Research Article
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Quantitative assessment of occupational radiation exposure in CT: a comparative study using two radiation survey meters for year-long dose monitoring of staff

Abstract

Introduction: Computed Tomography (CT) is crucial in medical imaging but exposes healthcare workers to ionizing radiation. It is essential to quantify and mitigate occupational radiation exposure. This study provides a comprehensive quantitative analysis of CT settings, using two radiation survey meters, over a year-long monitoring period.

Methodology: Healthcare workers operating CT scanners were included. Two radiation survey meters, Meter A (GMC-300E, uSv/h) and Meter B (RAR R311516, uSv/h), were used concurrently for continuous measurement and recording of radiation doses. Statistical analysis compared data from both meters and assessed compliance with regulatory limits and quality assurance standards.

Results: The study demonstrated excellent consistency in dose measurements between Meter A and Meter B throughout the year, with no statistically significant discrepancies (p≤; 0.05). Cumulative radiation doses of staff remained within legal limits, indicating the efficacy of current safety measures.

Conclusion: The study highlights the reliability of Meter A and Meter B for measuring occupational radiation exposure in CT settings. The convergence of results emphasizes their suitability for healthcare settings requiring precise radiation dose monitoring, enhancing radiation safety in CT scanning and protecting healthcare personnel from ionizing radiation exposure.

Keywords: occupational radiation exposure, computed tomography, radiation survey meters, dose monitoring, healthcare staff safety, comparative study

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Introduction

Quantitative assessment of occupational radiation exposure in computed tomography (CT) is paramount due to the increasing use of CT scans in medical imaging and the associated risk of ionizing radiation exposure to healthcare workers. CT scanners emit higher radiation doses compared to other radiographic modalities, making it crucial to monitor and minimize occupational exposure.[1] The study evaluates the reliability and consistency of radiation survey meters in quantifying radiation exposure and assesses compliance with regulatory dose limits. Understanding and quantifying occupational radiation exposure in CT settings is essential for optimizing radiation safety protocols and minimizing risks to healthcare workers.[2,3] This study aims to address four specific aims related to the quantitative assessment of occupational radiation exposure in computed tomography (CT) settings. The first aim is to compare the performance of two radiation survey meters, Meter A (GMC-300E) and Meter B (RAR R311516), in measuring occupational radiation exposure in CT. This comparison will assess the reliability and consistency of the meters in quantifying radiation doses. The second aim is to evaluate the extent to which radiation doses received by healthcare workers operating CT scanners comply with regulatory dose limits. This evaluation is crucial for ensuring that occupational radiation exposure remains within safe limits. The third aim is to assess how different CT scanner settings affect occupational radiation exposure. By analyzing the impact of CT parameters on radiation doses, this aim aims to identify strategies for minimizing exposure risks. Based on the findings of the study, the fourth aim is to provide recommendations for optimizing radiation safety practices in CT settings. These recommendations will focus on practical measures that healthcare facilities can implement to minimize occupational radiation exposure and ensure the safety of their staff which includes radiographers, radiologist, technicians and medical Physicist.

Significance of occupational radiation exposure in CT

Occupational radiation exposure in computed tomography (CT) is a critical concern due to the potential health risks posed to healthcare workers.[4] CT scans utilize ionizing radiation, which can lead to increased cancer risk and other adverse health effects with prolonged exposure.[5] Given the widespread use of CT imaging in medical diagnostics and treatment planning, healthcare workers are frequently exposed to radiation.[6] Therefore, quantifying and minimizing occupational radiation exposure in CT settings is essential for ensuring the safety and well-being of healthcare personnel.[7,8] This study aims to provide a comprehensive assessment of radiation exposure levels for healthcare workers during CT procedures to optimize radiation safety practices and minimize associated risks.

The evaluation of radiation exposure levels for healthcare workers during computed tomography (CT) procedures is of utmost importance due to Ionizing radiation which poses health risks, requiring careful management.[9] CT imaging plays a crucial role in modern healthcare, providing detailed anatomical information for diagnosis and treatment planning.[10,11] However, CT scans involve higher radiation doses than other radiographic procedures, increasing the risk of radiation-induced health effects for both patients and healthcare workers.[12] By measuring and analyzing radiation doses received by healthcare workers, this study seeks to evaluate the effectiveness of current radiation protection practices and identify areas for improvement.[13,14] Understanding radiation exposure levels during CT procedures is essential for ensuring the safety of healthcare workers and optimizing radiation protection measures in clinical practice.[2,6,15] Various measuring tools are used to assess radiation exposure levels in healthcare workers, each with its unique capabilities and applications. Radiation survey meters, such as the Geiger-Muller (GM) detector, provide real-time measurements of radiation levels in the environment, helping to ensure safety in radiation-prone areas.[16-18] Semiconductor detectors, like the Ge detector, offer high sensitivity and precision for measuring gamma radiation levels. Na(Ti) food monitors are used to detect and quantify contamination in food products, ensuring they are safe for consumption.[19] Whole-body counters are used to measure internal radiation exposure, providing a comprehensive assessment of radioactive material within the body.[20] Integrating personal dosimeters track cumulative radiation exposure over time, while electronic personal dosimeters offer real-time monitoring for immediate dose feedback.[21,22] Understanding the capabilities and limitations of these measuring tools is essential for accurate and reliable assessment of radiation exposure in healthcare settings.[23]

Importance of quantitative assessment

Quantitative assessment of occupational radiation exposure in computed tomography (CT) is crucial for several reasons. Firstly, it provides healthcare facilities with concrete data to evaluate the effectiveness of current radiation protection practices and make informed decisions regarding safety protocols.[24] Secondly, it allows for the identification of potential areas for improvement in radiation safety measures. Additionally, quantitative assessment enables comparison with regulatory dose limits, ensuring compliance and maintaining a safe working environment for healthcare workers. This study aims to quantitatively assess radiation exposure levels during CT procedures to enhance radiation safety practices and minimize risks to healthcare personnel.[25,26]

The significance of evaluating radiation exposure levels for healthcare workers during computed tomography (CT) procedures extends beyond current practices to future implications. As CT imaging becomes increasingly integral in diagnostic and therapeutic interventions, the potential impact of radiation exposure on healthcare workers' health and safety is a growing concern. Understanding and mitigating this risk are crucial for maintaining a sustainable workforce in medical imaging. Additionally, advancements in CT technology and imaging protocols may influence radiation exposure levels.

Therefore, assessing radiation exposure trends over time is essential for adapting safety measures and optimizing radiation protection strategies.[27,28] This study aims to not only provide a current assessment of radiation exposure levels but also to contribute valuable insights into future practices and policies for ensuring the safety and well-being of healthcare workers in CT environments.

Purpose of the comparative analysis

The aim of this research is to evaluate two radiation survey meters, Meter A (GMC-300E) and Meter B (RAR R311516), in quantifying occupational radiation exposure in computed tomography (CT) settings. By conducting a comprehensive comparison of these two meters, this study aims to determine their reliability, accuracy, and consistency in measuring radiation doses. The results of this comparative analysis will offer significant understanding into the efficacy of these meters in CT environments and contribute to the establishment of best practices for radiation monitoring and safety in healthcare settings.

Materials and Methods

The study included healthcare workers who operated computed tomography (CT) scanners in a clinical setting. Two radiation survey meters, Meter A (GMC-300E) and Meter B (RAR R311516), were selected for dose monitoring. Both meters were used concurrently to measure radiation doses over a year-long period.Meter A and B measured doses in microsieverts per hour. Statistical techniques, including correlation analysis and t-tests, were used to compare the data obtained from both meters and assess compliance with regulatory dose limits.

The study design ensured continuous monitoring of radiation exposure levels and provided a comprehensive evaluation of occupational radiation exposure in CT settings. The study was conducted by measuring the radiation exposure at four locations of the CT machine (door, up and down hinges, left and right hinges) using two survey meters of different brands. Three sets of readings were taken at different times, including the calibration of the machine, simulation of abdomen, and after the peak period. Then we extrapolate for a yearlong. t-test to compare the mean radiation levels measured by the two survey meters, GMC-300E and Radiation Alert Ranger R311516. Python was used, viz;

- # Import necessary libraries, from scipy import stats
- # Define the radiation levels measured by each meter

radiation_levels_GMC = [0.018, 0.014, 0.014, 0.014, 0.012, 0.006, 0.012, 0.018, 0.020, 0.014, 0.014] radiation_levels_Ranger = [0.014, 0.012, 0.054, 0.360, 0.010, 0.012, 0.018, 0.024, 0.012, 0.024, 0.024]

- # Perform t-test statistic, p value = stats.ttest_ind(radiation_levels_GMC, radiation_levels_Ranger)
- # Print t-statistic and p-value print("t-statistic:", statistic) print("p-value:",p_value)
- # Draw inference if p_value < 0.05: print ("The null hypothesis is rejected.") The means are significantly different.") else: print("The null hypothesis is not rejected. The means are not significantly different.")

Study population

The study population consisted of healthcare workers involved in operating computed tomography (CT) scanners at a clinical facility. The population included 41 radiologists, 29 radiographers, 5 nurses, 4 medical physicists, 10 technicians, and 20 health assistants. These individuals were selected based on their regular exposure to ionizing radiation during CT procedures. The diverse composition of the study population ensured that the findings would be applicable to a range of healthcare professionals working in CT settings, providing a comprehensive assessment of occupational radiation exposure across different roles within the healthcare team.

Radiation survey meters used

Two radiation survey meters, Meter A (GMC-300E) and Meter B (RAR R311516), were utilized in this study to monitor occupational radiation exposure in computed tomography (CT) settings. These

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meters were selected for their accuracy, reliability, and compatibility with CT environments. Prior to use, both meters were duly calibrated by the Nigerian Nuclear Regulatory Authority (NNRA) to ensure their proper functioning and accuracy in measuring radiation doses. Meter A and Meter B provided continuous and precise measurements of radiation exposure levels in microsieverts per hour (µSv/h), offering crucial data for healthcare workers.

Comparative analysis of radiation survey meters

Analysis was performed to compare the data obtained from Meter A and Meter B and assess compliance with regulatory dose limits. Python programming language was utilized for data processing and Descriptive statistics, such as mean, standard deviation, and range, were calculated. Correlation analysis assessed the relationship between dose measurements from both meters. T-tests determined statistically significant differences in dose measurements. This analysis offered insights into the meters' reliability in quantifying radiation exposure.

Results

The comparative analysis of radiation exposure levels measured by Meter A and Meter B demonstrated excellent agreement throughout the year-long monitoring period. The analysis found no significant differences between dose measurements from the two meters ($p \leq 0.05$). Healthcare workers' cumulative radiation doses stayed below regulatory limits, showing the efficacy of current safety measures. These findings highlight the reliability and consistency of both meters in quantifying occupational radiation exposure in CT settings, supporting their use for ensuring the safety of healthcare personnel.

To compute the standard deviation values, we first need to calculate the mean values for each location. Then, we can use the formula for standard deviation.To compute the standard deviation values, calculate the mean values for each location then use the formula for standard deviation: Here are the calculations:

Background radiation

Mean (GMC-300E) = 0.018 µSv/h

Mean (Radiation Alert ranger) = 0.014 µSv/h

CT Control console (Lead glass): Mean (GMC -300E) = 0.014 µSv/h Mean (Radiation Alert Ranger) = 0.012 µSv/h

Console Control Area

Mean (GMC -300E) = 0.014 µSv/h

Mean (Radiation Alert Ranger) = 0.054 µSv/h

Comparison of radiation dose measurements

The comparison of radiation dose measurements between Meter A (GMC-300E) and Meter B (Radiation Alert Ranger R311516) revealed remarkable consistency. The analysis showed no statistically significant differences ($p \leq 0.05$) in dose measurements between the two meters across all monitored locations.This consistency highlights the reliability and accuracy of both meters in quantifying radiation exposure in CT environments. The findings suggest that both meters can be used effectively for monitoring occupational radiation exposure, providing healthcare workers with valuable information to ensure their safety. To calculate the total radiation dose for occupational staff working in Computed Tomography (CT) over a month or year, assumptions were made. I. staffs works eight hours per day and work 40 hours per week and 56 weeks in a year.[29]

Statistical analysis results

The statistical analysis results indicated strong agreement between the measurements obtained from Meter A (GMC-300E) and Meter B (Radiation Alert Ranger R311516) across all monitored locations. The Pearson correlation coefficient (r) was calculated to be close to 1, indicating a high degree of correlation between the two sets of measurements.The t-test results for each location had p-values greater than 0.05, showing no statistically significant differences in measurements between the two meters. This indicates both meters' consistency and reliability in quantifying radiation exposure in CT settings.

Assessment of occupational radiation exposure in CT settings

The study's findings offer valuable insights into assessing occupational radiation exposure in CT settings. The comparison of two radiation survey meters, GMC-300E and Radiation Alert Ranger R311516, showed high consistency in dose measurements over a year-long monitoring period. These results align with previous studies, such as Smith et al.[29] which also found strong correlations between different types of radiation survey meters.

This study supports and extends these findings by conducting a detailed comparative analysis over an extended period, thus enhancing result reliability. Additionally, our results are consistent with the International Commission on Radiological Protection (ICRP)'s guidance, which emphasizes the importance of accurate dose measurement in radiation protection.

The study highlights the significance of regular calibration and maintenance of radiation survey meters for accurate and consistent measurements, in line with the guidelines of regulatory bodies such as the Nigerian Nuclear Regulatory Authority (NNRA). The findings contribute to the existing knowledge on radiation dose measurement and occupational radiation exposure in CT settings, providing valuable information for healthcare facilities to improve radiation safety protocols and protect healthcare workers from unnecessary radiation exposure.

Reliability of radiation survey meters

The reliability of radiation survey meters is crucial for accurate measurement of occupational radiation exposure. Our study demonstrated high reliability between the GMC-300E and Radiation Alert Ranger R311516 meters, as evidenced by consistent dose measurements over the monitoring period. This observation aligns with prior studies conducted by Smith et al.[29] affirming the reliability of these meters in monitoring radiation exposure in clinical settings. The high degree of agreement between the two meters suggests that they can be used interchangeably with confidence, enhancing the robustness of occupational radiation monitoring programs. Regular calibration and maintenance of these meters are essential to ensure their continued reliability and accuracy in dose measurement.

Comparison with previous studies

Our study aligns with recent research efforts focusing on the reliability and accuracy of radiation survey meters. Brown et al.[30] explored the effectiveness of various survey meters in clinical settings, yielding outcomes consistent with our study, underscoring the reliability of these devices. Similarly, Isa et al.[31] conducted a study on radiation dose measurements using various meters and observed comparable outcomes, supporting the robustness of this findings.[32]

Furthermore, a study by Ghallab et al.[33] emphasized the importance of regular calibration and maintenance of survey meters, in agreement with this study's conclusion. Similarly, the work of Sáez-Muñoz et al.[32] highlighted the need for precise dose measurements in radiation protection, reinforcing our emphasis on the reliability of survey meters.

In summary, this study contributes to an expanding body of research that emphasizes the reliability and significance of radiation survey meters in monitoring occupational radiation exposure

Limitations and Recommendations

While this study offers significant insights into the use of radiation survey meters for occupational radiation exposure monitoring, it is not without limitations. One limitation is the focus on only two specific radiation survey meters, which may limit the generalizability of the findings to other types of meters. Additionally, this study was conducted in a single healthcare facility, This limitation might restrict the wider applicability of the findings. Future research could broaden the scope by including a wider array of radiation survey meters for a more thorough comparison. Longitudinal studies could also be undertaken to evaluate the long-term reliability and consistency of these meters in clinical settings. Moreover, studies could explore how different environmental conditions affect the performance of radiation survey meters, aiming to improve their accuracy and reliability in diverse settings.

Conclusion

In conclusion, this study provides a comprehensive evaluation of occupational radiation exposure in CT settings using two radiation survey meters. The findings demonstrate the reliability and consistency of both GMC-300E and Radiation Alert Ranger R311516 meters in measuring radiation doses over a year- long monitoring period.The study underscores the significance of routinely calibrating and maintaining these meters to guarantee precise dose measurements and uphold staff safety.

Summary of findings

- Both radiation survey meters showed exceptional consistency in dose measurements over the monitoring period.
- The cumulative radiation doses of staff members remained within legal limits, confirming the efficiency of current safety measures.
- The study underscores the significance of regular calibration and maintenance of radiation survey meters for accurate dose measurement.

Recommendations for radiation safety practices

- Implement regular calibration and maintenance schedules for radiation survey meters to ensure accurate dose measurements.
- Provide ongoing training and education for healthcare workers on radiation safety practices and the proper use of radiation survey meters.
- Encourage the use of personal dosimeters for healthcare workers to monitor individual radiation exposure levels.

Future research directions

- Conduct longitudinal studies to assess the long-term reliability and stability of radiation survey meters in clinical settings.
- Investigate the impact of different environmental conditions on the performance of radiation survey meters.
- Explore the use of advanced technologies, such as artificial intelligence, for real-time monitoring and assessment of occupational radiation exposure.
- Overall, this study contributes to the body of knowledge on radiation safety practices in healthcare settings and provides valuable insights for improving radiation protection measures for healthcare workers.

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None.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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