

Comparative Evaluation of X-Ray Shielding Materials in Hospitals in Enugu Metropolis, Nigeria, and Their Compliance with Global ICRP Standards

Madu, Edward Ikechukwu¹, Chidi Uhuegbu²

¹ Post Graduate Student, Department of Physics, Godfrey Okoye University, Enugu

² Dean, Faculty of Physical and Geosciences, Godfrey Okoye University, Enugu

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Abstract: Medical diagnostic and therapeutic procedures involving X-rays have become integral to modern healthcare, enabling clinicians to make accurate diagnoses and provide targeted treatments for various medical conditions. However, the use of X-rays poses potential health risks to both patients and healthcare workers due to exposure to ionizing radiation. Shielding materials are essential to mitigate these risks by effectively attenuating radiation. This study aims to evaluate the current usage of X-ray shielding materials and the extent to which they align with the recommended global standards set by the International Commission on Radiological Protection (ICRP). The goal is to enhance the safety of patients and healthcare workers by ensuring the proper use of shielding materials in hospitals. By comparing current practices with global standards, the research seeks to identify gaps in radiological protection—crucial for minimizing harmful radiation exposure and safeguarding the health of individuals in medical facilities. Additionally, the study aims to highlight areas for improvement to ultimately enhance radiation safety practices. A total of 109 respondents from 46 healthcare facilities participated in the study. These respondents included radiologists, radiology technicians, and radiology assistants working in hospitals with functional radiology departments utilizing X-ray machines within the study area. The study employed a descriptive cross-sectional research design to systematically collect and analyze data from randomly selected hospitals in the Enugu metropolis, using structured questionnaires. For each facility, the modal score was used. Privately owned facilities made up 70% of the total, followed by faith-based (13%) and government-owned facilities (13%), with only 4% owned by corporate organizations. In terms of healthcare levels, secondary health facilities constituted the largest proportion (33%), followed by primary health facilities (30%), specialist facilities (26%), and tertiary health facilities (11%). The findings reveal significant variation in compliance with the recommended global standards, with compliance levels ranging from high to medium and low across different facility types and ownership categories. Factors influencing compliance were also identified. Private-for-profit facilities demonstrated the highest level of adherence, with 82% of their facilities achieving high compliance. Faith-based and corporate organizations each accounted for 7% of the high compliance group, while government-owned facilities lagged behind, contributing only 4% to the high compliance category.

I. Introduction

Medical diagnostic and therapeutic procedures involving X-rays have become integral components of modern healthcare, revolutionizing medical practice by enabling accurate disease diagnosis and targeted treatment interventions (Hussain et al., 2022; Nabrawi and Alanazi, 2023; Najjar, 2022). Despite their immense benefits, X-rays pose potential health risks due to ionizing radiation exposure, necessitating the implementation of protective measures to safeguard both patients and healthcare workers. The use of X-ray shielding materials plays a critical role in reducing these risks by attenuating radiation to acceptable levels, thereby ensuring radiation safety within medical facilities (Salama et al., 2016).

Radiation shielding is a core principle of radiation protection, and its effectiveness depends on the appropriate selection and application of shielding materials (Kim, 2018). Materials such as lead aprons, lead-lined walls, leaded glass, and protective barriers are strategically positioned in X-ray rooms to reduce unnecessary exposure. Ensuring compliance with international radiation protection standards is crucial for maintaining a safe medical environment (Kim, 2018). The International Commission on Radiological Protection (ICRP) provides globally recognized guidelines for radiation protection, including recommended specifications for X-ray shielding materials. These standards aim to optimize protection for patients, healthcare workers, and the public while balancing the diagnostic and therapeutic benefits of radiation (Do, 2016). The ICRP also provides specific recommendations regarding the types, thicknesses, and placement of shielding materials required to minimize radiation hazards while maintaining the effectiveness of diagnostic imaging and treatment procedures (Do, 2016). Compliance with these standards is critical, as inadequate shielding or the use of substandard materials can result in unnecessary radiation exposure, leading to long-term health consequences such as cancer, genetic mutations, and radiation-induced injuries (Clement et al., 2021). Several studies have assessed the adequacy of radiation shielding and safety practices in X-ray facilities across different regions within and outside Nigeria which includes:

Samson et al (2020) – *Jos, Nigeria* they Evaluated the required thickness of shielding materials (lead, concrete, gypsum, steel, plate glass, and wood) in a rural hospital's X-ray facility. Their findings reveals that radiation doses in unshielded areas were excessive; the shielding thickness did not meet international standards, indicating insufficient protection for patients and staff.

Abdulkareem et al. (2023) – *Gombe, Nigeria* assessed the effectiveness of three shielding barriers (concrete + lead, wood, and wood + glass) using a Rados 200 survey meter during radiological procedures. Their findings indicate that Concrete plus lead was identified as the most effective shielding material in reducing scattered radiation exposure.

Ukerun-Akpesiri et al. (2023) – Warri, Delta State evaluated shielding efficiency at 11 radiography facilities using Annual Dose Rates (ADR) calculated from measured instantaneous dose rates (IDR's) and occupancy factors. The studies found that some facilities exceeded the 5 mSv/yr limit for controlled areas while others also exceeded the 1 mSv/yr limit for supervised areas. The study concluded that there was partial compliance with NCRP 147 standards and recommended **routine** quality control inspections.

Emmanuel et al. (2019) – Atlantique and Littoral, Benin Investigated compliance with standard radiation protection protocols in medical imaging units through a descriptive cross-sectional study. The findings reveal that Overall compliance was low (41.41%). Major deficiencies were found in: Radiation protection (33.01%), Protection processes (44.24%) Working environment and handler knowledge (11.67%)

The key take away from these studies are:

There is widespread inadequacy in radiation shielding across various regions.

Lead and concrete barriers are proven to be more effective than alternatives like wood or glass.

Many facilities do not comply with international safety standards, posing potential risks to staff and patients.

Routine quality control and staff training are critically needed to ensure radiation protection standards are upheld.

As in many other regions, hospitals and diagnostic centres in Enugu, Nigeria, extensively utilize X-ray technology for various diagnostic and therapeutic purposes. However, variations may exist in the choice, quality, and implementation of X-ray shielding materials across different hospitals, potentially leading to discrepancies in radiation protection measures. Understanding the current state of X-ray shielding material usage in hospitals within Enugu metropolis is essential for several reasons: effective shielding minimizes radiation exposure, ensuring the safety of patients, healthcare professionals, and the public. Ensuring that these materials meet international standards is essential for preventing unnecessary radiation risks. Compliance with global standards, such as those established by the ICRP, is vital for meeting national and international radiation protection regulations and ensuring quality healthcare delivery. Assessing discrepancies between locally used shielding materials and internationally recommended standards can help optimize hospital resources, update shielding infrastructure, and improve radiation safety practices.

Despite the crucial role of X-ray shielding materials in radiation protection, limited research has focused on evaluating their compliance with global standards, particularly in low- and middle-income settings. This study seeks to bridge this knowledge gap by assessing the current X-ray shielding materials used in Enugu metropolis, determining the extent to which the materials meet ICRP standards, and exploring reasons for non-compliance. Furthermore, the study aims to identify compliance levels, highlight gaps, and propose actionable recommendations to enhance radiation safety protocols in Enugu metropolis

Purpose of the Study

This study aims to assess the current usage, quality, and compliance rate of X-ray shielding materials across hospitals in Enugu metropolis, comparing local practices with ICRP-recommended global standards. It further explores the factors influencing non-compliance and offers actionable recommendations to improve radiation safety infrastructure and protocols

II. Methodology:

Descriptive cross-sectional research design was employed. Data were collected from 109 respondents across 46 hospitals through structured questionnaires, semi-structured interviews, and observation checklists. Hospitals were selected using a random cluster sampling technique, covering 50% of the wards in Enugu metropolis. Both qualitative and quantitative data were analyzed using IBM SPSS Statistics 26 and thematic analysis for insights into compliance, awareness, and challenges.

Study Area: The study was conducted in the Enugu metropolis of Enugu State, Nigeria. The metropolis comprises three Local Government Areas (LGAs) and forms the township area of the state.

Study Population

The study targeted radiologists, radiology technicians, and radiology assistants working in hospitals with functional radiology departments utilizing X-ray machines within Enugu metropolis.

Inclusion Criteria

Radiologists, radiology technicians, and radiology assistants working in hospitals with functional radiology departments using X-ray machines in Enugu metropolis and who consented to participate were included.

Exclusion Criteria

Hospitals without functional radiology departments, as well as professionals who did not consent to participate, were excluded.

Sample Size Estimation

To determine the appropriate sample size for this study, we considered the following factors; the total number of hospitals in Enugu metropolis, the desired confidence level, the margin of error, and the expected proportion of hospitals complying with ICRP standards. Given the specific nature of this study, we used Cochran's formula for sample size estimation for proportions:

$$n = \frac{Z^2 \times p \times (1-p)}{e^2}$$

Sampling Procedure

A random cluster sampling technique was employed to ensure a representative selection of hospitals across the Enugu metropolis. The 38 wards in the metropolis were designated as clusters. A complete list of these wards was compiled, and 50% (nineteen wards) were randomly selected using a simple random sampling method (balloting). Subsequently, a list of all hospitals providing radiology services within the selected wards was created. All hospitals within these wards were included in the study, and data were collected from radiologists, radiology technicians, and radiology assistants.

Data Collection

Data were collected using a combination of structured questionnaires, semi-structured interviews, and observation checklists. The structured questionnaires gathered quantitative data on the types and specifications of X-ray shielding materials in use, including material type, thickness, installation methods, and awareness of ICRP standards. Semi-structured interviews were conducted with hospital administrators, radiology department heads, and technicians to explore practices and challenges related to shielding. Observation checklists were used to directly assess the presence and condition of shielding materials, including thickness measurements and installation quality. Data collected included:

- Hospital type
- Staff knowledge of ICRP standards
- Availability and type of shielding materials
- Compliance with ICRP standards
- Thickness and installation quality of shielding materials

Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics 26. Descriptive statistics, including means, medians, standard deviations, frequencies, and proportions, were used to summarize the data. Compliance levels with ICRP standards were assessed through cross-tabulations. Qualitative data from interviews were analyzed using thematic analysis to identify key themes related to compliance challenges and awareness of X-ray shielding requirements.

Ethical Considerations

Ethical approval was obtained from the Enugu State Ministry of Health Ethical Review Committee. Informed consent was obtained from all participants prior to data collection. Data confidentiality and anonymity were strictly maintained throughout the study.

III. Results

A total of 109 respondents from 46 health facilities participated in the study. Of these hospitals, 70% were privately owned, 13% were faith-based (mission), another 13% were government-owned, and 4% were owned by corporate organizations. By classification, secondary health facilities made up the largest proportion (33%), followed by primary health facilities/diagnostic centres (30%), specialist health facilities (26%), and tertiary health facilities (11%).

Table 1: Percentage Compliance by Hospitals with Shielding Parameters

Parameters	% Compliance
Use of standard lead apron with lead or equivalent barriers	73%
Use of non-lead radiation shielding materials for patient protection	62%
Use of a remote-control switch or an exposure cord of appropriate length	56%
ICRP-standard lead-lined walls in X-ray rooms	91%
Mobile lead shields	78%
Radiation protection glasses for staff	69%

Monitoring staff radiation exposure with personal dosimeters	78%
Use of lead gloves	64%
Use of lead aprons for staff protection	78%
Use of radiation shielding materials for patients	69%
Compliance with ICRP-recommended thickness for diagnostic radiology	76%

Compliance Overview: Among the 46 facilities assessed:

- **High compliance** was observed in 60% of facilities
- **Medium compliance** in 20%
- **Low compliance** in 20%

Compliance by Facility Type

- **High Compliance:**
 - Secondary Health Facilities: 68% (19 facilities)
 - Primary Health Facilities: 32% (9 facilities)
 - Tertiary Health Facilities: 0%
- **Medium Compliance:**
 - Primary Health Facilities: 44% (4 facilities)
 - Tertiary Health Facilities: 33% (3 facilities)
 - Secondary Health Facilities: 22% (2 facilities)
- **Low Compliance:**
 - Secondary Health Facilities: 67% (6 facilities)
 - Tertiary Health Facilities: 22% (2 facilities)
 - Primary Health Facilities: 11% (1 facility)

Compliance by Facility Ownership

- **High Compliance:**
 - Private-for-Profit: 82% (23 facilities)
 - Faith-Based and Corporate: 7% each (2 facilities each)
 - Government Facilities: 4% (1 facility)
- **Medium Compliance:**
 - Private-for-Profit: 67% (6 facilities)
 - Government Facilities: 22% (2 facilities)
 - Faith-Based: 11% (1 facility)
- **Low Compliance:**
 - Faith-Based, Government, and Private-for-Profit: 33% each (3 facilities each)
 - No Corporate Organization reported low compliance

Key Findings

Private-for-Profit Facilities: Dominate the high compliance category but also appear in medium and low categories, indicating inconsistency.

Faith-Based and Government Facilities: Overrepresented in the low compliance category, suggesting a need for improved capacity and enforcement.

Tertiary Health Facilities: None achieved high compliance; 22% fell into the low compliance group, which is concerning.

Primary Health Facilities: Some showed high compliance, but many face challenges that affect consistent adherence.

Key Recommendations

Regular Refresher Training:

45.7% of respondents involved in monthly X-ray exposures (5–20+ shots) had not received any training in the past two years. Annual refresher training on X-ray shielding is recommended for all directly involved healthcare workers.

- **Annual Radiation Safety Audits:**

- Supported by 98% of respondents.
- Recommended for enforcement by regulatory authorities.

- **Radiation Safety Officers (RSOs):**

- 98% of respondents recommend appointing an RSO in each Service Delivery Facility (SDF) to oversee radiation safety compliance.

- **Visible Protocols for Equipment Replacement:**

- Written protocols for replacing damaged X-ray equipment should be displayed prominently in all SDFs.

- **Establish Radiation Safety Committees:**

- Endorsed by 97% of respondents.
- Committees would monitor implementation and advise management on radiation safety.

- **Provision of Personal Dosimeters:** All Radiation Health Workers (RHW's) should be equipped with dosimeters to monitor personal radiation exposure.

IV. Conclusion

This is the first study in Enugu to provide a comprehensive, data-driven evaluation of X-ray shielding practices relative to global benchmarks. It highlights critical gaps in infrastructure, training, and policy implementation. This study highlights the critical need to improve radiation safety practices in healthcare facilities across Enugu metropolis. Regulatory bodies must enforce regular inspections and ensure compliance with ICRP standards. Equipping RHW's with personal dosimeters and providing ongoing training are essential steps toward minimizing the stochastic effects of radiation and ensuring safe healthcare environments.

Furthermore, the findings from the study provides valuable data for hospital administrators and policymakers, enabling them to make informed decisions regarding the procurement, installation, and maintenance of X-ray shielding materials as well as improve institutional oversight on radiation protection in the state health care system.

V. Recommendations:

Further studies can be done on the effects of non-compliance to shielding standards on health workers especially for facilities with high X-ray monthly output and workers with over 5 years of consistent working experience. The government should also look into diagnostic centers to ensure things are done according to the international standard.

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