, 2007).

The doses are of the same order as other Nigerian reports using personal dosimeters, including 0.03–0.32 mSv in Southern Nigeria (Nwokeoji & Ononugbo, 2019), 0.2442–0.2732 mSv among radiographers in Port Harcourt (Okawele et al., 2024) and a mean of 0.31 mSv in South West Nigeria (Oyeyemi et al., 2022). Higher figures have been reported elsewhere, for example a mean of 1.13 ± 0.51 mSv among radiology staff at UDUTH (Ibrahim, 2024), which may reflect differences in workload, modality mix, monitoring period and dosimetry method.

All doses were well below the 20 mSv annual limit, at most 1.0% of it, and ELCR values were of the order of 10^{-4}. This is consistent with findings that doses among healthcare workers in well-regulated facilities remain within recommended limits (Mettler et al., 2008; IAEA, 2018) and that cancer risk estimates for medical radiation workers are low under established protection programmes (Ezzell et al., 2018; Alghamdi et al., 2019; Sharma et al., 2021). Low doses do not remove the stochastic risk, so ALARA optimisation remains necessary.

Limitations. The study covered three hospitals and two departments, so results may not generalise to other settings or to other high-exposure units such as nuclear medicine, CT and interventional suites.

5. CONCLUSION

Diagnostic personnel in all three tertiary hospitals received higher occupational radiation doses, and had higher estimated excess lifetime cancer risk, than radiotherapy personnel. Radiographers were the most exposed diagnostic staff and radiation therapists (with brachytherapists) the most exposed in radiotherapy. Every measured dose remained below the ICRP occupational limit of 20 mSv per year, indicating that current radiation protection measures are generally effective. Differences between hospitals and professional groups nevertheless support continued improvement. The departmental comparison is summarised in Table 3 and Figure 3.

Table 3. Departmental mean annual effective dose (AED) and excess lifetime cancer risk (ELCR) across the three hospitals, compared with ICRP reference values.

Parameter	A Diagnostic	A Radiotherapy	B Diagnostic	B Radiotherapy	C Diagnostic	C Radiotherapy	Reference
Mean AED (mSv/y)	0.2004	0.158	0.190	0.140	0.185	0.145	20
% of ICRP limit	1.00	0.79	0.95	0.70	0.93	0.73	100
ELCR	0.00041	0.00032	0.00038	0.00028	0.00037	0.00029	≤ 0.05

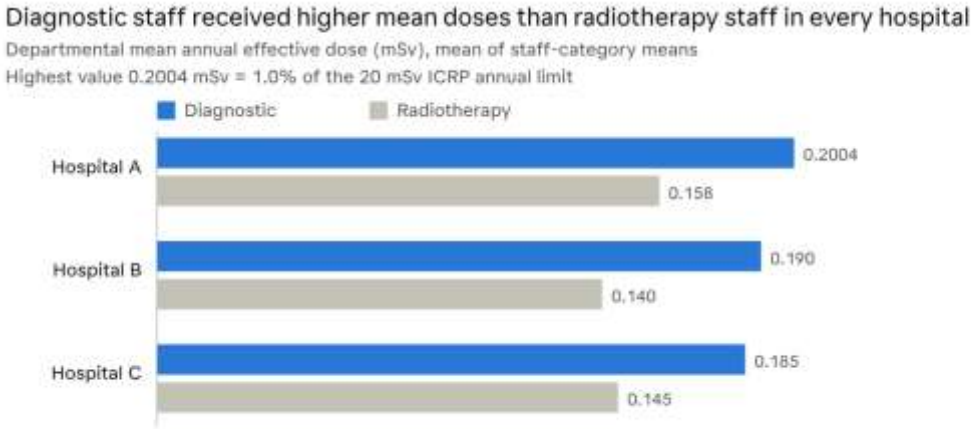


Figure 3. Departmental mean annual effective dose in the diagnostic and radiotherapy departments of the three hospitals.

RECOMMENDATIONS

1. Provide regular refresher courses for all radiation workers on dose minimisation, equipment handling and ALARA.
2. Review personal dosimeter readings frequently to identify upward trends and enable timely corrective action.
3. Apply workload rotation, optimised scheduling and periodic assessment of shielding integrity, especially in diagnostic units where activity levels are higher.
4. Carry out regular calibration, servicing and quality assurance checks of imaging and radiotherapy machines.

Suggestions for further studies

Future work should include additional radiation-using units (nuclear medicine, CT, interventional), more healthcare centres, the relationship between workload and dose, and the influence of protective equipment use and staff compliance on personnel dose.

Declarations

Ethical approval and consent: Health Research Ethical Committee, National Hospital Abuja, NHA/EC/182/2026.

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[Complete entries still to be added for works cited in the Discussion but missing from the original reference list: Alghamdi et al. (2019); Alotaibi et al. (2020); Bushberg et al. (2012); Ezzell et al. (2018); IAEA (2018); Mettler et al. (2008); Sharma et al. (2021).

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