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Evaluation of Risk Factors in Radiology Departments in Khartoum Hospitals

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Abstract: ***Introduction**: Exposure to ionizing radiation during radiological procedures poses serious health risks to patients and healthcare personnel. Despite the availability of international radiation protection standards, adherence varies, especially in developing countries like Sudan. This study aim to assess the knowledge, attitudes, and practices (KAP) of radiographers regarding radiation protection in Khartoum State. **Materials and Methods**: A descriptive cross-sectional study was conducted from December 2022 to March 2023. Using simple random sampling, 84 hospitals (18 governmental, 66 private) were selected from 107 in Khartoum State. An 18-item structured questionnaire was distributed to radiographers and radiation technicians across departments. Data were analysed using SPSS. **Results**: Most participants were from Khartoum (60.7%). Radiographers (36.9%) were the main decision-makers for calibration protocols. In emergencies, 57.1% prioritized recovering the radiation source. Significant associations were found between radiation protection knowledge and gender (P = 0.002), and age (P = 0.049), with younger radiographers and females showing better knowledge. No significant associations were observed with hospital type (P = 0.227) or years of experience (P = 0.665). Attendance of training courses significantly correlated with improved practices, such as use of dosimeters (P = 0.011), shielding pregnant patients (P = 0.000), and lower daily exposure (P = 0.007). Significant differences existed between in training access and exposure practices. **Conclusion**: Radiographers in Khartoum State have satisfactory knowledge of radiation hazards but demonstrate suboptimal adherence to safety practices. Continuous training, enforcement of protocols, and infrastructural upgrades are essential to enhance radiation safety and reduce unnecessary exposure risks.*

Keywords: Radiation protection, radiographers, ionizing radiation, occupational exposure, Sudan, safety practices

1. Introduction

Medical imaging and interventional radiology have experienced rapid transformation over recent years, primarily due to technological advancements, increased workloads, a shortage in the healthcare workforce, and the effects of globalization. With these developments, the risks associated with radiological procedures have also evolved. Risk is define as the possibility of incurring harm or loss that may affect patients or healthcare professionals. Radiology departments, by nature, pose various risks primarily due to the use of ionizing radiation. Therefore, risk management in these departments is critical to ensuring patient and staff safety by implementing effective control measures and safety protocols [1].

One of the key hazards in radiological practice is exposure to ionizing radiation, which, although a powerful diagnostic tool, poses serious health risks if not properly managed. Ionizing radiation has the capacity to damage cellular DNA, leading to potential long-term effects such as cancer or cardiovascular diseases. At higher exposure levels, acute radiation syndrome can develop, characterized by symptoms like nausea, skin burns, and even death. While low-level exposure typically does not produce immediate symptoms, it contributes to a cumulative cancer risk [2].

Radiation measurement involves several distinct units and concepts, including radioactivity (Ci/Bq), exposure (R/C/kg), absorbed dose (rad/Gy), and dose equivalent (rem/Sv). Understanding these measurements is crucial for managing occupational exposure, particularly in procedures such as CT scans, fluoroscopy, and mammography, which can significantly exceed background radiation levels [3]. For instance, a chest X-ray delivers around 0.02 mSv, while a CT scan of the abdomen can deliver 15–30 mSv. Prolonged or repeated exposure, especially in pediatric populations, raises substantial health concerns [4].Ionizing radiation has sufficient energy to damage cellular structures, especially DNA, through both direct and indirect interactions.

Staff education and adherence to standardized practices are essential to maintaining safety and operational integrity [5], despite the implementation of safety protocols, recent studies suggest a gap in awareness and adherence among radiologic technologists, especially concerning the appropriate use of protective measures and safe working behaviors in radiation zones. Radiology staff, being at the frontline of exposure, must possess a comprehensive understanding of both the physical risks and the procedural safeguards associated with ionizing radiation.

These effects are typically classified into deterministic effects (e.g., cancer, cataracts, infertility) and stochastic effects (e.g., genetic mutations and chromosomal damage), both of which can manifest after high or repeated low-level exposure [6, 7]. Factors that contribute to increased radiation exposure include inadequate shielding, prolonged exposure time, and incorrect distance between the radiation source and the body [8]. Research indicates that radiology workers commonly report issues such as thyroid disorders, vision problems, and hair loss [9–12]. Studies have shown that fluoroscopy, in particular, poses significant risks to DNA integrity through both direct DNA damage and the formation of free radicals via water molecule radiolysis [13, 14].

Multiple international studies emphasize that while radiographers are generally aware of radiation hazards, adherence to radiation protection (RP) practices remains inconsistent. For example, in Sudan, a study involving 50 radiographers from governmental and private hospitals in Khartoum State revealed considerable gaps in safety practices. Although most hospitals had basic protective tools like lead aprons, their consistent and correct use was lacking. The study also found poor availability of personnel monitoring records and gonadal shielding, especially in governmental hospitals. Alarmingly, a significant percentage of these hospitals used outdated X-ray machines and second-hand equipment, posing increased risks to both patients and staff [16].

Further investigation in Sudan evaluated the shielding effectiveness in diagnostic X-ray rooms. The findings showed that 89% of rooms failed to meet the shielding standards recommended by the International Atomic Energy Agency (IAEA), exposing the public, especially high-risk groups like children and pregnant women, to unnecessary radiation [17, 18]. This was attributed to a lack of qualified staff and inadequate supervision from regulatory authorities.

Internationally, studies in countries such as Iran and Turkey reported similar deficiencies. In Iran, over 550 radiology staff members were assessed for their knowledge, attitudes, and practices (KAP) regarding radiation protection. While no significant differences were observed by gender or education level, working experience and hospital type had a notable impact on KAP scores. The findings called for continuous training to promote better adherence to RP protocols [19]. In Turkey, a descriptive study involving 101 healthcare workers using ionizing radiation revealed that the majority lacked adequate training on radiation protection, particularly on the use of dosimeters and appropriate fluoroscopic techniques [20].

Additional studies have demonstrated the critical importance of radiation protection programs in radiology departments. One cross-sectional study found that while adherence to self-protection practices was relatively low (45.7%), adherence to environmental and patient protection was moderately higher (75.1% and 60.4%, respectively). Radiographers with greater age and experience had significantly better adherence, emphasizing the importance of targeted education and policy implementation [21]. Computed Tomography (CT) scans, which deliver some of the highest radiation doses among diagnostic modalities, warrant special attention. Establishing diagnostic reference levels (DRLs) and enforcing strict RP protocols are essential steps toward mitigating unnecessary exposure [22, 23].

Research involving dental interns further supports these findings. Despite satisfactory baseline knowledge about radiation safety, many interns held misconceptions about permissible exposure limits and safety measures during radiographic procedures. This underscores the need for continuous professional education to ensure up-to-date knowledge and effective implementation of radiation safety measures [24–26].

In the context of interventional cardiology, where prolonged and repeated exposures are common, specific recommendations have been made for reducing occupational doses. These include using personal dosimeters, protective lead gear, and adopting a Radiation Protection Program (RPP) within each facility to ensure consistent training and compliance with safety standards [27].

In more concerning findings, an epidemiological study in an orthopedic hospital in Italy linked poor RP compliance with elevated cancer incidence among radiation-exposed workers. Discrepancies in dosimeter use and unshielded workspaces significantly compromised dose assessment, underlining the need for strict policy enforcement and routine safety monitoring [28, 29].

Given the diverse and serious implications of improper radiation safety practices, there is an urgent need to assess current awareness levels and adherence to radiation protection guidelines among radiology professionals. Although there is considerable awareness of radiation hazards, the application of protective knowledge remains inconsistent, especially in resource-limited settings such as Sudan. This study aims to evaluate the knowledge, perceptions, and behaviors of radiology personnel regarding radiation safety and hazards, focusing on healthcare professionals working with ionizing radiation as part of their daily practice. By identifying gaps in safety practices, the study seeks to inform targeted interventions that can enhance occupational safety and protect public health. Therefore, this study aims to assess the knowledge, awareness, and risk mitigation behaviors of radiologic personnel working with ionizing radiation. By identifying potential gaps in understanding and practice, the study intends to inform targeted educational interventions and reinforce adherence to international safety standards.

2. Materials and Methods

This study was a descriptive cross-sectional study, which was carried out during December 2022 to March 2023. Simple random sampling method was used to select 84 hospitals out of 107 hospitals in Khartoum state. 18 were governmental hospitals and 66 were private hospitals. The participants were the radiographers and radiation technicians.

The participants were working in the departments of x-rays, CT scans, and mammography, fluoroscopy, dentistry, and bone densitometry were invited to participate in this study.

A questionnaire consisting of 18 multiple-choice questions was circulated among the radiographers to evaluate their knowledge of ionizing radiation and their awareness of the radiation risks that result from radiological examinations. The participants were asked for details of personal information, including their age and gender, as well as professional information, including how long they have worked, weather they attended courses about radiation protection or not, how do they considered their knowledge level about radiation risks, do they tell the patients about the radiation risks or not, how many times they exposed to radiation a day, weather they wear a dosimeter or not, and how they will react if an emergency occurred. In addition, to evaluate if the radiation doses they exposed to exceeded the allowable rate, and weather the pregnant women wear aprons while being exposed or not, questions were asked relating to issues including if the hospitals usually chick on the radiation equipment, if the theater shielded in case it contained x-ray, who decides the routine calibration for the radiation equipment and how far the distance between the radiation source and control room. The obtained data is analyzed with Statistical Package for the Social Sciences (SPSS).

3. Results

Distribution of Radiology Staff by Region and Hospital Type

The geographic distribution of participants revealed that the majority were from Khartoum (60.7%), followed by Omdurman (27.4%), and Bahri (11.9%). When considering hospital type, 21.4% of the sample were from government hospitals, with Khartoum accounting for 9.5%, Omdurman 7.1%, and Bahri 4.8%. In contrast, private hospitals comprised 78.6% of the sample, heavily concentrated in Khartoum (51.2%), with lower representations from Omdurman (20.2%) and Bahri (7.1%). These findings reflect the concentration of private healthcare facilities in Khartoum and indicate potential disparities in radiological service distribution across the state, shows table1.

Table 1: Distribution of Radiology Staff by Region and Hospital Type

Type of Hospital		Region			Total
		Omdurman	Khartoum	Bahri	
Government	Count	6	8	4	18
	% within Type of Hospital	33.3%	44.4%	22.2%	100.0%
	% within Region	26.1%	15.7%	40.0%	21.4%
	% of Total	7.1%	9.5%	4.8%	21.4%
Private	Count	17	43	6	66
	% within Type of Hospital	25.8%	65.2%	9.1%	100.0%
	% within Region	73.9%	84.3%	60.0%	78.6%
	% of Total	20.2%	51.2%	7.1%	78.6%
Total	Count	23	51	10	84
	% within Type of Hospital	27.4%	60.7%	11.9%	100.0%
	% within Region	100.0%	100.0%	100.0%	100.0%
	% of Total	27.4%	60.7%	11.9%	100.0%

Source: Prepared by the researcher by SPSS, 2025

Knowledge of Radiation Protection and Demographic Factors

From the Table2. we note that there is a significant correlation between sex and knowledge of radiation protection among radiation workers (P = 0. 002) male ratios were 40.48% (SD = 0.857) and females 59.52% (SD = .712), and an important relationship between age And radiation protection knowledge among radiation workers (P = 0.049) percentages less than 30 years were 61.90% (SD = 0.816), between 30 to 40 years 21.42% (SD = 0.575), between 30 to 50 years 8.40% (SD = 1.000), over 50 years 8.40% (SD = 0.690), there was no significant difference between the type of hospital (government hospital and private hospital) (P = 0.227), and also there was no significant effect on the level of doctors 'experience Radiology (P = 0.665) Besides, there was no imbalance A large difference between training and/or activation courses on radiation protection (P = 0.084).

Table 2: Knowledge of Radiation Protection and Demographic Factors

	Characteristic	Mean	SD	P-value
Sex	Male	1.85	.857	0. 002
	Female	1.94	.712	
Age	less than 30 years	1.96	.816	0. 049
	between 30 and 40	1.72	.575	
	between 40 and 50	2.00	1.000	
	more than 50	1.86	.690	
level of experience	less than 3 years	1.92	.795	0. 665
	4 to 10 years	1.97	.765	
	11 to 20 years	1.80	.789	
	more than 20 years	1.71	.756	
attended training and/or refresher courses on radiation protection	Yes, frequently	1.76	.779	0. 084
	Yes, seldom	1.92	.759	
	No, never	2.00	.778	
Hospital	Governmental	2.00	.686	0.227
	Private	1.88	.795	

Source: Prepared by the researcher by SPSS, 2025

Impact of Hospital Type on Safety Practices

Results of Table 3, we note that there is a significant correlation between sex and Type of hospital (P = 0. 013) male ratios were 40.5% (SD = 0.359) and females 59.5% (SD = 0.443), and an important relationship between attended training and/or refresher courses on radiation protection And Type of hospital (P = 0.003) percentages Yes, frequently 29.8% (SD = 0.436), Yes, seldom 29.8% (SD = 0.332), No, never 40.5% (SD = 0.448) , and there is a significant correlation between the most patient did take a radiation does before and Type of hospital (P = 0.000) percentages yes 58.3% (SD = 0.446), No 41.7% (SD = 0.355) , and an important relationship between times a day are you usually exposed to radiation and Type of hospital (P = 0.000) percentages less than 19.0% (SD = 0.403), from 3 to 21.4% (SD = 0.383), more than 5 59.5% (SD = 0.431), there was no significant difference between Type of hospital and Age (P = 0.160), and also there was no significant level of experience (P = 0.572)), and also there was no significant the hospital do a routine chick fore the radiation equipment (P = 0.349)), and also there was no significant usually use a protection shield (P = 0.259), and also there was no significant dosimeter while working (P = 0.356).

Table 3: Impact of Hospital Type on Safety Practices

	Characteristic	Mean	SD	P-value
Sex	Male	1.85	0.359	0.013
	Female	1.74	0.443	
Age	less than 30 years	1.75	0.437	0.160
	between 30 and 40	1.89	0.323	
	between 40 and 50	1.57	0.535	
	more than 50	2.00	0.000	
level of experience	less than 3 years	1.73	0.450	0.572
	4 to 10 years	1.80	0.407	
	11 to 20 years	1.80	0.422	

	more than 20 years	2.00	0.000	
attended training and/or refresher courses on radiation protection	Yes, frequently	1.76	0.436	0.003
	Yes, seldom	1.88	0.332	
	No, never	1.74	0.448	
the most patient did take a radiation does before	Yes	1.73	0.446	0.000
	No	1.86	0.355	
the hospital do a routine chick fore the radiation equipment	Yes	1.97	0.167	0.349
	No	1.48	0.512	
	Sometimes	1.78	0.424	
usually use a protection shield	always	1.89	0.319	0.259
	sometimes	1.74	0.442	
	never	1.56	0.527	
times a day are you usually exposed to radiation	less than 3	1.81	0.403	0.000
	from 3 to 5	1.83	0.383	
	more than 5	1.76	0.431	
dosimeter while working	Yes	1.92	0.277	0.356
	No	1.76	0.430	

Source: Prepared by the researcher by SPSS, 2025

Training and Its Effect on Safety Behavior

From the Table 4, we note that there is a significant correlation between the most patient did take a radiation does before and attended training and/or refresher courses on radiation protection (P = 0. 000) yes ratios were 58.3% (SD = 0. .816) and No 41.7% (SD = 0.857), and an important relationship between usually use a protection shield And attended training and/or refresher courses on radiation protection (P = 0.000) percentages always 42.9% (SD = 0.828), sometimes 46.4% (SD = 0.864), Never 10.7% (SD = 0.726) ,and there is a significant correlation between usually use a protection shield and attended training and/or refresher courses on radiation protection (P = 0.000) percentages always 42.9% (SD = 0.828), sometimes 46.4% (SD = 0.864), Never 10.7% (SD = 0.726), and there is a significant correlation between times a day are you usually exposed to radiation and attended training and/or refresher courses on radiation protection (P = 0.007) percentages less than 3 19.0% (SD = 0. .885), from 3 to 5 21.4% (SD = 0.826), more than 5 59.5% (SD = 0.768), and there is a significant correlation between pregnant women wear an apron while being exposed and attended training and/or refresher courses on radiation protection (P = 0.000) percentages yes 77.4% (SD = 0.818), No 22.6% (SD = 0.885) ,and there is a significant correlation between dosimeter while working and attended training and/or refresher courses on radiation protection (P = 0.011) percentages yes 15.5% (SD = 0.801), No 84.5% (SD = 0.848),and there is a significant correlation between the theater in your hospital contain x-ray and attended training and/or refresher courses on radiation protection (P = 0.000) percentages yes 64.3% (SD = 0.807), No 35.7% (SD = 0.900),and there is a significant correlation between the theater (in case there is an x-ray there)are shielded and attended training and/or refresher courses on radiation protection (P = 0.000) percentages yes 59.5% (SD = 0.807), No 40.5% (SD = 0.880), there was no significant difference between attended training and/or refresher courses on radiation protection and necessary to advice patients about the risk related to the use of ionizing radiation for medical purposes (P = 0.281), and also there was no significant effect on the daily doses do not exceed the maximum allowable dose (P = 0.175).

Table 4: Training and Its Effect on Safety Behavior

	Characteristic	Mean	SD	P-value
necessary to advice patients about the risk related to the use of ionizing radiation for medical purposes	Yes, always	2.02	0.861	0.281
	Yes, but only for patients who are younger than18 years old	3.00	0.000	
	Yes, but only for patients who are going to have a CT scan	1.86	0.690	
	Yes, but only for patients who are younger than 65 years old	2.33	0.577	
	No, never	2.46	0.776	
The most patient did take aradiation does before	Yes	2.20	0.816	0.000
	No	1.97	0.857	
the hospital do a routine chick fore the radiation equipment	Yes	2.11	0.854	0.106
	No	2.10	0.944	
	Sometimes	2.11	0.751	
usually use a protection shield	always	2.00	0.828	0.000
	sometimes	2.13	0.864	
	never	2.44	0.726	
times a day are you usually exposed to radiation	less than 3	1.88	0.885	0.007
	from 3 to 5	1.72	0.826	
	more than 5	2.32	.768	
pregnant women wear an apron while being exposed	Yes	2.05	0.818	0.000
	No	2.32	0.885	
dosimeter while working	Yes	2.15	0.801	0.011
	No	2.10	0.848	
daily doses do not exceed the maximum allowable dose	Yes	2.12	0.766	0.175
	sometimes	2.08	0.894	
	No	2.14	0.854	
the theater in your hospital contain x-ray	Yes	2.09	0.807	0.000
	No	2.13	0.900	
the theater (in case there is an x-ray there)are shielded	Yes	2.04	0.807	0.000
	No	2.21	0.880	

4. Discussion

The findings of this study highlight a significant concentration of radiology professionals in Khartoum (60.7%), with lower representation in Omdurman (27.4%) and Bahri (11.9%). This trend mirrors the distribution of private healthcare infrastructure, as 78.6% of respondents were affiliated with private hospitals, predominantly located in Khartoum. This imbalance suggests a centralization of diagnostic radiology services, potentially leading to unequal access to radiation protection resources and training in peripheral regions. Similar trends were reported in Nigeria, where urban radiology centers had better infrastructure and awareness (Eze et al., 2013; Adejumo et al., 2012).

A significant association was found between sex and knowledge of radiation protection ($p = 0.002$), with female participants demonstrating slightly higher mean knowledge scores. Age was also a determinant ($p = 0.049$), with younger professionals (<30 years) showing better awareness, possibly due to recent academic exposure to radiation safety protocols. These findings align with prior studies indicating that younger and recently trained staff often exhibit better knowledge and compliance with safety practices (Awosan et al., 2016; Zope et al., 2019). However, no significant differences were observed concerning years of experience, hospital type, or attendance at refresher courses—contrary to studies suggesting ongoing training enhances safety compliance (An et al., 2018; Johnston et al., 2011).

The type of hospital (government vs. private) was significantly associated with several safety-related variables. Male workers were more prevalent in government facilities ($p = 0.013$), and a higher proportion of government staff had never attended radiation protection courses ($p = 0.003$). Additionally, government hospital staff reported higher daily radiation exposure ($p = 0.000$) and less consistent patient dose tracking ($p = 0.000$). These findings reflect systemic challenges in public hospitals, possibly due to resource constraints and less stringent policy enforcement. This is consistent with findings from developing countries where private institutions often have better infrastructure and enforcement of radiation protection standards (Jafri et al., 2022; Abuzaid et al., 2019).

The results demonstrated a strong relationship between attendance at radiation protection courses and various protective practices. Respondents who received regular training were more likely to use protective shields consistently ($p = 0.000$), wear dosimeters ($p = 0.011$), and ensure that operating theaters were shielded ($p = 0.000$). Furthermore, trained individuals were significantly more likely to instruct pregnant patients to wear aprons during imaging ($p = 0.000$). These findings support the ICRP's assertion that education and training are critical components of the ALARA principle (ICRP, 2007; Durán et al., 2013). Similar results were observed in studies by Lara et al. (2019) and Shekhar et al. (2022), which emphasized the role of structured training in reducing occupational and patient exposure.

Interestingly, despite some respondents showing good knowledge of radiation protection, this did not consistently translate into practice. For instance, no significant difference was found between knowledge levels and the routine use of dosimeters or patient shielding ($p > 0.05$). This disconnect echoes concerns raised in previous literature, where awareness does not always equate to behavioral change, often due to lack of institutional enforcement, workload pressures, or availability of protective gear (Rahman et al., 2008; Finestone et al., 2003).

These findings suggest a need for policy standardization across hospital types, with a focus on mandatory and periodic training for all radiology staff. Enhanced monitoring, particularly in government hospitals, is crucial to bridge the gap between knowledge and safe practice. Furthermore, decentralizing resources to ensure equitable access to radiation protection infrastructure across all regions of Khartoum State is vital.

5. Conclusion

Our findings of this study underscore a concerning gap between the theoretical knowledge and the practical application of radiation protection measures among radiographers and radiation technicians in Khartoum State. While a majority of participant's particularly younger and female staff demonstrated satisfactory awareness of radiation risks, actual adherence to protective practices such as consistent use of dosimeters and shielding in clinical settings was suboptimal. The study revealed that attending radiation protection training or refresher courses was a strong predictor of improved safety behavior across several indicators, including frequency of exposure, protective equipment usage, and safe handling of pregnant patients. These associations affirm the critical role of continuous professional development in reinforcing safety culture in radiological departments. However, the limited use of personal dosimeters, the inconsistent calibration responsibilities, and the reactive emergency responses indicate the need for systemic improvements. Furthermore, disparities between public and private hospitals in terms of training access and safety practices suggest institutional variability that must be addressed through standardized national protocols.

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