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Research Article

Evaluation of the Existing Radiation Protection Measures to Minimize Radiation Risks and Optimize Contrast-Enhanced X-Ray Procedures

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Abstract:

Effective radiation protection is critical to safeguard patients and healthcare professionals from the adverse effects of ionizing radiation during medical imaging. Despite advancements in contrast-enhanced X-ray imaging, concerns persist regarding increased exposure risks. This research aims to assess existing radiation protection measures, identify gaps, and recommend strategies to optimize safety and diagnostic efficacy. A structured questionnaire was developed and administered in-person to collect the data in six participating facilities on the demographics, adherence to radiation safety protocols, and compliance with optimization standards, radiation dose monitoring and recording system, and Quality assurance. Results reveal disparities in adherence to radiation protection standards, including insufficient staffing, limited use of personal protective equipment, and inadequate monitoring systems. Centres like FUTHBK and UDUTH demonstrate high compliance with radiation safety protocols, whereas SYHM, FMCG, YGH, and MSDC show significant gaps. Issues such as poor implementation of QA programs, non-availability of monitoring badges, and lack of training resources contribute to non-compliance. The findings emphasize the necessity for systematic training, robust QA frameworks, and institutional commitment to improving radiological safety and optimizing patient care.

Keywords: radiation safety; contrast-enhanced radiology; quality assurance; north-western Nigeria

1.Introduction

Protecting patients and medical personnel from the negative effects of ionizing radiation in medical imaging requires radiation protection. Although contrast-enhanced X-ray imaging and other radiological methods have greatly increased diagnostic accuracy, there are still worries regarding the possible increase in radiation exposure. To minimize radiation hazards to patients and workers and maximize diagnostic efficacy, effective radiation protective measures are required. This is especially crucial in areas like Northwest Nigeria, where dangerous conditions could worsen due to a lack of access to cutting-edge training and technology. The implementation of well-structured radiation safety processes has been demonstrated to minimize needless radiation exposure and guarantee adherence to global standards (Applegate, 2023; UNSCEAR, 2017)

In healthcare facilities in Northwest Nigeria, the challenges associated with radiation protection are multifaceted, involving infrastructure, policy, and awareness issues. Limited availability of protective equipment, inconsistent adherence to safety guidelines, and insufficient training of personnel are some of the factors influencing radiation safety practices. Addressing these issues requires a comprehensive evaluation of existing measures and a multidisciplinary approach involving policymakers, healthcare providers, and radiological technologists. This research will fill the knowledge gap by providing evidence-based insights and actionable recommendations to mitigate radiation risks while optimizing contrast-enhanced radiological procedures in the region (Eze *et al.*, 2013).

The general objective of this study is to evaluate the existing radiation protection measures implemented during contrast-enhanced radiological X-ray procedures in Northwest Nigeria. It aims to identify gaps in current practices, assess the effectiveness of these measures, and propose strategies for optimizing radiation safety. By focusing on local healthcare settings, this study seeks to provide region-specific recommendations that align with global best practices in radiological safety. Ensuring the adoption of such measures can contribute to sustainable radioprotection and enhance the overall quality of healthcare services (WHO, 2018).

2.0 Material and Method

2.1 Study Area and Population

The study was conducted in several tertiary healthcare institutions across some states in North-Western Nigeria, including Kebbi, Sokoto, and Zamfara. These states were selected based on the availability and accessibility of radiological services and contrast-enhanced procedures in their major hospitals. The target population included radiologists, radiographers, medical physicists, and other healthcare professionals involved in radiological procedures at public and private healthcare facilities in North Western Nigeria.

2.2 Study Design

A cross-sectional, questionnaire-based study was conducted to evaluate the existing radiation protection measures aimed at minimizing radiation risks and optimizing contrast-enhanced radiological X-ray procedures in selected states of North-Western Nigeria. The study targeted healthcare facilities, including hospitals, clinics, and diagnostic centres, that offer contrast-enhanced radiological X-ray procedures. The study was carried out over a period of six weeks (**November - December, 2024**). Ethical approval was obtained from the relevant institutional review boards before the commencement of the study.

2.3 Data Collection Instrument

A structured questionnaire was developed to collect the data in six participating facilities on the following aspects

- **Demographic information:** Name of facilities, Age range, gender, role, and years of experience of respondent
- **Radiation Safety Measures:** Frequency of contrast enhanced radiological procedures, Policies & Procedure of protection, radiation safety training, Presence of Medical Physicist/ RSO, Personal protective equipment, visible signs and warnings in radiation areas, patient waiting and storage room, documented procedure for monitoring and maintaining radiation equipment leakage, Dose monitoring badges, and Mechanisms to track and analyze adverse events related to radiation exposure or contrast administration
- **Optimization of Radiological Procedures:** Justification principles, protocols for different X-ray examination, Number of X-ray images acquired per examination, collimation techniques, optimization techniques (kV, mAs, etc), educational resources, imaging parameters (e.g., field of view, dose levels),
- **Quality Assurance:** Quality assurance program, quality assurance audits, and Procedures to address and correct any identified issues during quality assurance,
- **Dose Monitoring:** System of dose monitoring & record, Dose Review
- **Collaboration and Communication in safety measures:** Effective communication and collaboration among radiologists, technologists, medical physicists, radiographers and others, Review and improvement of collaborative efforts

2.4 Questionnaire Validation

The questionnaire was pre-tested in a pilot study involving 20 radiographers and radiologists from a hospital outside the study areas to ensure clarity, relevance and reliability. Feedback from the pilot study was used to revise the questionnaire before the final deployment.

2.5 Inclusion and Exclusion Criteria

Inclusion criteria for this study were:

i. Healthcare professionals (radiologists, radiographers, medical physicists, etc.) with experience in performing contrast-enhanced X-ray procedures.

ii. Hospitals with established radiology departments providing contrast-enhanced radiological services.

Exclusion criteria were:

i. Healthcare professionals without experience in radiology.

ii. Institutions that did not offer contrast-enhanced radiological procedures.

2.6 Sample Size

A total of **100** questionnaires were distributed across 6 hospitals. The sample size was proportionally allocated to each hospital based on the number of available professionals involved in radiological procedures.

2.7 Data Collection and Analysis

The questionnaires were distributed to the participants in-person by the researcher. Each participant was provided with detailed instructions on how to complete the questionnaire, and responses were collected within 6 weeks. Follow-up visits were made to ensure timely completion of the questionnaires. About 97 administered questionnaires were returned filled and 3 were unfilled. Collected data were entered into a Statistical Package for the Social Sciences (SPSS) version 20.0 for the analysis. Descriptive statistics, such as frequencies, percentage, and compliance rate were estimated and tabulated to summarize the demographic characteristics of the respondents, existing radiation protection measures, Optimization, radiation dose monitoring, quality assurance, collaboration and communications among the staff based on radiation protection improvement.

3.0 Result and Discussion

3.1 Demographic Information of Participants

Gender

The results reveal a significant gender disparity among respondents regarding the assessment of existing radiation protection measures in hospitals. In all institutions surveyed, male respondents predominantly outnumbered female respondents. For instance, at the Federal Teaching Hospital Birnin Kebbi, 85% of the respondents were male, with only 15% female. Similar trends were observed across other hospitals, such as Sir Yahaya Memorial Hospital Birnin Kebbi (73.33% male, 26.67% female) and Yauri General Hospital, Yauri (70% male, 30% female). The same trend was found in Federal Medical Centre Gusau with 80% male and 20% male. This pattern reflects a general tendency for male respondents to participate more in radiological services and assessments related to radiation safety in these healthcare facilities.

However, the gender distribution also highlights the relatively smaller representation of females in the radiology department, even in hospitals with higher female participation like Usmanu Danfodiyo Teaching Hospital Sokoto (70% male, 30% female) and Medi-Stop Diagnostic and Clinical Centre (75% male, 25% female). This gender gap, with males consistently comprising the majority, indicates that radiological services might be more commonly associated with males in these settings. The total of 97 respondents across all hospitals reinforces this trend, with males accounting for 79.38% of the total participants and females comprising only 20.62%. The lower female representation might indicate a potential underrepresentation of female perspectives in radiological services. Furthermore, understanding these gender dynamics may highlight areas for future studies or interventions to encourage greater female participation in radiology-specialized areas.

Hospital	Frequency (N)	Percentage (%)	
Federal Teaching Hospital Birnin Kebbi	Male	17	85.0
	Female	3	15.0
Sir Yahaya Memorial Hospital Birnin Kebbi	Male	11	73.33
	Female	4	26.67

Yauri General Hospital, Yauri	Male	7	70.0
	Female	3	30.0
Usmanu Danfodiyo Teaching Hospital Sokoto	Male	14	70.0
	Female	6	30.0
Medi-Stop Diagnostic and Clinical Centre	Male	9	75.0
	Female	3	25.0
	Total	12	100.0
Federal Medical Centre Gusau	Male	16	80.0
	Female	4	20.0
TOTAL		**97**	

Table 4.1a: Gender of respondents across the Hospital

The age range of Participant

The age distribution of respondents in the evaluation of radiation protection measures reflects a significant concentration of younger professionals. At all the hospitals surveyed, the 20-30 age range had the highest representation, with notable figures such as 70% at Usmanu Danfodiyo Teaching Hospital Sokoto, 66.7% at Medi-Stop Diagnostic and Clinical Centre, and 65% at Federal Medical Centre Gusau as shown in **table 4.1b**. This suggests that younger healthcare workers are more involved in radiation protection assessments in these facilities, likely due to their active participation in the workforce and their familiarity with current safety protocols. The age group of 30-40 years also shows a decent presence, accounting for 26.7% to 40% across different hospitals.

In contrast, respondents over 40 years old are underrepresented, with few in the 40-50 and 50-above ranges. For instance, the Federal Teaching Hospital Birnin Kebbi and Sir Yahaya Memorial Hospital Birnin Kebbi had just 13.3% and 33.3%, respectively, in the 40-50 age range. This lower representation of older professionals might suggest fewer senior staff members actively participating in such radiological services. Overall, the total age distribution shows that the younger population, particularly those aged 20-30, plays a key role in the radiology department as well as evaluating radiation safety measures across these hospitals.

Hospital		Frequency (N)	Percentage (%)
Federal Teaching Hospital Birnin Kebbi	Below 20	0	0.0
	20-30	3	10.0
	30-40	8	26.7
	40-50	4	13.3
	50-above	5	16.7
Sir Yahaya Memorial Hospital Birnin Kebbi	Below 20	0	0.0
	20-30	4	26.7
	30-40	6	40.0
	40-50	5	33.3
	50-above	0	0.0
Yauri General Hospital, Yauri	Below 20	0	0.0
	20-30	7	70.0
	30-40	2	20.0
	40-50	1	10.0
	50-above	0	0.0
Usmanu Danfodiyo Teaching Hospital Sokoto	Below 20	0	0.0
	20-30	14	70.0
	30-40	6	30.0
	40-50	0	0.0
	50-above	0	0.0
Medi-Stop Diagnostic and Clinical Centre	Below 20	0	0.0
	20-30	8	66.7
	30-40	3	25.0
	40-50	1	8.3
	50-above	0	0.0
Federal Medical Centre Gusau	Below 20	0	0.0
	20-30	13	65.0
	30-40	6	30.0
	40-50	1	5.0
	50-above	0	0.0
TOTAL		**97**	

Table 4.1b: Age of respondents across the Hospital

Role of Respondents in Radiology

The distribution of respondents across the hospitals reflects the diverse roles of radiology professionals in healthcare delivery, with radiographers and X-ray technicians dominating the workforce. At the Federal Teaching Hospital Birnin Kebbi, radiographers make up 43.3% of the staff, the highest among all roles, highlighting their critical role in diagnostic imaging. Meanwhile, Sir Yahaya Memorial Hospital has the highest proportion of X-ray technicians (60%) as in **Table 4.1c**, emphasizing their importance in operating imaging equipment. Notably, medical physicists and radiation officers are underrepresented in most facilities, with several hospitals reporting no personnel in these specialized roles. This gap could indicate limited emphasis on advanced radiological safety and dosimetry practices.

In tertiary hospitals like Usmanu Danfodiyo Teaching Hospital Sokoto and Federal Medical Centre Gusau, there is a more balanced representation of radiologists, radiographers, and X-ray technicians, signifying broader diagnostic capabilities. For example, Usmanu Danfodiyo has a notable presence of medical physicists (10%) and radiation officers (5%), essential for ensuring safety in complex procedures. Private diagnostic centers, such as Medi-Stop Diagnostic and Clinical Centre, rely heavily on X-ray technicians (66.7%), suggesting a focus on basic imaging services. The lack of medical physicists and radiation officers in these centers could pose risks in maintaining radiation protection standards, emphasizing the need for policy and workforce development in radiological health services.

Hospital		Frequency	Percentage
Federal Teaching Hospital Birnin Kebbi	Radiologist	2	6.7
	Radiographer	13	43.3
	X-ray technician	4	13.3
	Medical Physicist	0.0	3.3
	Radiation officer	1	66.7
Sir Yahaya Memorial Hospital Birnin Kebbi	Radiologist	4	27.7
	Radiographer	2	13.3
	X-ray technician	9	60.0
	Medical Physicist	0	0.0
	Radiation officer	0	0.0
Yauri General Hospital, Yauri	Radiologist	0	0
	Radiographer	2	20.0
	X-ray technician	8	80.0
	Medical Physicist	0	0.0
	Radiation officer	0	0.0
Usmanu Danfodiyo Teaching Hospital Sokoto	Radiologist	3	15.0
	Radiographer	8	40.0
	X-ray technician	6	30.0.0
	Medical Physicist	2	10.0
	Radiation officer	1	5.0
Medi-Stop Diagnostic and Clinical Centre	Radiologist	1	8.3
	Radiographer	3	25.0
	X-ray technician	8	66.7
	Medical Physicist	0	0.0
	Radiation officer	0	0.0
Federal Medical Centre Gusau	Radiologist	3	15.0
	Radiographer	6	30.0
	X-ray technician	10	50.0
	Medical Physicist	1	5.0
	Radiation officer	0	0.0
TOTAL		**97**	

Table 4.1c: Role of Respondents across the Hospital

The educational level of the participant

The educational levels of participants involved in the assessment of radiation protection measures reveal a varied distribution, reflecting the workforce's qualifications in different healthcare institutions as shown in **Table 4.1d**. Federal Teaching Hospital Birnin Kebbi has the highest proportion of Bachelor's degree holders (75%), highlighting a strong foundation in professional training among its staff. Additionally, 20% of its personnel hold diplomas, while only 5% have obtained a Master's degree. This distribution suggests an emphasis on formal academic preparation for radiological roles, but a limited representation of advanced postgraduate expertise. Similarly, Usmanu Danfodiyo Teaching Hospital Sokoto demonstrates a balanced workforce, with 60% holding Bachelor's degrees and 30% possessing diplomas, supported by a small proportion of Master's degree holders (10%). This indicates an intermediate level of academic diversity that may be beneficial for ensuring effective radiation safety practices.

Other facilities such as Sir Yahaya Memorial Hospital Birnin Kebbi, Yauri General Hospital, and Medi-Stop Diagnostic and Clinical Centre rely heavily on diploma holders, who constitute 53.3%, 70%, and 58.3% of their respective workforces (**table 4.1d)**. While Bachelor's degree holders are also present, the absence of personnel with doctoral qualifications across all facilities reflects a gap in advanced research-oriented expertise necessary for optimizing radiation protection measures. Notably, the Federal Medical Centre Gusau strikes a near balance, with diploma holders at 50% and Bachelor's degree holders at 45%. This trend underscores the varying levels of academic preparation among participants, which could influence the effectiveness of radiation safety protocols across institutions.

Hospital		Frequency	Percentage
Federal Teaching Hospital Birnin Kebbi	Certificate	0	0.0
	Diploma	4	20.0
	B.Sc	15	75.0
	M.Sc	1	5.0
	PhD	0	0.0
Sir Yahaya Memorial Hospital Birnin Kebbi	Certificate	0	0.0
	Diploma	8	53.3
	B.Sc	5	33.3
	M.Sc	2	13.3
	PhD	0	0.0
Yauri General Hospital, Yauri	Certificate	1	10.0
	Diploma	7	70.0
	B.Sc	2	20.0
	M.Sc	0	0.0
	PhD	0	0.0
Usmanu Danfodiyo Teaching Hospital Sokoto	Certificate	0	0.0
	Diploma	6	30.0
	B.Sc	12	60.0
	M.Sc	2	10.0
	PhD	0	0.0
Medi-Stop Diagnostic and Clinical Centre	Certificate	1	8.3
	Diploma	7	58.3
	B.Sc	3	25.0
	M.Sc	1	8.3
	PhD	0	0.0
Federal Medical Centre Gusau	Certificate	0	0.0
	Diploma	10	50.0
	B. Sc	9	45.0
	M.Sc	1	5.0
	PhD	0	0.0
TOTAL		**97**	

Table 4.1d: Educational level of participant

Year of experience in CE-Radiological Procedure

The range of experience among participants reflects a mix of expertise levels across the assessed hospitals, providing insight into the capacity for implementing and sustaining radiation protection measures. At the Federal Teaching Hospital Birnin Kebbi, the distribution is relatively even, with a notable proportion of staff having 5–10 years of experience (35%), followed by experienced professionals with 15–20 years (20%) and 20–25 years (20%) as in **table 4.1e**. This balanced representation suggests a workforce capable of both innovation and mentorship, which is vital for optimizing radiological procedures and minimizing risks. Similarly, Sir Yahaya Memorial Hospital shows a strong presence of mid-career professionals with 10–15 years of experience (46.7%), indicating a stable base of experienced staff, although there is no representation of those with over 20 years of expertise.

In Usmanu Danfodiyo Teaching Hospital Sokoto and Federal Medical Centre Gusau are dominated by participants with 0–5 years of experience (50% and 60%, respectively), reflecting a younger workforce that may require more training to enhance radiation safety practices. Yauri General Hospital and Medi-Stop Diagnostic and Clinical Centre demonstrate higher proportions of participants with extensive experience (15–25 years), accounting for 60% and 58.3% of their respective staff. These facilities may benefit from leveraging their experienced personnel to develop and enforce robust radiation protection measures. However, the limited presence of highly experienced professionals across several hospitals highlights a potential need for capacity-building programs to ensure consistent adherence to safety protocols.

Hospital		Frequency	Percentage
Federal Teaching Hospital Birnin Kebbi	0-5	3	15.0
	5-10	7	35.0
	10-15	2	10.0
	15-20	4	20.0
	20-25	4	20.0
Sir Yahaya Memorial Hospital Birnin Kebbi	0-5	2	13.3
	5-10	2	13.3
	10-15	7	46.7
	15-20	4	26.7
	20-25	0	0.0
Yauri General Hospital, Yauri	0-5	1	10.0
	5-10	2	20.0
	10-15	1	10.0

	15-20	3	30.0
	20-25	3	30.0
Usmanu Danfodiyo Teaching Hospital Sokoto	0-5	10	50.0
	5-10	6	30.0
	10-15	2	10.0
	15-20	2	10.0
	20-25	0	0.0
Medi-Stop Diagnostic and Clinical Centre	0-5	1	8.3
	5-10	3	25.0
	10-15	1	8.3
	15-20	4	33.3
	20-25	3	25.0
Federal Medical Centre Gusau	0-5	12	60.0
	5-10	6	30.0
	10-15	2	10.0
	15-20	0	0.0
	20-25	0	0.0
TOTAL		**97**	

Table 4.1e: Year of experience in healthcare

3.2 Existing Radiation Safety Measures

The results for the frequency of CERP sessions reveal high compliance across most centres, with FUTHBK, SYHM, YGH, and MSDC showing compliance rates between 70.0% and 93.3%. UDUTH demonstrated full compliance (100%), indicating that the centre was frequently performing CERP. However, FMCG had a relatively low compliance rate (50.0%), signaling the low performance of CERP. Written Policies and procedures for radiation safety received exceptional compliance scores in most centres, with FUTHBK, SYHM, YGH, and UDUTH achieving rates of 80.0% to 100%. MSDC also demonstrated high compliance (91.7%). Conversely, FMCG showed a lower compliance rate of 55.0%, which indicates potential lapses in implementing and updating radiation safety policies. The findings advocate that robust documentation and enforcement of safety policies are integral to ensuring consistent adherence to radiation protection standards. Significant discrepancies were observed regarding the presence of a medical physicist or RSO. FUTHBK, UDUTH, and FMCG had compliance rates of 85.0% to 100%, demonstrating proper staffing in these critical roles. However, SYHM (33.3%), YGH (20.0%), and MSDC (16.7%) were non-compliant, indicating severe deficiencies. The absence of qualified personnel in these roles undermines safety oversight and emphasizes the necessity of recruiting certified professionals to monitor and guide radiation practices effectively

Centre	Category	Yes	No	Not Sure	Total	Yes %	No %	Not Sure %	Compliance Status
FUTHBK	Frequency of CERP	14	6	0	20	70.0%	30.0%	0.0%	Compliant
	Policies and Procedures	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Staff Training	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Presence of Medical Physicist and RSO	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Availability of PPE	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Signs and Warnings	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Patient Waiting Area	18	0	2	20	90.0%	0.0%	10.0%	Compliant
	Radiation Leakage Monitoring	11	2	7	20	55.0%	10.0%	35.0%	Needs Improvement
	Radiation Monitoring Badges	18	1	1	20	90.0%	5.0%	5.0%	Compliant
	Tracking Radiation Adverse Events	12	6	2	20	60.0%	30.0%	10.0%	Needs Improvement
SYHM	Frequency of CERP	14	1	0	15	93.3%	6.7%	0.0%	Compliant
	Policies and Procedures	15	0	0	15	100.0%	0.0%	0.0%	Compliant
	Staff Training	15	0	0	15	100.0%	0.0%	0.0%	Compliant
	Presence of Medical Physicist and RSO	5	10	0	15	33.3%	66.7%	0.0%	Non-Compliant
	Availability of PPE	13	2	0	15	86.7%	13.3%	0.0%	Compliant
	Signs and Warnings	14	1	0	15	93.3%	6.7%	0.0%	Compliant
	Patient Waiting Area	14	1	0	15	93.3%	6.7%	0.0%	Compliant
	Radiation Leakage Monitoring	3	12	0	15	20.0%	80.0%	0.0%	Non-Compliant
	Radiation Monitoring Badges	2	13	0	15	13.3%	86.7%	0.0%	Non-Compliant
	Tracking Radiation Adverse Events	3	12	0	15	20.0%	80.0%	0.0%	Non-Compliant

YGH	Frequency of CERP	8	2	0	10	80.0%	20.0%	0.0%	Compliant
	Policies and Procedures	9	1	0	10	90.0%	10.0%	0.0%	Compliant
	Staff Training	10	0	0	10	100.0%	0.0%	0.0%	Compliant
	Presence of Medical Physicist and RSO	2	8	0	10	20.0%	80.0%	0.0%	Non-Compliant
	Availability of PPE	6	4	0	10	60.0%	40.0%	0.0%	Needs Improvement
	Signs and Warnings	8	2	0	10	80.0%	20.0%	0.0%	Compliant
	Patient Waiting Area	8	2	0	10	80.0%	20.0%	0.0%	Compliant
	Radiation Leakage Monitoring	3	7	0	10	30.0%	70.0%	0.0%	Non-Compliant
	Radiation Monitoring Badges	2	8	0	10	20.0%	80.0%	0.0%	Non-Compliant
	Tracking Radiation Adverse Events	1	9	0	10	10.0%	90.0%	0.0%	Non-Compliant
UDUTH	Frequency of CERP	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Policies and Procedures	16	4	0	20	80.0%	20.0%	0.0%	Compliant
	Staff Training	14	6	0	20	70.0%	30.0%	0.0%	Compliant
	Presence of Medical Physicist and RSO	17	3	0	20	85.0%	15.0%	0.0%	Compliant
	Availability of PPE	13	7	0	20	65.0%	35.0%	0.0%	Needs Improvement
	Signs and Warnings	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Patient Waiting Area	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Radiation Leakage Monitoring	12	8	0	20	60.0%	40.0%	0.0%	Needs Improvement
	Radiation Monitoring Badges	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Tracking Radiation Adverse Events	9	11	0	20	45.0%	55.0%	0.0%	Needs Improvement
MSDC	Frequency of CERP	10	2	0	12	83.3%	16.7%	0.0%	Compliant
	Policies and Procedures	11	1	0	12	91.7%	8.3%	0.0%	Compliant
	Staff Training	11	0	1	12	91.7%	0.0%	8.3%	Compliant
	Presence of Medical Physicist and RSO	2	9	1	12	16.7%	75.0%	8.3%	Non-Compliant
	Availability of PPE	7	5	0	12	58.3%	41.7%	0.0%	Needs Improvement
	Signs and Warnings	10	2	0	12	83.3%	16.7%	0.0%	Compliant
	Patient Waiting Area	10	2	0	12	83.3%	16.7%	0.0%	Compliant
	Radiation Leakage Monitoring	4	8	0	12	33.3%	66.7%	0.0%	Non-Compliant
	Radiation Monitoring Badges	3	9	0	12	25.0%	75.0%	0.0%	Non-Compliant
	Tracking Radiation Adverse Events	1	11	0	12	8.3%	91.7%	0.0%	Non-Compliant
FMCG	Frequency of CERP	10	6	4	20	50.0%	30.0%	20.0%	Needs Improvement
	Policies and Procedures	11	8	1	20	55.0%	40.0%	5.0%	Needs Improvement
	Staff Training on Radiation Safety	13	7	0	20	65.0%	35.0%	0.0%	Compliant
	Presence of Medical Physicist/RSO	20	0	0	20	100.0%	0.0%	0.0%	Compliant
	Availability of PPE	11	8	1	20	55.0%	40.0%	5.0%	Needs Improvement
	Signs and Warnings	14	6	0	20	70.0%	30.0%	0.0%	Compliant
	Patient Waiting Area	15	5	0	20	75.0%	25.0%	0.0%	Compliant
	Radiation Leakage Monitoring	8	9	3	20	40.0%	45.0%	15.0%	Needs Improvement
	Radiation Monitoring Badges	7	13	0	20	35.0%	65.0%	0.0%	Non-Compliant
	Tracking Radiation Adverse Events	5	13	2	20	25.0%	65.0%	10.0%	Non-Compliant

Table 3.2: Radiation safety measure

Federal University Teaching Hospital Birnin Kebbi (FUTHBK), SYHM, and UDUTH demonstrated commendable compliance in Personal Protective Equipment (PPE) availability, with scores ranging from 65.0% to 100%. Conversely, YGH, MSDC, and FMCG showed lower compliance levels, with needs improvement statuses ranging from 55.0% to 60.0%. The inconsistencies in PPE availability raise concerns about worker and patient safety in these centers. These results underline the critical need for adequate budgeting and procurement to ensure the consistent availability of protective equipment. Monitoring radiation leakage and adverse events received mixed outcomes. While FUTHBK showed moderate compliance (55.0% to 60.0%) in these categories, other centers such as YGH, MSDC, and FMCG were non-compliant, with compliance rates as low as 8.3% to 40.0%. SYHM performed poorly in radiation leakage monitoring (20.0%). The lack of robust monitoring systems in these centers increases the risk of undetected radiation exposure and underscores the need for standardized monitoring protocols and incident reporting frameworks. The use of radiation monitoring badges also varied significantly. FUTHBK, UDUTH, and SYHM exhibited high compliance (90.0% to 100%), reflecting effective personnel dosimetry practices. In contrast, YGH, MSDC, and FMCG displayed alarming non-compliance rates (20.0% to 35.0%). The absence of badges in these centers suggests inadequate worker safety monitoring, posing a potential health risk. These findings highlight the necessity of ensuring access to dosimetry devices and training personnel on their proper usage.

3.3 Optimization of Contrast-enhanced Radiological Procedures

Optimizing contrast-enhanced radiological procedures is essential for enhancing diagnostic accuracy, minimizing patient exposure to contrast agents, and radiation, and improving overall imaging quality. The findings from various centres reveal both compliant and non-compliant status for an area that needs improvement in this regard. At FUTHBK, 80% of staff adhere to justification principles, ensuring that contrast-enhanced procedures are performed when clinically necessary. In contrast, SYHM reports only 33.3% compliance, indicating a need for improved adherence to these principles. YGH and MSDC also show lower compliance rates at 20% and 25%, respectively. UDUTH stands out with 90% compliance, reflecting a strong commitment to justifying the use of contrast agents and exposure parameters. FMCG reports 80% compliance, suggesting room for improvement. In general, these figures highlight the importance of reinforcing justification protocols across all centres to ensure the appropriate use of contrast agents. The establishment and adherence to specific Contrast-Enhanced Radiological Procedures (CERP) protocols are crucial for standardizing practices. FUTHBK, UDUTH, and FMCG demonstrate high compliance rates of 85%, 80%, and 85%, respectively. SYHM and YGH show 86.7% and 50% compliance, indicating variability in protocol adherence. MSDC reports 50% compliance, suggesting a need for standardization efforts. These disparities underscore the necessity for uniform protocol development and training to ensure consistent application across all centres.

Centre	Category	Yes Freq (%)	No Freq (%)	Not Sure Freq (%)	Compliance Status
FUTHBK	Justification principles by the staff	16 (80.0%)	3 (15.0%)	1 (5.0%)	Compliant
	Establishing and following different CERP Protocols	17 (85.0%)	2 (10.0%)	1 (5.0%)	Compliant
	Minimizing the number of images required for CERP	17 (85.0%)	0 (0.0%)	3 (15.0%)	Compliant
	Availability of collimation techniques	18 (90.0%)	0 (0.0%)	2 (10.0%)	Compliant
	Optimization techniques based on patients' size and indications	19 (95.0%)	1 (5.0%)	0 (0.0%)	Compliant
	Availability of educational resources for staff update	16 (80.0%)	4 (20.0%)	0 (0.0%)	Compliant
	Reviewing and adjusting imaging parameter	9 (45.0%)	7 (35.0%)	4 (20.0%)	Non-compliant
SYHM	Justification principles by the staff	5 (33.3%)	10 (66.7%)	0 (0.0%)	Non-compliant
	Establishing and following different CERP Protocols	13 (86.7%)	2 (13.3%)	0 (0.0%)	Compliant
	Minimizing the number of images required for CERP	14 (93.3%)	1 (6.7%)	0 (0.0%)	Compliant
	Availability of collimation techniques	14 (93.3%)	1 (6.7%)	0 (0.0%)	Compliant
	Optimization techniques based on patients' size and indications	12 (80.0%)	3 (20.0%)	0 (0.0%)	Compliant
	Availability of educational resources for staff update	4 (26.7%)	11 (73.3%)	0 (0.0%)	Non-compliant
	Reviewing and adjusting imaging parameter	1 (6.7%)	14 (93.3%)	0 (0.0%)	Non-compliant
YGH	Justification principles by the staff	2 (20.0%)	8 (80.0%)	0 (0.0%)	Non-compliant
	Establishing and following different CERP Protocols	5 (50.0%)	5 (50.0%)	0 (0.0%)	Non-compliant
	Minimizing the number of images required for CERP	7 (70.0%)	3 (30.0%)	0 (0.0%)	Compliant
	Availability of collimation techniques	8 (80.0%)	2 (20.0%)	0 (0.0%)	Compliant
	Optimization techniques based on patients' size and indications	8 (80.0%)	2 (20.0%)	0 (0.0%)	Compliant
	Availability of educational resources for staff update	2 (20.0%)	8 (80.0%)	0 (0.0%)	Non-compliant

	Reviewing and adjusting imaging parameter	1 (10.0%)	9 (90.0%)	0 (0.0%)	Non-compliant
UDUTH	Justification principles by the staff	18 (90.0%)	2 (10.0%)	0 (0.0%)	Compliant
	Establishing and following different CERP Protocols	16 (80.0%)	4 (20.0%)	0 (0.0%)	Compliant
	Minimizing the number of images required for CERP	20 (100.0%)	0 (0.0%)	0 (0.0%)	Compliant
	Availability of collimation techniques	19 (95.0%)	1 (5.0%)	0 (0.0%)	Compliant
	Optimization techniques based on patients' size and indications	19 (95.0%)	1 (5.0%)	0 (0.0%)	Compliant
	Availability of educational resources for staff update	10 (50.0%)	9 (45.0%)	1 (5.0%)	Compliant
	Reviewing and adjusting imaging parameter	15 (75.0%)	5 (25.0%)	0 (0.0%)	Compliant
MSDC	Justification principles by the staff	3 (25.0%)	9 (75.0%)	0 (0.0%)	Non-compliant
	Establishing and following different CERP Protocols	6 (50.0%)	6 (50.0%)	0 (0.0%)	Compliant
	Minimizing the number of images required for CERP	8 (66.7%)	4 (33.3%)	0 (0.0%)	Compliant
	Availability of collimation techniques	10 (83.3%)	2 (16.7%)	0 (0.0%)	Compliant
	Optimization techniques based on patients' size and indications	10 (83.3%)	2 (16.7%)	0 (0.0%)	Compliant
	Availability of educational resources for staff update	3 (25.0%)	9 (75.0%)	0 (0.0%)	Non-compliant
	Reviewing and adjusting imaging parameter	2 (18.2%)	9 (81.8%)	0 (0.0%)	Non-compliant
FMCG	Justification principles by the staff	16 (80.0%)	4 (20.0%)	0 (0.0%)	Compliant
	Establishing and following different CERP Protocols	17 (85.0%)	3 (15.0%)	0 (0.0%)	Compliant
	Minimizing the number of images required for CERP	17 (85.0%)	3 (15.0%)	0 (0.0%)	Compliant
	Availability of collimation techniques	17 (85.0%)	3 (15.0%)	0 (0.0%)	Compliant
	Optimization techniques based on patients' size and indications	17 (85.0%)	3 (15.0%)	0 (0.0%)	Compliant
	Availability of educational resources for staff update	6 (30.0%)	12 (60.0%)	2 (10.0%)	Non-compliant
	Reviewing and adjusting imaging parameter	10 (50.0%)	10 (50.0%)	0 (0.0%)	Compliant

Table 4.3: Optimization of CE-Radiological Procedures

Reducing the number of images taken during contrast-enhanced procedures can decrease patient exposure and improve workflow efficiency. FUTHBK, UDUTH, and FMCG achieve 85%, 100%, and 85% compliance, respectively, in this area. SYHM and YGH report 93.3% and 70% compliance, while MSDC shows 66.7% compliance. These figures suggest that while some centers are highly efficient, others may benefit from reviewing and optimizing their imaging protocols to minimize unnecessary imaging. Proper collimation techniques are vital for reducing radiation exposure and enhancing image quality, FUTHBK, UDUTH, and FMCG report high compliance rates of 90%, 95%, and 85%, respectively. SYHM and YGH show 93.3% and 80% compliance, while MSDC reports 83.3% compliance. These results indicate that most centers have access to and utilize collimation techniques effectively, though continuous training and equipment maintenance are essential to maintain high standards.

Tailoring contrast-enhanced procedures to individual patient characteristics is crucial for safety and efficacy. FUTHBK, UDUTH, and FMCG demonstrate high compliance rates of 95%, 95%, and 85%, respectively. SYHM and YGH report 80% compliance, while MSDC shows 83.3% compliance. These figures suggest that while some centers effectively customize procedures, others may need to enhance their practices to consider patient-specific factors more thoroughly. Continuous education ensures that staff are informed about the latest practices and technologies in contrast-enhanced imaging. FUTHBK and UDUTH report 80% and 50% compliance, respectively, indicating a need for improved educational resources. SYHM and YGH show 26.7% and 20% compliance, highlighting significant gaps in staff training. MSDC and FMCG report 25% and 30% compliance, respectively, suggesting that both centers should invest in ongoing educational programs to enhance staff knowledge and skills. Regular review and adjustment of imaging parameters are essential for optimizing image quality and patient safety. FUTHBK reports 45% compliance, indicating that this practice is not consistently followed. SYHM and YGH show 6.7% and 10% compliance, respectively, suggesting a significant need for improvement. UDUTH reports 75% compliance, while MSDC and FMCG show 18.2% and 50% compliance, respectively. These variations highlight the necessity for standardized protocols and regular training to ensure that imaging parameters are consistently reviewed and adjusted as needed

3.4 Radiology Quality Assurance

Quality Assurance (QA) programs are fundamental to ensuring radiation safety in radiology. They aim to optimize diagnostic imaging by balancing image quality with minimal radiation exposure to patients. The findings offer insights into the implementation of QA programs across various centers, highlighting their compliance status and the frequency of responses related to the availability of QA programs, conducting QA audits, and addressing and correcting issues. The results from the quality assurance (QA) programs reveal a significant variation in the implementation and compliance with radiation safety practices across the radiology departments. The QA program's availability is a key factor in radiation safety practices, as it ensures regular monitoring and adherence to safety standards. At FUTHBK, 35% of the responses indicated the availability of a QA program, with an equal proportion (35%) reporting its absence. However, the centre’s compliance status was rated as compliant due to the balancing effect of other categories, where addressing and correcting issues was rated positively at 50%. This demonstrates a partial adherence to QA protocols, but it also points to a need for improvement, especially in QA audits, which were found to be non-compliant with 65% of respondents indicating the absence of such audits as indicated in **table 3.4**

Centre	Category	Yes Frequency (%)	No Frequency (%)	Not Sure Frequency (%)	Total Responses	Compliance Status
FUTHBK	Availability of QA Program	7 (35%)	7 (35%)	6 (30%)	20	Compliant
	Conducting QA Audit	5 (25%)	13 (65%)	2 (10%)	20	Non-Compliant
	Addressing and Correcting Issues	10 (50%)	8 (40%)	2 (10%)	20	Compliant
SYHM	Availability of QA Program	1 (6.67%)	13 (86.67%)	1 (6.67%)	15	Non-Compliant
	Conducting QA Audit	1 (6.67%)	13 (86.67%)	1 (6.67%)	15	Non-Compliant
	Addressing and Correcting Issues	1 (6.67%)	14 (93.33%)	0 (0%)	15	Non-Compliant
YGH	Availability of QA Program	1 (10%)	8 (80%)	1 (10%)	10	Non-Compliant
	Conducting QA Audit	1 (10%)	8 (80%)	1 (10%)	10	Non-Compliant
	Addressing and Correcting Issues	2 (20%)	8 (80%)	0 (0%)	10	Non-Compliant
UDUTH	Availability of QA Program	6 (30%)	14 (70%)	0 (0%)	20	Non-Compliant
	Conducting QA Audit	4 (20%)	15 (75%)	1 (5%)	20	Non-Compliant
	Addressing and Correcting Issues	4 (20%)	6 (30%)	10 (50%)	20	Non-Compliant
MSDC	Availability of QA Program	1 (8.33%)	10 (83.33%)	1 (8.33%)	12	Non-Compliant
	Conducting QA Audit	1 (8.33%)	10 (83.33%)	1 (8.33%)	12	Non-Compliant
	Addressing and Correcting Issues	4 (33.33%)	8 (66.67%)	0 (0%)	12	Non-Compliant
FMCG	Availability of QA Program	4 (20%)	14 (70%)	2 (10%)	20	Non-Compliant
	Conducting QA Audit	2 (10%)	17 (85%)	1 (5%)	20	Non-Compliant
	Addressing and Correcting Issues	2 (10%)	15 (75%)	3 (15%)	20	Non-Compliant

Table 3.4: **Frequency and Compliance Status of Quality Assurance Program Responses**

In disparity, the SYHM centre showed very low compliance with QA programs, with only 6.67% of responses confirming the availability of QA programs. Similarly, 86.67% of respondents reported that QA audits were not being conducted, and 93.33% felt that issues were neither addressed nor corrected. This extreme non-compliance highlights a critical gap in radiation safety practices at SYHM. The absence of both QA audits and corrective actions can pose a serious risk to patient and staff safety, as it indicates a lack of continuous evaluation and improvement of radiological practices. Without QA audits, the radiology department may fail to identify and rectify issues that could result in unnecessary radiation exposure or other safety hazards. The YGH center also exhibited low compliance with QA programs, with 80% of respondents indicating the absence of a QA program. While a slight improvement was seen in the category of addressing and correcting issues, with 20% indicating some form of corrective action, the center still fell short of industry standards. The lack of regular QA audits (80% non-compliant) further compounds the problem, as this process is vital for ensuring that radiology practices meet safety regulations. This non-compliance at YGH further underscores the necessity for establishing a robust QA system that not only monitors but also acts on deficiencies in radiology safety practices.

At UDUTH, a similar trend of non-compliance is evident across all categories, with a significant proportion (70%) reporting that QA programs were not available. While there was a slight variation in addressing and correcting issues, with 50% of respondents unsure about whether actions were taken, the majority (75%) of responses indicated that QA audits were absent. This lack of QA audits and corrective actions could lead to prolonged radiation exposure risks for patients, staff, and the general public. The absence of such foundational QA practices in

UDUTH, as with other centers, highlights the need for greater commitment to radiation safety, particularly in developing a proactive QA framework that addresses safety issues before they escalate. The MSDC and FMCG centers demonstrated similarly poor compliance across all categories. At MSDC, 83.33% of respondents indicated the non-existence of a QA program, and audits were similarly absent (83.33%). The corrective actions category also reflected a high non-compliance rate of 66.67%, with only 33.33% confirming that issues were addressed. Similarly, FMCG exhibited alarming statistics with 70% of responses indicating no availability of QA programs and no audits being conducted. The responses from both centers suggest a significant gap in meeting the required safety protocols in radiology. This widespread non-compliance is indicative of systemic issues within the radiology departments, where a lack of training, resources, or institutional support may be contributing factors. The results across all centers highlight a troubling trend of inadequate QA programs in the radiology departments. Although FUTHBK demonstrated partial compliance, other centers such as SYHM, YGH, UDUTH, MSDC, and FMCG showed minimal adherence to the key elements of a quality assurance program. The absence of regular QA audits and corrective actions points to an urgent need for policy changes, enhanced training programs, and stricter enforcement of radiation safety regulations. The inconsistency in QA program implementation across these centers reveals the pressing need for a unified approach to ensure that all radiology departments are equipped to protect both patients and staff from unnecessary radiation exposure.

3.5 Radiation Dose Monitoring

The results for the System of monitoring and recording radiation doses show a significant variance in the response rates across different centres. At **FUTHBK**, 55% of respondents indicated that they have a system in place, while 45% reported no such system, and a small portion (5%) were uncertain. This suggests a partial adherence to radiation dose monitoring protocols, but there is room for improvement. At **SYHM**, only 6.67% confirmed the presence of such a system, with the majority (93.33%) indicating no system, signaling a serious gap in radiation monitoring practices. The same issue is observed at **YGH**, where 90% of respondents reported no monitoring system, and only 10% claimed to have one. **UDUTH** had a more balanced response, with 15% indicating the presence of a system, but still showing a high 75% without one. Similarly, **MSDC** and **FMCG** reported no systems at all, with only a small percentage of respondents affirming their existence. These results indicate that radiation dose monitoring systems are generally underutilized or absent across these centres, with a clear need for implementation and better adherence to monitoring standards.

Centre	Category	Yes Frequency (%)	No Frequency (%)	Not Sure Frequency (%)	Total Responses	Compliance Status
FUTHBK	**System for monitoring and recording radiation doses**	11 (55%)	8 (40%)	1 (5%)	20	Non-compliant
	Reviewing and analyzing radiation doses for optimization after each procedure	9 (45%)	11 (55%)	0 (0%)	20	Non-compliant
SYHM	**System for monitoring and recording radiation doses**	1 (6.67%)	14 (93.33%)	0 (0%)	15	Non-compliant
	Reviewing and analyzing radiation doses for optimization after each procedure	1 (6.67%)	13 (86.67%)	1 (6.67%)	15	Non-compliant
YGH	**System for monitoring and recording radiation doses**	0 (0%)	9 (90%)	1 (10%)	10	Non-compliant
	Reviewing and analyzing radiation doses for optimization after each procedure	0 (0%)	4 (40%)	6 (60%)	10	Non-compliant
UDUTH	**System for monitoring and recording radiation doses**	3 (15%)	15 (75%)	2 (10%)	20	Non-compliant
	Reviewing and analyzing radiation doses for optimization after each procedure	2 (10%)	1 (5%)	17 (85%)	20	Non-compliant
MSDC	**System for monitoring and recording radiation doses**	0 (0%)	11 (68.75%)	1 (6.25%)	16	Non-compliant
	Reviewing and analyzing radiation doses for optimization after each procedure	0 (0%)	5 (31.25%)	7 (43.75%)	16	Non-compliant
FMCG	**System for monitoring and recording radiation doses**	2 (11.76%)	15 (88.24%)	3 (17.65%)	17	Non-compliant
	Reviewing and analyzing radiation doses for optimization after each procedure	3 (17.65%)	3 (17.65%)	14 (82.35%)	17	Non-compliant

Table 3.5: Radiation dose monitoring system

For reviewing and analyzing radiation doses for optimization, the trends reflect similar low engagement in optimizing radiation practices.

FUTHBK shows 45% of respondents confirming some form of review and analysis, but 55% reported no such practice, suggesting inconsistent procedures for dose optimization. At **SYHM**, 6.67% of respondents affirmed optimization efforts, while the remaining 93.33% reported no review or analysis, a clear indication of inadequate practices. **YGH** similarly demonstrates poor compliance, with 90% of responses indicating no review practices. **UDUTH** fares slightly better, with 10% confirming dose analysis, but the high percentage (85%) indicating no review reflects a substantial gap. **MSDC** and **FMCG** show even less engagement, with both centers reporting no optimization practices at all. These findings highlight a critical need or centers to establish systematic procedures for reviewing and optimizing radiation doses, as this is essential for reducing patient exposure and improving overall safety standards.

3.6 Collaboration and Communication Among the Staff on Radiation Safety Measures

The results from the survey indicate a notable variability in collaboration and communication regarding radiation safety measures among the different centres as shown in **table 3.6.** In centres like FUTHBK and SYHM, there is a relatively high frequency of positive responses to effective communication (75% and 80%, respectively), suggesting that these institutions may have established some level of communication among staff regarding radiation safety. However, the results also highlight a significant gap in the review and improvement of radiation safety efforts, with respondents reporting a high frequency of non-compliant responses (95% at FUTHBK and 50% at SYHM) (**table 3.6)**. This aligns with findings from several studies, which emphasize that while initial communication within healthcare settings can be robust, there is often a lack of follow-up in terms of safety measures and continuous improvement. This gap in practice suggests that communication alone is not sufficient; structured feedback mechanisms and continuous review processes are essential for ensuring sustained safety practices.

Centre	Category	Yes Frequency (%)	No Frequency (%)	Not Sure Frequency (%)	Total Responses	Compliance Status
FUTH	Effective Communication Among Staff	15 (75%)	5 (25%)	0 (0%)	20	Compliant
	Review and Improvement of Efforts	1 (5%)	19 (95%)	0 (0%)	20	Non-Compliant
SYHM	Effective Communication Among Staff	12 (80%)	3 (20%)	0 (0%)	15	Compliant
	Review and Improvement of Efforts	0 (0%)	7 (46.67%)	8 (53.33%)	15	Non-Compliant
YGH	Effective Communication Among Staff	5 (50%)	2 (20%)	3 (30%)	10	Non-Compliant
	Review and Improvement of Efforts	5 (50%)	5 (50%)	0 (0%)	10	Non-Compliant
UDUTH	Effective Communication Among Staff	13 (65%)	7 (35%)	0 (0%)	20	Non-Compliant
	Review and Improvement of Efforts	3 (15%)	10 (50%)	7 (35%)	20	Non-Compliant
MSDC	Effective Communication Among Staff	5 (41.67%)	3 (25%)	4 (33.33%)	12	Non-Compliant
	Review and Improvement of Efforts	0 (0%)	6 (50%)	6 (50%)	12	Non-Compliant
FMCG	Effective Communication Among Staff	12 (60%)	5 (25%)	3 (15%)	20	Non-Compliant
	Review and Improvement of Efforts	4 (20%)	6 (30%)	10 (50%)	20	Non-Compliant

Table 3.6: Collaboration and communication among the staff on radiation safety measures

On the other hand, centers like YGH, MSDC, and FMCG show poorer compliance in both communication and safety improvement efforts, with several respondents indicating ineffective communication (50%, 41.67%, and 60%, respectively) and insufficient review efforts (50%, 50%, and 50%). These findings are consistent with the literature that highlights the challenges many healthcare facilities face in fostering a culture of safety. A study by Kelly *et al.* (2012) identified that in some radiology departments, clear communication between the staff members can lead to improved accuracy of patient diagnosis and patient protection, a lack of collaboration and communication between team members hindered the effective implementation of radiation protection protocols, resulting in higher rates of non-compliance. Furthermore, the failure to review and improve efforts may stem from a lack of dedicated resources or institutional support, as highlighted by Christensen *et al.* (2024), who found that inadequate training and the absence of a formal feedback system were key barriers to ensuring that radiation safety measures were consistently updated and followed as well as patient characteristics, interaction between the patient and the operator/staff and issues related to the situation and examination. These findings suggest that improving communication among staff, coupled with systematic review and continuous improvement mechanisms, is crucial to enhancing radiation safety practices across healthcare institutions.

4.0 Discussion

The findings from this study highlight varying degrees of compliance with radiation safety standards across the surveyed centres. These findings align with and diverge from existing literature on radiation protection, which emphasizes the necessity of standardized practices to ensure safety. The robust compliance in most centres with radiation safety policies reflects the best practices outlined by Guide (2018). The deficiencies in FMCG align with findings by Adelodun and Anyanwu (2024), who underscores the importance of continuous evaluation and adaptation of public health policies to ensure effective radiation protection and safety in an ever-changing technological landscape. Insufficient policy enforcement often leads to lapses in radiation safety. This calls for institutional support to strengthen policy implementation. The lack of RSOs or medical physicists in centers like SYHM, MSDC, and YGH is consistent with the findings of Konstantinidis (2024)**,** who highlighted a shortage of skilled radiation safety personnel as well as radiographers in low- and middle-income countries. The presence of RSOs in FUTHBK and UDUTH adheres to IAEA standards, which stress the importance of having qualified personnel for monitoring radiation safety . Addressing these gaps is critical for improving safety compliance. High compliance in PPE availability, as observed in centers like FUTHBK, supports findings by Yoshandi (2023), which emphasize the importance of adequate PPE in minimizing occupational radiation exposure. However, non-compliance in other centers aligns with previous studies which reported that financial constraints and procurement inefficiencies often hinder PPE availability in developing regions. The mixed compliance regarding radiation leakage monitoring and adverse event tracking reflects broader trends noted in the literature. For instance, Yusuf *et al.* (2020) identified gaps in adverse event reporting frameworks in many healthcare settings, citing good staff training and lack of awareness and written radiation protection programs. The need for systematic monitoring and reporting systems aligns with ICRP recommendations for fostering a culture of safety (Vañó *et al.*, 2017). Centers with high compliance in badge usage, like FUTHBK, are in line with studies by Roberts and Bull (2020), which found that routine monitoring is essential for assessing operational conditions and detecting abnormal exposures as well as consistent dosimetry practices effectively track occupational doses and prevent overexposure. Non-compliance in centers like YGH and FMCG reflects findings by Almalki *et al.* (2022), who noted a lack of access to badges as a persistent challenge in resource-constrained facilities and emphasized the importance of the close monitoring of radiation using badges

It is important to contextualize the compliance rates in terms of best practices and known challenges in radiology departments. The results on optimization practices reveal significant disparities in areas such as justification principles, protocol adherence, collimation, optimization techniques, and staff education, which are well-documented in the literature. The findings from the Literature support the need for strict adherence to justification principles to ensure that radiological procedures, especially those involving contrast agents, are only performed when clinically necessary (Vom and Williams, 2017). A study by Vom and Williams (2017) emphasized that justification is a critical step in ensuring patient safety and reducing unnecessary radiation exposure. The poor compliance observed in SYHM, YGH, and MSDC underscores the necessity of regular training and awareness campaigns on the importance of justifying procedures. The strong compliance in (FUTHBK, UDUTH, FMCG) in establishing and following specific protocols aligns with best practices recommended by organizations like the International Atomic Energy Agency (IAEA), which highlights the importance of standardized protocols to optimize radiation doses and imaging outcomes (Guide, 2018). However, the variability in compliance, particularly the lower rate observed in YGH (50%), echoes findings in other studies, where inconsistent protocol adherence has been linked to variations in imaging quality and patient safety (Fathabadi and Oloomi, 2024). The study suggests that protocol standardization across departments is vital for ensuring consistent care and safety.

The high compliance observed at UDUTH and FMCG in minimizing the number of images contrasts with the lower compliance seen in MSDC and YGH. The literature supports the notion that reducing the number of images can decrease both patient exposure to radiation and operational **costs (**Chakole *et al.*, 2022**).** Studies have shown that optimizing imaging protocols by reducing unnecessary images can significantly improve radiation safety (Dudhe *et al.*, 2024). The lower compliance in some centers suggests a need for revisiting imaging practices to avoid unnecessary exposure. High compliance rates for collimation techniques, especially at UDUTH and FUTHBK, are consistent with current recommendations for radiation protection. Proper collimation is a key factor in minimizing patient radiation exposure. The importance of collimation is emphasized in various guidelines, including those by the American College of Radiology (ACR) and Radiological Society of North America (RSNA), which advocate for collimation as part of routine quality control measures (Toussaint *et al.*, 2023**).** However, even though most centers demonstrate high compliance, continued training and equipment maintenance are essential, as evidenced by the slight non-compliance at centers like YGH and MSDC. The high compliance rates in FUTHBK, UDUTH, and FMCG for optimization based on patient size and indications are in line with the Previous findings, which stress the importance of tailoring imaging parameters to individual patient needs. According to IAEA (2017), adjusting radiation dose according to patient size and clinical indications is a fundamental component of dose optimization. However, the lower compliance rates at SYHM and YGH indicate that some centers may need to invest more in equipment and training to fully implement these optimization techniques.

The lack of educational resources at SYHM, YGH, and MSDC is a critical issue. Studies have shown that continuous education and training are essential for maintaining high standards in radiology, especially as imaging technology and radiation safety guidelines evolve. The poor compliance in these centers mirrors findings in other regions, where insufficient training resources have led to gaps in knowledge and suboptimal practices (Chakole *et al.*, 2022). The results suggest a need for investment in ongoing education to keep staff updated on the latest developments in radiological practices. The findings of poor compliance in reviewing and adjusting imaging parameters, especially at SYHM, YGH, and MSDC, reflect a widespread challenge in radiology departments. Literature indicates that regular review and adjustment of imaging parameters based on patient size, clinical condition, and equipment capability are crucial for optimizing image quality while minimizing radiation exposure. The results from this study highlight the need for better adherence to these principles, particularly in centers with low compliance, as this could lead to unnecessary radiation exposure or suboptimal image quality.

The findings from the study on quality assurance (QA) programs in radiology across various centers reflect a critical gap in the implementation of QA protocols, which is consistent with the challenges identified in the existing literature. Radiology departments play a pivotal role in ensuring radiation safety, and a comprehensive QA program is a crucial component of maintaining safety standards. However, as the study results indicate, the absence of such programs in several centers reflects a broader trend observed globally. According to **Abaza (2016),** the absence of regular QA audits and corrective actions in radiology departments can lead to suboptimal radiation safety practices and increased risks for both patients and staff. These findings are particularly relevant to the centers like **SYHM, YGH,** and **MSDC,** where compliance rates for key QA categories such as availability of QA programs, conducting QA audits, and addressing issues were alarmingly low. Similar findings have been reported in other regions, particularly in developing countries, where limited resources and inadequate training are major barriers to the successful implementation of QA programs. For instance, **Abdulkadir (2020)** found that a lack of proper QA audits and corrective actions in

Nigerian hospitals led to significant gaps in radiation safety protocols. This aligns with the results from centers such as **UDUTH** and **FMCG,** where the lack of QA audits and corrective actions could exacerbate radiation risks. The absence of these foundational QA practices at these centers suggests that institutional support, which is crucial for the enforcement of safety protocols, may be lacking. Varghese *et al.* (2024) found that radiology departments with high compliance rates to QA protocols had lower radiation doses administered to patients and improved imaging quality. However, the results from this study suggest that many of the centers studied do not fully comply with QA standards, particularly regarding audits and corrective actions, which are essential for ensuring radiation safety, Lötter (2018) highlighted that QA audits help identify and rectify inconsistencies in imaging protocols, leading to more accurate diagnoses and minimizing unnecessary radiation exposure. In the same vein, Fitzgerald et al. (2021) revealed that a comprehensive QA audit allows for real-time adjustments and enhances the reliability of radiological equipment.

The results from **FUTHBK**, where 35% of responses indicated the availability of a QA program and 50% reported corrective actions being addressed, are more in line with the standards seen in radiology departments in developed countries. **Johnson *et al.* (2009)** highlighted that radiology departments with well-established QA programs tend to show better compliance with radiation safety regulations. For example, **FUTHBK** can be compared to findings from **Chau (2024),** where hospitals with comprehensive QA programs in place reported higher levels of compliance with safety protocols. These institutions typically implement routine audits and actively address identified issues, resulting in a higher standard of patient care and minimized radiation exposure. A study by Lipoti (2008) emphasized that centers with active QA programs significantly reduced instances of unnecessary radiation exposure and ensured more accurate diagnostic imaging. The International Atomic Energy Agency (IAEA) and World Health Organization (WHO) recommend a robust system for addressing issues identified in QA audits, stating that the correction of issues should be immediate to prevent potential harm (Guide, 2024) Despite the positive example seen in **FUTHBK**, the overall trend in the study points to significant gaps in QA compliance. They note that even in developed countries, some hospitals fail to implement effective QA programs due to factors such as insufficient funding, lack of trained personnel, and organizational inertia (Gadeka and Esena, 2020). The results from centers like **SYHM, YGH**, and **MSDC**, where a large proportion of respondents indicated that no QA audits were conducted, reflect these challenges. Gadeka and Esena (2020) emphasize that such non-compliance can lead to long-term adverse effects, including undetected equipment malfunctions, overexposure to radiation, and compromised patient safety. As highlighted by different literature, centres that lack QA protocols are at risk of inconsistencies in radiation doses, leading to the overexposure of patients. This is especially concerning in pediatric imaging, where overexposure can lead to more severe consequences. The failure to conduct QA audits and address identified issues could result in missed opportunities to optimize radiation doses, as emphasized by (Ding *et al.*, 2023)**.** This finding is reflected in the non-compliant centers in the study, where the absence of audits and corrective actions increases the likelihood of patients receiving unnecessary radiation.

Additionally, the finding that 50% of respondents in **UDUTH w**ere unsure about whether issues were addressed is consistent with the literature on the importance of clear and transparent communication within QA processes. Ploussi and Efstathopoulos (2016) indicated that effective QA programs require not only routine audits but also clear documentation of corrective actions, as well as continuous staff training to ensure that issues are promptly addressed. The uncertainty observed in **UDUTH** reflects the potential lack of effective communication and record-keeping, which is essential for improving QA outcomes**.** According Frane and Bitterman (2020) demonstrated that a lack of compliance with QA protocols may lead to increased risks for patients, as radiation doses could exceed safe thresholds, potentially leading to long-term health consequences such as radiation-induced cancer. Finally, the results from the study highlight the need for a more robust and standardized QA framework across all centers to ensure the safety of both patients and radiology staff. The consistent lack of QA audits and corrective actions across several centers (e.g., **SYHM**, **YGH**, and **MSDC**) points to systemic issues that are not unique to the centers in this study. The literature underscores the importance of institutional commitment, resource allocation, and continuous professional development in overcoming these challenges. **Moore (2020)** emphasizes that the establishment of a comprehensive QA framework, backed by regular audits and prompt corrective actions, is essential for minimizing radiation risks and ensuring high-quality care in radiology departments.

In light of these findings, the literature suggests several improvements for radiology departments to enhance their QA programs. According to Zygmont *et al.* (2017), incorporating the latest QA technologies and methodologies can also improve the effectiveness of these programs. Moreover, establishing clear accountability structures for addressing issues and conducting audits can ensure that radiation safety standards are consistently met. This is particularly important in resource-limited settings, such as some of the centers in this study, where external support and collaboration with international QA agencies could be key to improving compliance.

Comparing the results with literature on radiation dose monitoring and optimization practices reveals a concerning trend that aligns with reports of similar deficiencies in healthcare facilities worldwide. Effective radiation dose monitoring and optimization are critical in minimizing the risks associated with radiological procedures. However, the majority of centres in the current study show low or no implementation of systems for monitoring and recording radiation doses, which is consistent with global findings of inadequate dose management in low- and middle-income countries (LMICs). According to several studies, healthcare centres in LMICs often lack proper infrastructure, protocols, and training to ensure systematic radiation dose monitoring. A study by Khan et al. (2018) found that many hospitals in developing countries fail to implement routine dose management systems, largely due to financial constraints, limited access to advanced technologies, and insufficient knowledge among healthcare workers. Furthermore**,** a 2020 report by the International Atomic Energy Agency (IAEA) emphasized that radiation dose monitoring and optimization is a critical area where improvements are necessary, particularly in settings where resources are limited (Rehani *et al.*, 2012), these reports highlight that the lack of systems for reviewing and analyzing radiation doses, as seen in this study, is a widespread issue, resulting in suboptimal safety measures for both patients and healthcare staff.

The absence of dose optimization practices in the current study further supports the conclusions of international studies that emphasize the need for continuous review and analysis of radiation doses. A 2023 report by ICRP noted that while radiation protection standards have improved in many developed nations, LMICs continue to struggle with implementing effective optimization protocols (ICRP, 2023). This is corroborated by the high percentage of respondents at SYHM, YGH, UDUTH, MSDC, and FMCG reporting no dose analysis practices. These deficiencies highlight the urgent need for healthcare facilities in Northern Nigeria and similar regions to improve their radiation dose management systems through training, implementation of technological solutions, and stronger adherence to international standards for radiation protection. In contrast, developed countries generally have more robust dose management systems due to better infrastructure, regulatory oversight, and higher funding. For instance, studies from the U.S. and Europe report that the majority of healthcare centers routinely monitor and optimize radiation doses to ensure patient safety **(Al Khudairi *et al.*, 2023).** In these regions, the use of dose-tracking software, regular audits, and compliance with national and international radiation protection guidelines significantly reduces patient exposure. Therefore, the results of this study align with existing literature indicating a need for substantial improvements in radiation dose management practices, particularly in resource-constrained settings.

Conclusion

The findings underline the variability in compliance with radiation safety protocols across centers. While some institutions demonstrate commendable practices, others face challenges in meeting global standards, particularly in QA audits, educational resources, and radiation dose monitoring. High compliance centers highlight the potential of adhering to IAEA and WHO standards, but systemic issues like resource constraints, inadequate training, and absence of essential safety measures in others threaten overall efficacy. A lack of medical physicists and radiation safety officers exacerbates these challenges, leaving patients and staff at heightened risk of radiation exposure. Addressing these gaps is critical for reducing radiation risks and enhancing patient outcomes, especially in resource-limited settings. This research emphasizes the need for targeted interventions, including:

1. Recruitment and training of qualified personnel such as medical physicists.
2. Implementation of comprehensive QA frameworks, including regular audits and corrective measures.
3. Investment in advanced radiation monitoring technologies and personal dosimetry devices.
4. Development of standardized protocols for justification and optimization of procedures.
5. Promoting collaboration and communication among staff to foster a culture of safety.

Addressing these gaps requires coordinated efforts from healthcare institutions, policymakers, and international bodies. By adopting these recommendations, the radiology departments in the region can significantly enhance diagnostic accuracy while safeguarding patient and staff well-being.

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