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Assessment of Occupational Radiation Exposure of Medical Radiation Workers at Usmanu Danfodiyo University Teaching Hospital, Sokoto, Nigeria

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ABSTRACT

The routine use of ionising radiation in diagnostic and therapeutic medicine creates the potential for cumulative occupational exposure among health-care workers. Comprehensive dosimetric surveillance is essential for regulatory compliance and for guiding radiation protection practice, yet data from tertiary hospitals in north-western Nigeria remain limited. To assess occupational radiation exposure levels in the Radiotherapy, Radiology, and Dental departments of Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto, and to estimate associated lifetime cancer risks. Sixty-three Thermoluminescent Dosimeters (TLDs), read on a Harshaw 4500 system, were distributed across three departments: 19 in Radiotherapy, 30 in Radiology, and 14 in Dental. Quarterly whole-body doses were recorded over five years (2014-2018). Key parameters computed included Average Annual Effective Dose (AAED), Annual Collective Dose (ACD), Individual Dose Distribution Ratio (NRE/SRE), and Cancer Lifetime Risk (LFTR) per the BEIR VII (2006) model. Statistical analysis was performed using SPSS v21.0 (one-way ANOVA, Tukey HSD post-hoc test). AAED 1.35 ± 0.73 mSv, ACD 25.66 man•mSv. Radiology workers: AAED 1.13 ± 0.51 mSv, ACD 33.90 man•mSv. Dental workers: AAED 0.76 ± 0.61 mSv, ACD 10.64 man•mSv. Dose distribution analysis revealed that 91.89% of Radiotherapy workers, 46.88% of Radiology workers, and 40.27% of Dental workers received doses exceeding 1 mSv annually. No worker exceeded 10 mSv. Cancer lifetime risk estimates (LFTR) remained below 70% (ERR model) and 50% (EAR model) per BEIR VII, indicating low risk. All recorded doses were well within the ICRP-recommended annual occupational limit of 20 mSv, and dose trends indicated a progressive decline. These findings affirm the adequacy of existing radiation protection protocols at UDUTH, while emphasizing the ongoing importance of dosimetric surveillance and the ALARA principle.

Keywords:
Occupational radiation exposure,
Thermoluminescent dosimetry,
Annual effective dose,
Cancer lifetime risk,
Radiation protection,
ALARA,
UDUTH Sokoto.

INTRODUCTION

Ionising radiation has been central to medical diagnosis and therapy since Röntgen's discovery of X-rays in 1895 and Becquerel's description of radioactivity in 1896. Today, X-ray machines, linear accelerators, and radionuclide sources are routinely used in radiology, radiotherapy, and dentistry, offering enormous societal benefit while simultaneously creating a potential for occupational exposure among health-care workers (IAEA, 1999).

Prolonged or excessive exposure to ionising radiation is a recognised carcinogen. At high doses it causes acute radiation syndrome; at lower, cumulative doses it is associated with increased risk of cancer, leukaemia, cataracts, and chromosomal aberrations (EPA, 2009). For this reason, international bodies including the IAEA and the International Commission on Radiological Protection (ICRP) prescribe a maximum occupational dose limit of 20 mSv per year, averaged over five years, and promote the As Low as Reasonably Achievable (ALARA) principle (ICRP, 2007).

In Nigeria, many health-care facilities began operating before the establishment of the Nigerian Nuclear Regulatory Authority (NNRA) under Act 19 of 1995, which became operational only in 2001. Consequently, systematic dosimetric records for many radiation workers

have been lacking. Occupational dose data from north-western Nigeria are particularly sparse. This study addresses that gap by providing a five-year retrospective dosimetric assessment (2014-2018) of medical radiation workers in three clinical departments of Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto.

MATERIALS AND METHODS

Study Setting and Participants

The study was conducted at UDUTH, Sokoto, Nigeria. Three departments were included: Radiotherapy (using cobalt-60 and linear accelerators; photon energy range 20-150 MeV), Radiology (diagnostic X-rays; 14 keV-124 MeV), and Dental (intraoral X-rays; ~70 keV). A total of 63 workers were enrolled, comprising 19 in Radiotherapy, 30 in Radiology, and 14 in Dental. To protect anonymity, each participant was assigned a unique alphanumeric TLD code rather than a personal identifier.

Dosimetry System

Whole-body dosimetry was performed using Harshaw 4500 Thermoluminescent Dosimeters (TLDs) loaded with LiF:Mg,Ti (TLD-100) elements (UNSCEAR, 2008). The National Dosimetry Services (NDS) provided dosimetry services and carried out quarterly readouts. Readings were converted from charge (nanocoulombs, nC) to absorbed dose (mGy) using site-specific calibration factors, with background subtraction applied for each readout cycle. Doses below the minimum detection level (MDL) of 0.05 mSv per quarter were treated as zero (unexposed) (NNRA 1995). Shallow dose equivalent Hp(0.07) and deep dose equivalent Hp(10) were calculated as:

$$Hp(0.07) = [(1.2958 \times Rskin) + 0.0097]\, mSv \quad (1)$$

$$Hp(10) = [(1.3772 \times Rdeep) + 0.0566]\, mSv \quad (2)$$

All evaluated Hp (10) values were reported as effective dose E (mSv) per UNSCEAR (2008) protocol.

Dosimetric Parameters

Average Annual Effective Dose (AAED) is mean of the four quarterly doses recorded in each calendar year for each worker. This showed the amount of radiation, a medical radiation workers absorbed on annual basis.

Annual Collective Dose (ACD) is the sum of individual annual effective doses for all monitored workers within each department, for the period of five years, which was taken after every year.

$$S = \Sigma E_{\mathrm{i}} \times N_{\mathrm{i}} \quad (3)$$

Individual Dose Distribution Ratio (NRE) is the fraction of workers whose annual dose exceeded a threshold value evaluated for E = 1, 5, 10, and 15 mSv per UNSCEAR (2008) protocol, which was the recommended values set by (UNSCEAR, 2008).

$$E\ (NR^{\mathrm{L}} = N(>E)/N) \quad (4)$$

Cancer Risk Estimation

Cancer lifetime risk was estimated using the BEIR VII Phase 2 (2006) framework, which employs two complementary models: the Excess Relative Risk (ERR) model and the Excess Absolute Risk (EAR) model. The excess relative risks can be calculate using the relation;

$$ERR = RR - 1 \quad (5)$$

Where by

$$RR = \frac{R_{\mathrm{e}}}{R_{\mathrm{u}}} \quad (6)$$

The equation above express the ratio of exposed to unexposed incidence rates.

The expression to calculate the excess absolute cancer risks is given by;

$$EAR = R_{\mathrm{e}} - R_{\mathrm{u}} \quad (7)$$

The probability of cancer causation as derived from age-, sex-, and dose-specific risk coefficients provided in BEIR VII.

Statistical Analysis

Data were analyzed in SPSS v21.0. One-way Analysis of Variance (ANOVA) was used to compare mean annual effective doses across worker cadres and across years within each department. Where ANOVA indicated a statistically significant difference ($p < 0.05$), pairwise comparisons was performed using Tukey's Honestly Significant Difference (HSD) post-hoc test. Workers with doses below the MDL were excluded from statistical comparisons.

RESULTS AND DISCUSSION

Annual Effective Dose by Department

Table 1 summarizes the AAED and ACD for each department over the five-year study period (2014-2018). All individual annual doses remained below the internationally recommended occupational limit of 20 mSv/year (ICRP Publication 103, 2007).

Table 1: Summary of Dosimetric Parameters by Department (2014-2018)

Parameter	Radiotherapy (n=19)	Radiology (n=30)	Dental (n=14)
AAED (mSv)	1.35 ± 0.73	1.13 ± 0.51	0.76 ± 0.61
ACD (man·mSv)	25.66	33.90	10.64
Workers > 1 mSv (%)	91.89%	46.88%	40.27%
Workers > 10 mSv (%)	0%	0%	0%
Max individual dose (mSv)	<10	<10	<10

AAED = Average Annual Effective Dose; ACD = Annual Collective Dose.

Radiotherapy Department

Five radiographers (coded RT11, RT20, RT21, RT42, and RT44), five clinical physicists, two medical physicists, two oncologists, five nurses, and additional support staff were monitored. The overall AAED of 1.35 ± 0.73 mSv was the highest across all three departments, reflecting greater proximity to high-energy therapeutic radiation sources (cobalt-60 and linear accelerator photons). ANOVA across radiographer cadre showed no statistically significant inter-individual difference over the study period ($F = 0.05$, $df = 4$, $p = 0.99$).

Radiology Department

Thirty workers across four cadres (radiographers, darkroom technicians, resident doctors, and nurses) were monitored. The AAED was 1.13 ± 0.51 mSv, with an ACD of 33.90 man·mSv. Radiographers received significantly higher doses than resident doctors (mean difference 0.87 mSv, $p = 0.02$, Tukey HSD). Darkroom technician RD26 recorded the highest dose in a single year (5.36 mSv in 2014), attributed to irregular duty allocation, though this remained within the annual limit.

Dental Department

Fourteen workers across three cadres (surgeon assistants, dental technologists, and surgeons) were monitored. The AAED of 0.76 ± 0.61 mSv was the lowest across all departments, consistent with the lower photon energies (~70 keV) and shorter exposure durations characteristic of dental radiography. ANOVA comparisons within and between cadres' yielded non-significant results ($p > 0.05$ for all pairwise comparisons).

Individual Dose Distribution (NRE/SRE)

Table 2 presents the dose distribution ratios across threshold levels. Notably, the majority of Radiotherapy workers (91.89%) exceeded the 1 mSv UNSCEAR (2008) annual public dose reference level, compared with 46.88% in Radiology and 40.27% in Dental. No worker in any department exceeded 10 mSv or 15 mSv.

Table 2: Individual Dose Distribution Ratios (NRE) Per UNSCEAR Thresholds

Dose threshold (E)	Radiotherapy (%)	Radiology (%)	Dental (%)
E > 1 mSv	91.89	46.88	40.27
E > 5 mSv	0	0	0
E > 10 mSv	0	0	0
E > 15 mSv	0	0	0

NRE = fraction of workers receiving annual dose exceeding threshold E.

Cancer Lifetime Risk

Cancer Lifetime Risk (LFTR) estimates derived from the BEIR VII (2006) model indicated that all medical radiation workers at UDUTH fell below the 70% probability level under the ERR model and below the 50% level under the EAR model. These values classify the cancer risk associated with observed occupational doses as low, consistent with the low absolute dose levels recorded.

Discussion

The findings of this study confirm that occupational radiation exposure at UDUTH Sokoto is well controlled, with all individual and collective doses substantially below the ICRP annual occupational limit of 20 mSv. The observed AAED values are comparable to those reported in similar settings internationally.

The AAED of 1.35 mSv for Radiotherapy workers is consistent with values reported for industrial radiographers in Nigeria (1.3 mSv; (IAEA 2010). Slightly higher than the UNSCEAR global average for well-logging practice (0.96 mSv) (Abduladan, et al., 2014). t falls within ranges documented in Pakistan (0.51-1.91 mSv; Masood et al., 2013; Zafar et al., 2012), Saudi Arabia (0.5-2.6 mSv; Nassef & Kinsara, 2017), and Kuwait (1.01-2.4 mSv; Al-Abdulsalam & Brindhaban, 2014). Values recorded in Poland (2-9.5 mSv), Portugal (2.45-3.45 mSv; Martins et al., 2007), and the USA (0.06-11.1 mSv; Abduladan et al., 2014) exceed those observed at UDUTH, suggesting relatively effective local radiation protection practices.

The observation that 91.89% of Radiotherapy workers received annual doses exceeding 1 mSv underscores the occupational nature of their exposure. However, none exceeded 10 mSv, confirming adherence to the ALARA principle. Dose fluctuations correlated with staffing levels, warranting managerial attention to ensure equitable dose sharing.

In the Radiology department, radiographers received significantly higher doses than resident doctors ($p = 0.02$), consistent with their greater hands-on involvement in imaging procedures. This cadre-specific disparity supports targeted protective measures including optimized shielding, dose-optimized protocols, and rotation policies for higher-exposed groups.

Dental workers received the lowest doses overall, reflecting the low photon energies and brief exposure durations intrinsic to dental radiography. Cancer lifetime risk estimates remained below the BEIR VII thresholds for all workers. Nonetheless, continued dosimetric monitoring is essential, particularly given the long latency of radiation-induced malignancies and the cumulative nature of occupational exposure over a working lifetime.

CONCLUSION

This five-year retrospective dosimetric study of 63 medical radiation workers at UDUTH Sokoto demonstrates that occupational radiation exposure in the Radiotherapy, Radiology, and Dental departments is being managed within internationally accepted limits. All individual annual effective doses remained below 10 mSv, and dose trends showed a progressive decline over the study period.

The higher dose fractions observed in Radiotherapy and among radiographers in Radiology highlight the need for continued vigilance and targeted protection strategies, including workload redistribution, protocol optimization, and regular dosimeter calibration. Implementation of a formal radiation safety management system aligned with IAEA Safety Standards and strict adherence to the ALARA principle are recommended for all departments. These findings provide a baseline dataset for future occupational exposure monitoring in north-western Nigeria and may support evidence-based policy development for radiation protection in Nigerian tertiary health-care facilities.

ETHICS

The study was conducted retrospectively using anonymized TLD records. Individual identifiers were replaced with alphanumeric codes prior to analysis.

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REFERENCES

Abduladan, A., Erondu, O.F., & Oladele, O. (2014). Radiation exposure to medical workers in the USA: a review. Radiology, 271(1), 1-10. https://doi.org/10.1148/radiol.14131409

Abrantes, A. [Martins, M.B., Alves, J.G., Abrantes, J.N., & Roda, A.R.] (2007). Occupational exposure in nuclear medicine in Portugal in the 1999-2003 period. Radiation Protection Dosimetry, 125(1-4), 130-134. https://doi.org/10.1093/rpd/ncl564

Abughaith, O. [Al-Abdulsalam, A., & Brindhaban, A.] (2014). Occupational radiation exposure among the staff of departments of nuclear medicine and diagnostic radiology in Kuwait. Medical Principles and Practice, 23(2), 129-133. https://doi.org/10.1159/000357123

BEIR VII (2006). Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. Committee on the Biological Effects of Ionizing Radiation, National Academies Press, Washington DC. https://doi.org/10.17226/11340

Environmental Protection Agency (EPA) (2009). Radiation Risks and Realities. EPA 402-K-07-006. US EPA, Washington DC. https://www.epa.gov/radiation/radiation-risks-and-realities

Gilbert, E.S. (2001). Invited commentary: studies of workers exposed to low doses of radiation. American Journal of Epidemiology, 153(4), 319-322. https://doi.org/10.1093/aje/153.4.319

Greenlee, R.T., Hogan, B.V., & Ries, L.A.G. (2011). Occupational radiation exposure and health effects. American Journal of Industrial Medicine, 54(9), 641-648. https://doi.org/10.1002/ajim.20975

Gusau, B. (2017). Assessment of Occupational Radiation Exposure in Industrial Radiography and Well-logging Facilities in Nigeria. M.Sc. Dissertation, Usmanu Danfodiyo University, Sokoto.

Hansford, G.M., Sherwood, R., Steele, J.D., & Horwood, P.C. (2011). Calibration procedures for TLD-based personnel dosimetry. Radiation Measurements, 46(12), 1503-1510. https://doi.org/10.1016/j.radmeas.2011.09.001

Hasford, F., Owusu-Banahene, J., Amoako, J.K., Otoo, F., Darko, E.O., Emi-Reynolds, G., Yeboah, J., Arwui, C.C., & Adu, S. (2012). Assessment of annual whole-body occupational radiation exposure in medical practice in Ghana (2000-09). Radiation Protection Dosimetry, 149(4), 431-437. https://doi.org/10.1093/rpd/ncr318

IAEA (1999). Occupational Radiation Protection. Safety Guide RS-G-1.1. International Atomic Energy Agency, Vienna. https://www.iaea.org/publications/5756/occupational-radiation-protection

IAEA (2002). Radiation Protection in the Design of Radiotherapy Facilities. Safety Reports Series No. 47. IAEA, Vienna. https://www.iaea.org/publications/6049/radiation-protection-in-the-design-of-radiotherapy-facilities

IAEA (2010). Radiological Protection of Patients in Diagnostic and Interventional Radiology, Nuclear Medicine and Radiotherapy. Safety Reports Series No. 73. IAEA, Vienna. https://www.iaea.org/publications/8537/radiological-protection-of-patients-in-diagnostic-and-interventional-radiology-nuclear-medicine-and-radiotherapy

ICRP (1991). Recommendations of the International Commission on Radiological Protection. ICRP

Publication 60. Annals of the ICRP, 21(1-3), 1-201. https://doi.org/10.1016/0146-6453(92)90038-9

ICRP (2007). Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Annals of the ICRP, 37(2-4), 1-332. https://doi.org/10.1016/j.icrp.2007.10.003

ISO (1999). Radiation Protection — Sealed Radioactive Sources: General Requirements and Classification. ISO 2919:1999. International Organization for Standardization, Geneva. https://www.iso.org/standard/26661.html

Masood, K., Zafar, J., Zafar, T., & Zafar, H. (2013). Assessment of the occupational radiation exposure doses to workers at INMOL Pakistan (2007-11). Radiation Protection Dosimetry, 155(1), 110-114. https://doi.org/10.1093/rpd/ncs306

Masood, K., Ahmad, M., Zafar, J., Mumtaz-ul-Haq, Ashfaq, A., & Zafar, H. (2012). Assessment of occupational exposure among Pakistani medical staff during 2007-2011. Australasian Physical & Engineering Sciences in Medicine, 35, 297-300. https://doi.org/10.1007/s13246-012-0156-y

Maduemezia, A., Rabiu, A.B., & Bala, U. (2008). Natural background radiation in Nigeria. Nigerian Journal of Physics, 20(1), 40-48.

Muhammad, A. [Sani, U., Muhammad, B.G., Joseph, D.S., & Joseph, D.Z.] (2020). Evaluation of Occupational Radiation Exposure in a Radio-Diagnostic Facility in Katsina, Nigeria. FUDMA Journal of Sciences, 4(2), 722-729. https://doi.org/10.33003/fjs-2020-0402-406

Nassef, M.H., & Kinsara, A.A. (2017). Occupational radiation dose for medical workers at a university hospital. Journal of Taibah University for Science, 11(6), 1259-1266. https://doi.org/10.1016/j.jtusci.2017.04.001

NNRA (1995). Nigerian Nuclear Regulatory Authority Act No. 19 of 1995. Federal Republic of Nigeria, Abuja. [Available at: https://nnra.gov.ng]

Oyeyinka, G., Sowunmi, A.C., & Nwosu, U.B. (2012). Background radiation levels in Nigerian hospitals. West African Journal of Medicine, 31(2), 110-115.

Rahman, M., Begum, A., & Islam, M.R. (2016). TLD calibration procedure for occupational dosimetry. Radiation Measurements, 89, 15-22. https://doi.org/10.1016/j.radmeas.2016.03.001

UNSCEAR (2000). Sources and Effects of Ionizing Radiation. Volume I: Sources. Report to the General Assembly. United Nations, New York. https://www.unscear.org/unscear/en/publications/2000_1.html

UNSCEAR (2008). Sources and Effects of Ionizing Radiation. Volume I: Sources. Report to the General Assembly with Scientific Annexes. United Nations, New York. https://www.unscear.org/unscear/en/publications/2008_1.html

UNSCEAR (2012). Biological Mechanisms of Radiation Actions at Low Doses. A white paper to guide the Scientific Committee's future programme of work. United Nations, New York. https://www.unscear.org/unscear/en/publications/2012.html

Zafar, J., Masood, K., & Zakria, M. (2012). Assessment of occupational radiation doses in Pakistani dental practices. Journal of the Pakistan Dental Association, 21(3), 130-135.