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*Original Article*

# Assessing Low Ionizing Radiation Exposure and Health Impact on Professional Workers in South Eastern Nigerian Hospitals: A Comparative Study across Medical and Non-Medical Personnel

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## Abstract

Radiation encompasses a spectrum of electromagnetic and particle radiation, posing potential health risks when exposure surpasses recommended limits. This study assesses the health impact of low ionizing radiation on professional radiation workers in selected South Eastern Nigerian hospitals, comparing doses among medical and non-medical personnel with International Commission on Radiological Protection (ICRP) standards. Among medical workers, Centre (A) records the highest effective dose (0.9160±0.2248 mSv), followed by center (B) (0.7726±0.1374 mSv), and center (C) with the lowest (0.7204±0.1561 mSv). Non-medical workers exhibit a similar trend, with center (A) having the highest dose (0.6247±0.2561 mSv), followed by center (B) (0.5687±0.1413 mSv), and center (C) with the lowest (0.4429±0.1546 mSv). Despite slightly higher doses for medical workers, all values fall below ICRP limits, emphasizing safety adherence. Statistical analyses confirm significant differences in mean doses between medical and non-medical workers across all centers, providing valuable insights into radiation health impact in these tertiary hospitals.

**Keywords:** Radiation, Ionizing radiation, Health impact, Professional radiation workers, Doses, International Commission on Radiological Protection (ICRP), Tertiary hospitals.

## Introduction

Radiation encompasses electromagnetic radiation, comprising radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays, as well as particle radiation (such as alpha, beta, and neutron particles), and acoustic radiation (in the forms of ultrasound and seismic waves). It is commonly classified into ionizing and non-ionizing categories; ionizing radiation possesses energies exceeding 10 eV, sufficiently potent to disrupt chemical bonds in atoms and molecules. This distinction is crucial due to the substantial variations in the detrimental effects of ionizing radiations on living organisms. A recent technological breakthrough involves the application of ionizing electromagnetic radiation across diverse domains, spanning from scientific research to industrial processes and medical practices [1, 2].

Ionizing radiation (IR), predominantly X-rays and emissions from radioactive substances, plays a pivotal role in both diagnostic and therapeutic medical applications [3, 4]. Despite its critical functions, ionizing radiation is globally recognized as a potential occupational hazard in workplaces, attributed to its capacity for causing biological harm [5, 6].

Negative biological consequences may occur if an individual is exposed at a level above the occupation exposure limit (OEL) recommended by the international commission on Radiological Protection [7,8]. The specified exposure limits are set at 20 mSv/year over a consecutive five-year duration, with a capped maximum effective dose of 50 mSv/year. Additionally, equivalent doses for the skin, hands, and feet are limited to 500 mSv/year, and for the lens of the eye, the restriction is set at 20 mSv/year over a defined five-year period, ensuring that no single year surpasses 50 mSv/year. It is noteworthy that, despite the utilization of appropriate personal protective equipment (PPE), individuals working with medical radiation unavoidably encounter prolonged exposure to low-dose ionizing radiation [9, 10]. Ionizing radiation is used in two-thirds of radiological operations for medical imaging equipment [11]. To ensure that the acceptable limits are not exceeded, occupational (industrial and medical) radiation professionals could be routinely observed using radiation Dosimetry, which is primarily used to protect against ionizing radiation [12].

Dosimeters are primarily used for human ionizing radiation monitoring and for assessing absorbed dosage in industrial and medical radiography. Finger dosimeters and work environment dosimeters are just two examples of the electronic personal dosimeters that are available [13]. Lummis the Instadose (Digital dosimeter) and the Thermoluninescene dosimeter (TLD) are the two most widely used personal radiation dosimeters in Nigeria [14]. It is on the other hand, combines four Thermoluminiscent detectors with anodized aluminum foil [15]. TLD, or Thermoluminescent Dosimeter, commonly consists of lithium fluoride activated with magnesium and calcium fluoride activated with manganese [16]. The dosimeter serves as a storage unit for the energy derived from ionizing radiation [17]. In the assessment process, TLD is usually subjected to heating at a temperature of 300 °C. This procedure facilitates the release of stored energy in the form of light, enabling the measurement of the radiation dose received by the device. The radiation dose each detector receives determines how much light is emitted [18]. The main advantages of TLD are its affordability, good tissue equivalent, simplicity of use, sensitivity, and accuracy. It is reusable and independent of environmental factors [19] and TLD was chosen as the dosimeter for this study because of the aforementioned benefits.

This work aimed to determine the health impact of low ionizing radiation of Professional radiation workers in some selected tertiary hospitals in south Eastern Nigeria.

## Materials and Methods

*Area of the Study*

The investigation was carried out in specific tertiary hospitals and a Radiodiagnostic Centre situated in the South-East region of Nigeria. These include the Federal Medical Centre (FMC) in Umuahia, Abia State (referred to as Centre A), the Federal Medical Centre (FMC) in Owerri, Imo State (center B), and the National Orthopedic Hospital (NOH) in Enugu State (center C). Each of these selected facilities is characterized by a substantial influx of patients, indicating a high volume of medical activities. Consequently, these hospitals and the radiodiagnostic center are anticipated to accommodate a considerable number of Medical Radiation Professionals due to the elevated patient flow.

*Design of the Study*

The research spanned from December 2018 to December 2020, with the data collection phase covering a duration of eighteen months, commencing from June 2019 and concluding in December 2020. A comparative cross-sectional study was undertaken to evaluate the impact of ionizing radiation on both Medical and Non-Medical Radiation workers. The study focused on individuals employed in selected government tertiary hospitals and a Radiodiagnostic Centre situated in the South-Eastern region of Nigeria.

*Population*

The work employed almost 42 Professional radiation workers working comprising of 3 Radiologist (one from each center), 30 Medical Radiographer (ten from each center), 3 Resident Doctors in Radiology (two from each center) and 3 Medical Physicists (one from each centre) were examined in the selected Hospital and Radio-diagnostic center.

The study recruited 42 Healthy controls from other department and units not involved in any radiation activities, with equal age range, gender, and place of residence with the exposed workers were taken. Hence a total of 84 personnel was examined.

*Inclusion and Exclusion Criteria*

All workers in good health with one-year tenure (1 year) and beyond and the radiation workers who work with ionizing radiation were included for this study. Individuals, including those with exposure and those without exposure, who are pregnant, individuals with a documented history of diabetes mellitus, cardiovascular diseases and malignancy, those who have taken chemotherapy or radiotherapy, those who are smoker and radiation workers working with Non-ionizing radiation were all excluded.

*Variables*

The dependent variable in this research is radiation parameters while the variables that are independent encompass gender, workplace/hospital location, utilization of protective equipment, and work experience.

*Sampling Method*

Data for the study were collected using a convenient sampling method from the study site, with participants being actively engaged in their work during the data collection process. Convenience sampling is a non-probability method in which units are chosen to be part of the sample due to their accessibility to the researcher. In the context of medical research, convenience sampling frequently involves selecting clinical cases or participants readily available within a specific location, such as a hospital, or from database of a medical records. Sample size was determined by taking all Radiologists, Resident doctors in Radiology and Medical Radiographers/medical imaging scientists in the eight hospitals and radio-diagnostic Centre participants included in the study were those available throughout the data collection period, meeting the specified criteria, and willingly volunteering to participate by providing informed consent. A total of 84 participants were recruited for this study, comprising 42 apparently healthy occupational radiation-exposed workers and 42 apparently healthy and unexposed controls.

*Procedure for Data Collection*

Information concerning socio-demographic background, occupational history, and medical details, including exposure to mutagenic agents, safety precautions taken, exposure duration, use of therapeutic drugs, and smoking habits, was gathered through a questionnaire completed by each participant. This data played a crucial role in the process of including or excluding participants from the study. Physical Dosimetry was used to collect data on the absorbed dose of ionizing radiation by the radiation workers and Biological Dosimetry is used to collect data on the hematological parameter by all the participants.

*Physical Dosimetry*

Occupational exposure to ionizing radiation was consistently overseen using personal exposure measurement devices (Thermo luminescent dosimeter, TLD). The absorbed radiation dose measured in millisieverts using the TLD was compared with the values of International Commission on Radiological Protection (ICRP) 20 mSv/yr for radiation workers. The TLD badge contains the TLD chips (LiF). The calibration of both the TLD reader and chips took place at the secondary standard Dosimetry laboratory, located at the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan. This laboratory is responsible for maintaining radiation protection standards in Nigeria. The NIRPR serves as the custodian of the national secondary traceable, ensuring traceability to the IAEA standard laboratory in Vienna. Subsequently, the dosimeter chips were read at the TLD Laboratory, Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife. Nigeria and NNRA Laboratory University of Ibadan.

The preparation of the Thermoluminence Dosimeters was done at the TLD laboratory, Physics and Engineering Physics Department, Obafemi Awolowo University Ile-Ife Osun State and the Nigerian Nuclear Regulatory Authority Laboratory, Elizabeth Way University of Ibadan, Oyo State. The Harshaw Model 3500 manual TLD Reader was used for the thermoluninescene Dosimetry measurement. The TLD Reader is a personal computer driven manually operated table top instrument. The Harshaw 3500 reader reads a dosimeter per loading and accommodates a variety of TL configuration including chips, disk, rods and powder. The system comprises essential components, including the TLD Reader and the Windows Radiation Evaluation and Management System (WinREMS) Software, installed on a personal computer (PC). The PC is connected to the reader through a serial communication port.

*Calibration Procedure*

The primary goal of calibrating the TLD is to guarantee uniform responses among all dosimeters within a system when subjected to a specific radiation exposure. The Estimated Calibration Coefficient (ECC) serves as a multiplier applied to the reader output dosimeter within a designated group of dosimeters, which are maintained as calibration dosimeters. This ensures that each dosimeter's readings are appropriately adjusted. The purpose of reader calibration is to sustain a consistent output from the reader over time, utilizing a locally accessible source for convenience. This is achieved through the Reader Calibration Factor (RCF). The factor converts the raw charge data from the PMT (nacocoulombs) to dosimeteric units (rems) or generic unit using Equation (1) based on the report by [19].

$$\text{Exposure} = \frac{\text{Estimated Calibration Coefficient (ECC)}}{\text{Reader Calibration Factor (RCF)}} \quad (1)$$

*Data Analysis and Interpretation*

The results obtained from the TLD and hematological tests were input into the Statistical Package for Social Sciences (SPSS) software, specifically version 21, for comprehensive statistical analysis. The student t-test was applied to compare the radiation dose of radiation workers with Standard value of 20 mSv given by the ICRP, the t-test is also use to compare the hematological parameters of occupational radiation workers with the standard complete blood count Reference limits, and to compare the hematological parameters of healthy radiation professionals and healthy non-radiation workers.

The effects of ionizing radiation on the hematological parameters of radiation workers were compared using simple regression analysis. The findings were presented through tables, bar charts, and figures to effectively illustrate the results.

*Ethical Approval*

The study began following the receipt of ethical approval from the Ethical and Research Committees of each hospital and the Radiodiagnostic Centre.

*Statistical Analysis used for the study*

The statistical tools used for this study work includes the cumulative mean, standard deviation, and mean difference, as well as t-test.

*Mean Cumulative:* The cumulative mean is an approach employed statistically to computes the average of a set of numbers up to a specific moment in time or following a particular number of observations. This is given in Equation (2) according to [20].

$$\frac{\sum \text{Effective dose for n personel}}{\text{total number of personel (n)}} \quad (2)$$

The effective dose in mSv is given in Equation (3) according to [21].

$$\boldsymbol{E.D\ (Sv)} = \sum (W_R \times H_T) \quad (3)$$

Where $W_R$ is the radiation weighting factor and $H_T$ is the equivalent dose given in Equation (4) according to [21].

$$H_T = D_T \times W_R \quad (4)$$

Where,

$H_T$ = Equivalent dose, $D_T$ = Absorbed dose (Dose Measurement from the TLD readings for the n personnel), $W_R$ = Radiation weighting factor, and Weighting factor for x-ray = 1 [21].

*Standard Deviation:* The standard deviation is a measure of the average distance between each data point and the mean value within a set of data given in Equation (5) according to [22] as.

$$S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{X})^2}{n-1}} \quad (5)$$

Where,

S= Standard Deviation = Square root of Variance, n = 84, and $\bar{x}$ = cumulative mean.

*Mean Difference:* Difference in means, quantifies the absolute disparity between the average values of two distinct groups. In clinical trials, it provides insight into the extent of variation between the averages of the experimental group and control groups. This is given in Equation (6) according to [23].

$$\text{Mean Difference } = \bar{X}_A - \bar{X}_B \quad (6)$$

*T-test:* The t-test is a statistical tool used for comparing the means of two groups, commonly employed in hypothesis testing to determine whether a specific procedure or treatment has a significant impact on the population of interest or if there is a discernible difference between two groups [24,25].

A t-test can be utilized to assess whether a single group differs from a known value (one-sample t-test) or whether two groups differ from each other (independent two-sample t-test). In this study, it is employed to compare the mean cumulative radiation dose with the international standard dose recommended by ICRP [26, 27]. The t-test statistic for evaluating the significance of the difference between means of two groups is expressed as pointed out by [26, 27] in Equations (7), (8), and (9):

$$t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{S_A}{n_A} + \frac{S_B}{n_B}}} \quad (7)$$

$$\bar{X}_A = \frac{\sum_{i=1}^{n} X_A}{n_A} \quad (8)$$

$$\bar{X}_B = \frac{\sum_{i=1}^{n} X_B}{n_B} \quad (9)$$

Where, $\bar{X}_A$ is the mean of the sample for group A, $\bar{X}_B$ is the sample average of group B, $S_A$ is the standard deviation of group A, $S_B$ is the standard deviation of group B, $n_A$ is the number of observation in group A, and $n_B$ is the number of observation in group B [28]. Equation (8) and 9 are the equations for the sample mean of group A and B respectively.

## Results and Discussion

In this section, the population of the personnel employed for the study is presented in Table 1 while the mean doses, mean differences and t-Test from the study centers are presented in Table 2.

**Table 1** Population of the personnel employed for the study

| Personnel | Medical Workers | | | | Non- Medical Workers | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | Total | A | B | C | Total |
| Radiologists | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 |
| Radiographers | 10 | 10 | 10 | 30 | 10 | 10 | 10 | 30 |
| Resident Doctors | 2 | 2 | 2 | 6 | 2 | 2 | 2 | 6 |
| Medical Physicists | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 |
| Total | 14 | 14 | 14 | 42 | 14 | 14 | 14 | 42 |

**Table 2:** Mean doses, mean differences and t-test from the study centers

| Centers | Medical Workers Dose (mSv) | Non- Medical Workers Dose (mSv) | Mean Difference | t-Test | p-Value | MPL |
|---|---|---|---|---|---|---|
| Centre A | 0.9160±0.2248 | 0.6247±0.2561 | 0.2913 | 1.260185 | 0.2111 | 5 |
| Centre B | 0.7726±0.1374 | 0.5687±0.1413 | 0.2039 | 1.727284 | 0.08784 | 5 |
| Center C | 0.7204±0.1561 | 0.4429±0.1546 | 0.2775 | 1.724579 | 0.08833 | 5 |

Based on the data presented in Figure 2, center (A) has the highest effective dose for medical workers with mean value of 0.9160±0.2248 mSv, followed by center (B) with mean value of 0.7726±0.1374 mSv, then center (C) with the lowest mean value of 0.7204±0.1561. in the case of non-medical workers, same trend was obeyed, with center (A) having the highest mean value of 0.6247±0.2561 mSv, followed by center (B) with mean value of 0.5687±0.1413 mSv, and then center (C) with the lowest mean value of 0.4429±0.1546 mSv.

On the other hand, it could be understood from the table that, the medical workers are subjected to higher dose compared to the non-medical workers. Although, the mean difference indicated a just a slight variation between the medical and the non-medical workers. The high values in medical workers compared to non-medical workers may be due to their closeness with the medical radiation facilities.

The t-test values computed and presented in Table 2 for each center suggest the results of a statistical test, which is commonly used to compare the means of two groups and assess whether the observed differences are statistically significant. Centre (A) (t = 1.260185) indicates a moderate difference between the groups associated with medical and non-medical workers in center (A). Centre (B) (t = 1.727284) suggests a relatively larger difference between the medical and non-medical workers in center (B) compared to center (A). Centre (C) (t = 1.724579) has a t-Test value similar to center (B), indicating a similar magnitude of difference. The p-values you provided in Table 2 correspond to each center's t-test and are associated with a two-tailed test with a significance level (α) of 0.05.

Centre (A) (p = 0.2111) (Figure 1) is higher than the significance level of 0.05 This showed that the observed difference in means for Centre (A) is statistically significant at the 0.05 level.

Centre (B) (p = 0.08784) (Figure 2) is less than 0.05 but still relatively high indicating that the result is suggestive but not conclusive. The observed difference in Centre (B) suggests that the observed difference is statistically significant.

Centre (C) (p = 0.08833) (Figure 3) is also less than 0.05 but still relatively high which implies that the result is not highly significant. The observed difference in Centre (C) suggests that the observed difference is statistically significant.

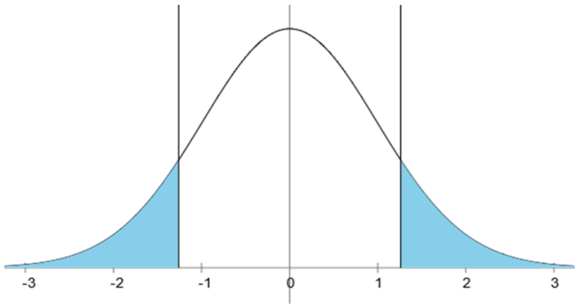


**Figure 1** The p-value plot of Centre (A)

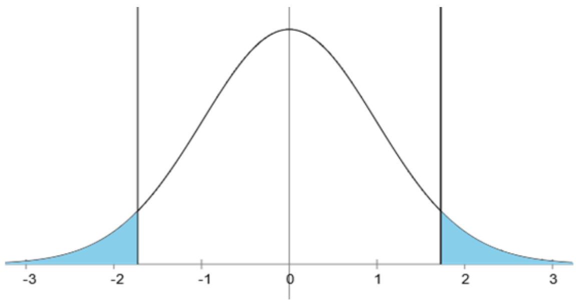


**Figure 2** The p-value plot of Centre (B)

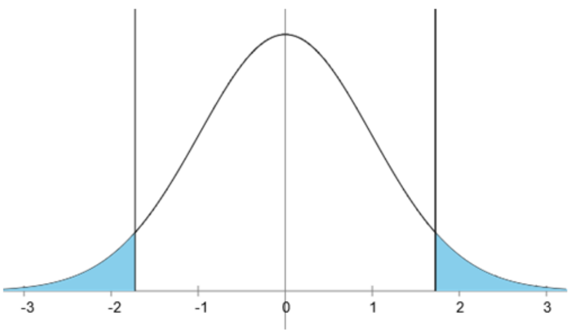


**Figure 3** The p-value plot of Centre (C)

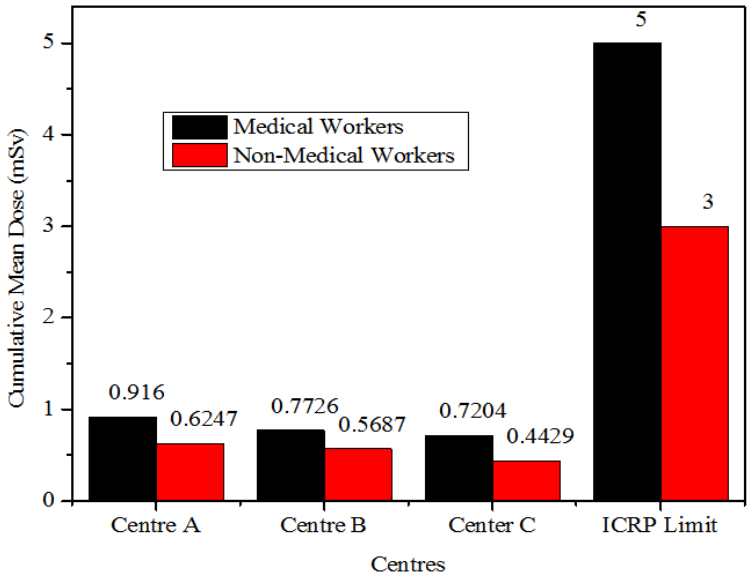


**Figure 4** Comparison of cumulative mean dose for various centers with ICRP limits

Based on the observation from the chart above (Figure 4), the medical workers for all centers have higher doses than the non-medical workers. Interestingly, all these doses fall below the doses prescribed by International Commission on Radiological Protection (ICRP).

## Discussion

The data presented in Figure 2 illustrates that among medical workers, Centre (A) exhibits the highest effective dose with a mean value of 0.9160±0.2248 mSv, followed by Centre (B) with a mean value of 0.7726±0.1374 mSv, and Centre (C) with the lowest mean value of 0.7204±0.1561 mSv. Similarly, for non-medical workers, the trend persists, with Centre (A) having the highest mean value of 0.6247±0.2561 mSv, Centre (B) following closely with a mean value of 0.5687±0.1413 mSv, and Centre (C) exhibiting the lowest mean value of 0.4429±0.1546 mSv. Notably, medical workers consistently experience higher doses compared to their non-medical counterparts, albeit with only a slight mean difference. This discrepancy is attributed to the proximity of medical workers to radiation facilities. This results not in line with the one reported by Maikudi *et al.* (2016) [29] who worked on the Occupational Radiation Monitoring in Tertiary Health Institutions of Northwestern Nigeria. The t-Test values presented in Table 2 further confirm these findings, indicating moderate to relatively larger differences between medical and non-medical workers in each center.

The computed p-values in Figure 1 for Centre (A) ($p = 0.2111$) are higher than the significance level of 0.05, signifying a statistically significant difference in means for Centre (A) at the 0.05 level. In Figure 2, Centre (B) ($p = 0.08784$) shows a p-value less than 0.05 but still relatively high, suggesting a result that is suggestive but not conclusive. The observed difference in Centre (B) is deemed statistically significant. Similarly, Figure 3 reveals that Centre (C) ($p = 0.08833$) has a p-value less than 0.05, although relatively high, indicating a statistically significant difference. Therefore, all three centers demonstrate statistically significant differences in means between medical and non-medical workers.

According to Figure 4, which compares the cumulative mean dose for various centers with International Commission on Radiological Protection (ICRP) limits, it is evident that medical workers in all centers receive higher doses than non-medical workers. Remarkably, despite these elevated doses, all values remain below the prescribed ICRP limits, emphasizing the adherence to safety standards.

## Conclusion

A research to determine the health impact of low ionizing radiation of Professional radiation workers in some selected tertiary hospitals in south Eastern Nigeria was conducted by comparing their doses with non-medical radiation workers and ICRP. The study employed medical and non-medical workers from three (3) different hospitals such as Federal Medical Centre (FMC), Umuahia, Abia State (center A), Federal Medical Centre (FMC), Owerri, Imo State (center B) and National Orthopedic Hospital (NOH), Enugu State (center C). The data analysis reveals distinct dose variations between medical and non-medical workers across the three centers. The statistical significance assessed through t-test values and p-value plots underscores the reliability of these differences.

Furthermore, the adherence to ICRP limits indicates a commitment to maintaining radiation exposure within internationally recognized safety thresholds. This comprehensive evaluation contributes valuable insights into the health impact of ionizing radiation on professional radiation workers in the selected tertiary hospitals in South Eastern Nigeria.

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