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Evaluation of radiation protection knowledge and practices among Moroccan operating room nurses

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Abstract – This descriptive cross-sectional study evaluated radiation protection knowledge and practices among 206 Moroccan operating room nurses through a tailored 42-item self-administered questionnaire. The study population exhibited a predominance of male participants (81.1%) and a significant proportion of young professionals (42.2% aged 20–29). Notably, 91.7% of participants reported no prior formal radiation protection training. Data analysis revealed a mean global knowledge score of 4.98 ± 1.02 out of 10, with only 1.9% of participants achieving a high level of knowledge. Specifically, the mean scores for ionizing radiation (IR) and radiation protection (RP) knowledge reached 5.17 ± 1.05 and 4.79 ± 1.18, respectively, with 1.5% of participants demonstrating high-level understanding in both domains. Statistical analysis revealed significant positive correlations between ionizing radiation (IR) and radiation protection (RP) knowledge scores ($r^2 = 0.446$, $p < 0.001$), as well as between global knowledge and practice scores ($r^2 = 0.481$, $p < 0.001$). This investigation highlights a significant gap between theoretical understanding and practical application, emphasizing the need for preliminary training programs before operating room assignments and ongoing education initiatives. Such training should prioritize hands-on experience while addressing resource limitations and the influence of existing operational procedures to improve radiological safety in Moroccan operating rooms.

Keywords: Radiation protection / knowledge / practices / nurses / operating room

1 Introduction

Using ionizing radiation in medicine has increased significantly recently, especially in surgical procedures (UNSCEAR, 2022). While this development provides significant patient advantages, it also raises important questions regarding safeguarding medical staff from potentially hazardous consequences. Operating room nurses are particularly vulnerable to external ionizing radiation exposure, and the extent of this exposure varies significantly according to the procedures employed. These range from straightforward static control images (radiography) to dynamic images with brightness amplification (fluoroscopy) (Castagnet *et al.*, 2009). Since these nurses receive repeated, seemingly low-level radiation doses over time, they must ensure their radiological safety by adhering to the International Commission on Radiological Protection (ICRP) recommendation (ICRP, 2007) to reduce the potential risks associated with prolonged exposure.

In light of this, radiation safety in hospitals, especially in operating rooms, has become an important priority. This fact highlights the critical necessity of providing comprehensive radiation protection training to all personnel, including nurses, and the use of adequate protective measures. These initiatives aim not only to ensure the safety of medical personnel but also to optimize the quality of healthcare for patients by balancing the beneficial use of ionizing radiation with the minimization of associated risks.

Previous studies have investigated nurses' awareness and understanding of radiation exposure. These studies revealed significant knowledge gaps, especially among nurses without specialized training. They also demonstrated that nurses' practices do not always follow the most current recommendations (Babaloui *et al.*, 2018; Dianati *et al.*, 2014; Hirvonen *et al.*, 2019).

According to other studies, effective radiation protection education can enhance nurses' attitudes and understanding about radiation protection. (Yunus *et al.*, 2014; Alahmari and Sun, 2015; Alahmari *et al.*, 2016; Kim *et al.*, 2018). These studies highlight the value and efficiency of radiation protection education programs in closing recognized knowledge gaps and enhancing radiation safety protocols among nursing personnel.

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Recent research in three Moroccan hospitals revealed significant deficiencies in the understanding of operating room personnel about the dangers of X-ray exposure. This study emphasizes the urgent need for training and support programs (Housni *et al.*, 2023). However, there remains a lack of data on Moroccan operating room nurses' specific radiation protection practices and knowledge. This lack of information raises concerns about their preparedness for radiation risks and the effectiveness of existing safety measures.

In this context, our study intends to close this information gap by carefully evaluating the radiation protection practices and knowledge of Moroccan nurses who work in operating rooms, where they can potentially exposed to ionizing radiation. The objective is twofold: first, to evaluate their present proficiency with radiation protection concepts and their application of those concepts; second, to find any weaknesses in their safety procedure application and training. In the end, this study provides crucial data for improving radiation protection in operating rooms in Morocco.

2 Materials and methods

This descriptive cross-sectional study, conducted between October 1 and December 31, 2023, evaluated radiation protection knowledge and practices among 206 Moroccan operating room nurses. The study used a structured questionnaire with 42 items, developed from existing literature and organized into five sections. These sections covered socio-demographic information, including age, gender, education level, professional experience, sector, primary surgical specialty, and radiation protection training. Additionally, they addressed the availability and usage constraints of personal protective equipment (PPE) and dosimeters, knowledge of ionizing radiation and its effects, understanding of radiation protection principles, and radiation protection practices.

The research unfolded in two phases: the first involved administering the questionnaire in person, while the second utilized Google Forms for electronic distribution. Before the main study, we conducted a pilot test with 20 nurses to ensure the questionnaire's clarity and accuracy. Throughout the process, participants completed the surveys anonymously to safeguard the privacy of the collected data.

We employed a binary scoring system to evaluate participants' understanding of ionizing radiation (IR) and radiation protection (RP). Each participant received individual scores for ionizing radiation comprehension (IRKS) and radiation protection knowledge (RPKS), with one point awarded for each correct answer out of ten questions per category. We then calculated the Global Knowledge Score (GKS) by averaging the IRKS and RPKS scores. This approach allowed us to categorize knowledge levels as low (<50% correct answers), moderate (50-70% correct answers), or high (>70% correct answers). Additionally, we assessed participants' practices using a 5-point Likert scale, ranging from 1 (Never) to 5 (Always). We computed the average score for each participant based on ten questions, classifying practices as weak (<2.5), acceptable (2.5–3.5), or high (>3.5).

We performed statistical analyses using IBM SPSS Statistics version 26. We computed descriptive statistics, including frequencies, percentages, means, and standard deviations, to generate knowledge and practice scores and describe the dataset. We analyzed differences in scores based on socio-demographic characteristics using independent *t*-tests and one-way ANOVAs, applying Tukey's post-hoc tests as necessary. We employed Pearson correlation to examine the relationships between IRKS and RPKS, along with those between GKS and practice scores. Furthermore, we conducted multiple regression analyses to identify factors influencing the radiation protection practices of operating room nurses. All statistical tests used a significance level of $p < 0.05$.

This study utilized the AI tool ChatGPT (GPT-4, developed by OpenAI) as part of the manuscript preparation. The tool was employed to assist with language editing, specifically for improving grammar, style, and clarity, without influencing the scientific content of the paper. No part of the data analysis, interpretation, or scientific conclusions was generated by AI.

3 Results

3.1 Participant socio-demographic data

Table 1 summarizes the socio-demographic characteristics of participants. A total of 206 operating room nurses from different Moroccan hospitals participated in our research. Most participants were men (81.1%), with 42.2% in the 20–29 age group. Nearly half (47.6%) held a nursing diploma. Regarding job experience, 25.2% of the participants had worked for one to five years. Of the participants, 62.6% worked in public hospitals, with 26.7% in the orthopedics specialty. It is important to note that 91.7% of participants had not received any training in radiation protection.

2.1 AI disclaimer

This study utilized the AI tool ChatGPT (GPT-4, developed by OpenAI) as part of the manuscript preparation. The tool was employed to assist with language editing, specifically for improving grammar, style, and clarity, without influencing the scientific content of the paper. No part of the data analysis, interpretation, or scientific conclusions was generated by AI.

3.2 Availability and constraints related to personal protective equipment and dosimeters

The results revealed that 10.7% of nurses reported the absence of personal protective equipment (PPE) in their facility's operating rooms. Regarding specific PPE availability, 90.3% of participants noted the presence of leaded aprons, 58.7% of leaded goggles, 24.7% of thyroid shields, 9.7% of gonad shields, and 6.3% of leaded gloves. Moreover, 61.4% of nurses believed there were insufficient PPEs for all operating room staff. 65.0% of participants owned dosimeters, and 95.1% knew wearing them was a regulation necessity.

The study also highlighted significant challenges related to PPE and dosimeter usage, with 43.1% of nurses reporting discomfort from prolonged use of this equipment, particularly during complex

Table 1. Socio-demographic characteristics of participants

Characteristics		Number of nurses	Percentage
Gender	Male	167	81.1
	Female	39	18.9
Age group	20–29 years	87	42.2
	30–39 years	47	22.8
	40–49 years	48	23.3
	≥50 years	24	11.7
Education level	Diploma	98	47.6
	Bachelor	85	41.3
	Master	19	9.2
	Doctorat	4	1.9
Work experience in years	<1	36	17.5
	1–5	52	25.2
	6–10	32	15.5
	11–15	44	21.4
	>15	42	20.4
Work sector	Public hospital	129	62.6
	Private clinic	77	37.4
Speciality	Cardiac surgery	48	23.3
	Vascular surgery	36	17.5
	Orthopedic surgery	55	26.7
	Urology	31	15.0
	Neurosurgery	36	17.5
Formal training on radiation protection	Yes	17	8.3
	No	189	91.7

Table 2. Mean knowledge scores of participants.

Score	Mean ± SD	Min	Max
GK	4.98 ± 1.02	3.00	8.00
IRK	5.17 ± 1.05	2.00	8.00
RPK	4.79 ± 1.18	3.00	8.00

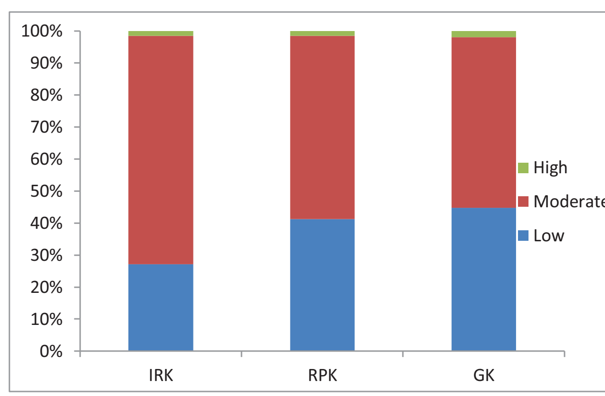

Fig. 1. Distribution of participants' knowledge levels in IR, RP, and global knowledge.

procedures. Other obstacles to optimal use included lack of time and work overload (41.3%), supply difficulties (32.5%), and the need for more comprehensive training (31.9%).

3.3 Participants' knowledge of radiation protection

Our study assessed participants' knowledge in two specific areas: ionizing radiation (IR) and radiation protection (RP). We calculated a knowledge score for each domain and then combined these to generate an overall knowledge score (GKS). Table 2 summarizes the mean scores obtained by participants. The mean IRKS was 5.17 ± 1.05, with 1.5% of participants demonstrating advanced proficiency. The mean RPKS was 4.79 ± 1.18, with another 1.5% exhibiting a high level of understanding. The mean GKS was 4.98 ± 1.02, with 1.9% of participants achieving a superior level of comprehension (see Fig. 1).

Table 3 displays the results of knowledge score evaluations and statistical analyses related to socio-demographic data.

A comprehensive examination of participant knowledge scores unearthed notable variations associated with several socio-demographic factors. Interestingly, the GKS and IRKS revealed a significant difference with all investigated socio-demographic characteristics, except surgical specialty. In contrast, RPKS showed no significant differences based on gender or work sector.

A comprehensive analysis of participant knowledge scores revealed significant variations across socio-demographic groups. Male participants outperformed their female counterparts in GK (5.06 ± 1.02, $p = 0.024$) and IRK (5.27 ± 1.05, $p = 0.006$). Additionally, older nurses (over 50 years of age)

Table 3. Knowledge scores results and statistical analysis related socio-demographic data.

Characteristics		IRKS			RPKS			GKS		
		M ± SD	t/F	*p*	M ± SD	t/F	*p*	M ± SD	t/F	*p*
Gender	Female	4.77 ± 0.95	–2.877	0.006	4.54 ± 1.15	–1.500	0.139	4.65 ± 0.96	–2.323	0.024
	Mal	5.27 ± 1.05			4.85 ± 1.18			5.06 ± 1.02		
Age group	20–29 years	4.37 ± 0.75	66.40	0.000	3.98 ± 0.85	57.42	0.000	4.17 ± 0.62	88.809	0.000
	30–39 years	5.38 ± 0.64			4.81 ± 0.82			5.10 ± 0.61		
	40–49 years	5.85 ± 0.87			5.56 ± 0.89			5.71 ± 0.76		
	≥50 years	6.33 ± 0.69			6.17 ± 0.99			6.25 ± 0.77		
Education level	Diploma	5.60 ± 0.74	62.108	0.000	5.18 ± 0.95	64.223	0.000	5.39 ± 0.73	92.172	0.000
	Bachelor	4.36 ± 0.70			3.92 ± 0.74			4.14 ± 0.55		
	Master	6.16 ± 1.10			6.16 ± 0.67			6.16 ± 0.77		
	Doctorat	7.25 ± 0.45			7.25 ± 0.86			7.25 ± 0.58		
Work experience in years	<1	4.00 ± 0.41	60.875	0.000	3.75 ± 0.68	61.889	0.000	3.88 ± 0.40	93.660	0.000
	1–5	4.73 ± 0.66			4.00 ± 0.76			4.37 ± 0.55		
	6–10	5.06 ± 0.87			4.78 ± 0.82			4.92 ± 0.63		
	11–15	5.66 ± 0.85			5.32 ± 0.73			5.49 ± 0.67		
	>15	6.31± 0.67			6.12 ± 0.93			6.21 ± 0.71		
Work sector	Public hospital	5.41 ± 1.00	–4.321	0.000	4.87 ± 1.22	–1.247	0.214	5.14 ± 1.03	–2.968	0.003
	Private clinic	4.78 ± 1.02			4.66 ± 1.09			4.72 ± 0.94		
Surgical speciality	Cardiac Surgery	5.19 ± 1.15	0.069	0.991	5.44 ± 1.17	5.085	0.001	5.31 ± 1.05	1.675	0.157
	Vascular Surgery	5.25 ± 1.07			4.58 ± 1.24			4.92 ± 1.10		
	Orthopedic Surgery	5.15 ± 0.92			4.56 ± 0.95			4.85 ± 0.85		
	Urology	5.16 ± 1.08			4.65 ± 1.07			4.90 ± 0.99		
	Neurosurgery	5.14 ± 1.06			4.61 ± 1.24			4.88 ± 1.08		
Formal training in radiation protection	No	5.04 ± 0.97	24.272	0.000	4.60 ± 1.02	40.232	0.000	4.82 ± 0.88	40.636	0.000
	Initial training	6.33 ± 0.49			6.67 ± 0.49			6.50 ± 0.43		
	Continuing training	6.79 ± 0.68			6.93 ± 0.71			6.86 ± 0.62		

demonstrated superior performance in all three knowledge domains: GK (6.25 ± 0.77, $p < 0.001$), IRK (6.33 ± 0.69, $p < 0.001$), and RPK (6.17 ± 0.99, $p < 0.001$). Nurses holding doctoral degrees in nursing also achieved the highest scores across all knowledge domains: GK (7.25 ± 0.58, $p < 0.001$), IRK (7.25 ± 0.45, $p < 0.001$), and RPK (7.25 ± 0.86, $p < 0.001$). An equivalent pattern emerged for nurses with more than 15 years of experience, who exhibited the highest scores in GK (6.21 ± 0.71, $p < 0.001$), IRK (6.31 ± 0.67, $p = 0.001$), and RPK (6.12 ± 0.93, $p < 0.001$).

We observed statistical differences in GKS and IRKS across employment sectors. Nurses working in the public sector demonstrated significantly higher scores compared to other fields, with mean scores of 5.14 ± 1.03 ($p = 0.003$) for GKS and 5.41 ± 1.00 ($p < 0.001$) for IRKS. Additionally, we found significant variations in RPKS across surgical specialties. Notably, nurses specializing in cardiac surgery demonstrated superior knowledge in this area, achieving the highest mean RPKS of 5.44 ± 1.17 ($p = 0.001$) compared to other specialties. Finally, the study revealed that nurses who received continuous radiation protection training achieved significantly higher scores than those who had no training or only initial training for GK (6.86 ± 0.62, $p < 0.001$), IRK (6.79 ± 0.68, $p < 0.001$), and RPK (6.93 ± 0.71, $p < 0.001$).

The results of the multiple comparisons for knowledge scores in ionizing radiation (IR) and radiation protection (RP), stratified by age, educational level, experience, surgical specialty, and radiation protection training, confirmed this observation (data not shown).

3.4 Correlation between ionizing radiation knowledge and radiation protection knowledge

The correlation between knowledge of ionizing radiation and radiation protection showed a significantly positive correlation ($r^2 = 0.446$, $p < 0.001$).

3.5 Participants' radiation protection practices

Table 4 summarizes the responses provided by operating room nurses regarding their radiation protection practices. The mean score for radiation protection practices was 2.16 ± 0.40 out of 5, with 83.0% of participants (171 individuals) classified as having low practices and 17.0% (35 individuals) as having acceptable practices.

The study also revealed significant differences in practice scores according to socio-demographic characteristics. Gender showed a notable difference, with men achieving slightly higher mean scores than women (2.19 ± 0.41, $p = 0.047$). Age revealed notable differences; nurses over 50 and those between 40 and 50 obtained the highest scores (2.58 ± 0.39 and 2.43 ± 0.42, respectively) compared to other age groups

Table 4. Operating room nurses' self-reported radiation protection practices.

Items	Responses				
	Always	Often	Sometimes	Rarely	Never
I wear a lead apron during all procedures.	9 (4.4%)	12 (5.8%)	13 (6.3%)	32 (15.5%)	140 (68.0%)
I wear lead glasses during procedures that carry a risk of eye exposure.	0 (0.0%)	0 (0.0%)	1 (0.5%)	9 (4.4%)	196 (95.1%)
I wear lead-lined gloves during procedures involving potential ionizing radiation exposure to my hands.	0 (0.0%)	2 (1.0%)	2 (1.0%)	5 (2.4%)	197 (95.6%)
I use thyroid shields during procedures involving ionizing radiation.	0 (0.0%)	1 (0.5%)	4 (1.9%)	13 (6.3%)	188 (91.3%)
I use gonadal shields during procedures involving ionizing radiation.	0 (0.0%)	0 (0.0%)	2 (1.0%)	5 (2.4%)	199 (96.6%)
I adhere to radiation protection principles in all my activities in the operating room	119 (57.8%)	69 (33.5%)	15 (7.3%)	2 (1.0%)	1 (0.5%)
I position myself in a way that maximizes my distance from the radiation source	36 (17.5%)	73 (35.4%)	56 (27.2%)	37 (18.0%)	4 (1.9%)
I minimize the time of exposure to ionizing radiation as much as possible during procedures.	9 (4.4%)	37 (18.0%)	47 (22.8%)	71 (34.5%)	42 (20.4%)
I use protective barriers to shield myself from ionizing radiation during radiological procedures.	45 (21.8%)	122 (59.2%)	28 (13.6%)	11 (5.3%)	0 (0.0%)
I wear a dosimeter while working in the operating room.	3 (1.5%)	3 (1.5%)	7 (3.4%)	21 (10.2%)	172 (83.5%)

($p < 0.001$). Level of education also showed significant differences, with nurses holding doctorates or masters degrees achieving higher scores (2.93 ± 0.13 and 2.42 ± 0.30, respectively) than those with lower qualifications. In addition, professional experience revealed a significant difference, with nurses with more than 15 years of experience achieving the highest scores (2.62 ± 0.40, $p < 0.001$). The work sector and surgical specialty also exhibited significant differences in practice scores. Notably, nurses working in private clinics achieved the highest scores (2.21 ± 0.44, $p = 0.027$), while those specializing in cardiac or orthopedic surgery showed higher practice scores (2.33 ± 0.38 and 2.18 ± 0.50, respectively, $p = 0.009$). Ongoing training in radiation protection also led to significantly higher practice scores, with regularly trained participants achieving considerably higher scores (2.83 ± 0.32, $p < 0.001$) than those with no training (Tab. 5).

3.6 Correlation between global knowledge and radiation protection practices

The correlation between global knowledge and practices in radiation protection showed a significantly positive correlation ($r^2 = 0.481$, $p < 0.01$, Fig. 2).

3.7 Factors affecting radiation protection practices

We conducted a multivariate regression analysis to investigate factors affecting radiation protection behaviors among operating room nurses. The regression model included the GKS, participants' socio-demographic information, and the accessibility of dosimeters and PPE.

To assess the dependent variables, we examined them for multicollinearity and autocorrelation. The Durbin-Watson score of 1.958 indicated the absence of autocorrelation. Correlations between independent variables ranged from −0.329 to 0.694, not exceeding 0.80, demonstrating the independence of the explanatory factors. Tolerance values ranged from 0.225 to 0.946, all above 0.1. The variance inflation factor (VIF) ranged from 1.057 to 4.880. These values remained below five after excluding the 20–29 age group and education level variables, which had shown VIFs exceeding ten. These results confirmed the absence of significant multicollinearity, justifying the use of multiple regression for our analysis.

The regression model was significant ($F = 14.72$, $p < 0.001$) and explained 53.2% of the variability in radiation protection practices among nurses. Key factors included the nurses' GKS ($\beta = 0.28$, $p < 0.001$), professional experience, and ongoing training in radiation protection ($\beta = 0.128$, $p = 0.032$) (Tab. 6).

Table 5. Practices scores results and statistical analysis related socio-demographic data.

		Score of practices			Multiple comparisons				
		M ± SD	t/F	p					
Gender	Female	2,06 ± 0,36	-2,023	0,047					
	Mal	2,19 ± 0,41							
					20-29	30-39	40-49	> 50	
Age group in years	20-29	1,93 ± 0,27	39,95	0,000	-	0,016	0,000	0,000	
	30-39	2,11 ± 0,25			0,016	-	0,000	0,000	
	40-49	2,43 ± 0,42			0,000	0,000	-	0,239	
	> 50	2,58 ± 0,39			0,000	0,000	0,239	-	
					Diploma	Bachelor	Master	Doctorat	
Education level	Diploma	2,31 ± 0,40	32,86	0,000	-	0,000	0,551	0,002	
	Bachelor	1,91 ± 0,24			0,000	-	0,000	0,000	
	Master	2,42 ± 0,30			0,551	0,000	-	0,031	
	Doctorat	2,93 ± 0,13			0,002	0,000	0,031	-	
					< 1	1-5	6-10	11-15	> 15
Work Experience in years	< 1	1,89 ± 0,22	39,82	0,000	-	0,974	0,111	0,000	0,000
	1-5	1,93 ± 0,27			0,974	-	0,249	0,000	0,000
	6-10	2,08 ± 0,28			0,111	0,249	-	0,027	0,000
	11-15	2,29 ± 0,33			0,000	0,000	0,027	-	0,000
	> 15	2,62 ± 0,40			0,000	0,000	0,000	0,000	-
Work sector	Public hospital	2,08 ± 0,33	-2,224	0,027			-		
	Private clinic	2,21 ± 0,44							
					Cardiac Surgery	Vascular Surgery	Orthopedic Surgery	Urology	Neuro surgery
Surgical Specialty	Cardiac Surgery	2,33 ± 0,38	3,448	0,009	-	0,028	0,266	0,063	0,023
	Vascular Surgery	2,08 ± 0,42			0,028	-	0,754	1,000	1,000
	Orthopedic Surgery	2,18 ± 0,50			0,266	0,754	-	1,000	1,000
	Urology	2,09 ± 0,28			0,063	1,000	0,069	-	1,000
	Neurosurgery	2,07 ± 0,29			0,023	1,000	0,716	1,000	-
					No	Initial training	Continuing training		
Formal training in radiation protection	No	2,11 ± 0,36	25,66	0,000	-	0,548	0,000		
	Initial training	2,33 ± 0,50			0,548	-	0,084		
	Continuing training	2,83 ± 0,32			0,000	0,084	-		

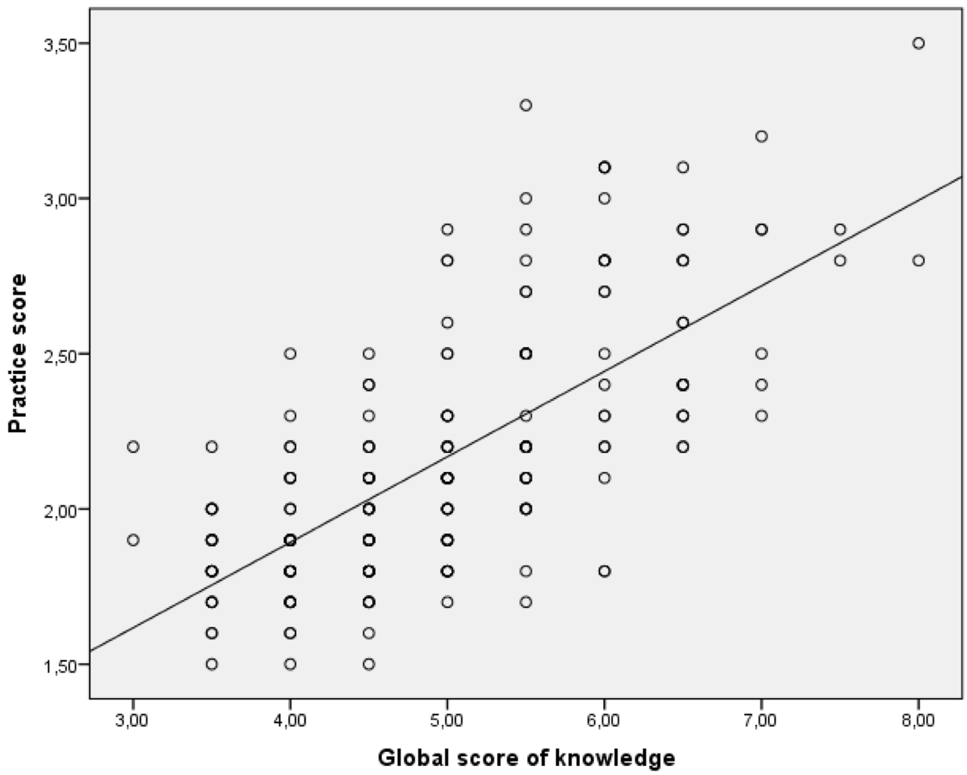

Fig. 2. Impact of knowledge on radiation protection practices.

4 Discussion

This study evaluated Moroccan operating room nurses' knowledge and practices regarding radiation protection. The mean scores for IRK (5.17 ± 1.05), RP (4.79 ± 1.18), and GK (4.98 ± 1.02) indicate a moderate level of understanding. A significant positive correlation ($r^2 = 0.446$, $p < 0.001$) between IRK and RPK suggests that nurses with a better IRK also have better RPK, reflecting the interconnectedness of these two areas of expertise.

Moroccan nurses demonstrated relatively positive theoretical knowledge compared to their counterparts in Japan, Saudi Arabia, Kuwait, and Iran, where studies have shown a more limited understanding of radiation physics, principles, and protective measures (Ohno and Kaori, 2011; Dianati *et al.*, 2014; Alotaibi *et al.*, 2015, 2018; Hirvonen *et al.*, 2019; Alomairy, 2024).

The study revealed a lack of adherence to radiation protection protocols among nursing staff. The mean practice score of 2.16 ± 0.40 indicated that 83% of participants demonstrated inadequate practice. A significant positive correlation ($r^2 = 0.481$, $p < 0.05$) between the GKS and practices suggests that improving theoretical knowledge could enhance practical adherence. Existing literature (Jeong and Jang, 2016) supports this notion, emphasizing the critical role of knowledge for operating room nurses in adopting appropriate radiation safety practices. Ongoing training to strengthen nurses' understanding could enhance adherence to standards and mitigate exposure risks for all involved.

While a deeper understanding of ionizing radiation and safety protocols is crucial for enhancing practices, it alone cannot ensure consistent implementation. A significant discrepancy exists between professed adherence to radiation protection principles and observed practices in the field. For instance, although 57.8% of participants reported systematically adhering to these principles, our findings indicate otherwise. Although most participants have access to lead aprons (90.3%), lead goggles (58.7%), and thyroid protectors (24.7%), their use remains minimal. Similarly, while the vast majority (95.1%) recognize the regulatory requirement to wear a dosimeter and 65.0% own one, only a tiny fraction (1.5%) consistently use them despite their lightweight and convenience. This disparity between theoretical knowledge, equipment availability, and actual practice underscores the challenges of translating awareness into sustained behavioral change in the hospital setting. These results align with other studies conducted in Iran (Azimi *et al.*, 2018), Turkey (Ozbas *et al.*, 2021), and Portugal (Antunes-Raposo *et al.*, 2022), which reported similar discrepancies in the use of radiation protection equipment among healthcare workers.

Numerous complex barriers stemming from organizational structures and individual behaviors hinder the adoption of radiation protection practices. Other studies (Antunes-Raposo *et al.*, 2022; Neves *et al.*, 2011) back up our results, highlighting the critical role of organizational constraints. These include limited resources (PPE, dosimeters), excessive workload, unclear protocols, and difficult working conditions. Notably, 41.3% of participants cited lack of time and excessive workload as significant barriers, while 32.5% reported difficulties acquiring necessary equipment.

Individual factors, such as attitudes, beliefs, and motivations, significantly influence healthcare workers' adherence to

Table 6. Factors affecting radiation protection practices among operating room nurses.

Variable	B	SE	β	t	p
(Constant)	1.419	0.250		5.681	<0.001
GSK	0.161	0.038	0.406	4.283	<0.001
Gender :Female†	–0.001	0.065	–0.001	–0.020	0.984
Age group†					
30–39 years	0.034	0.080	0.035	0.423	0.673
40–49 years	0.085	0.073	0.089	1.158	0.248
Work experience†					
<1 year	–0.239	0.114	– 0.225	–2.100	0.037
1–5 years	–0.287	0.094	–0.309	–3.066	0.002
6–10 years	–0.272	0.102	–0.244	–2.659	0.009
11–15 years	–0.208	0.080	–0.211	–2.604	0.010
Workplace†					
Private clinic	0.018	0.044	0.022	0.418	0.676
Specialty †					
Cardiac Surgery	0.133	0.068	0.139	1.947	0.053
Orthopedic Surgery	0.105	0.064	0.115	1.636	0.104
Vascular Surgery	–0.025	0.070	–0.024	–0.358	0.720
Neurosurgery	–0.038	0.071	–0.038	–0.536	0.592
Radiation protection training†					
Initial training	0.135	0.176	–0.040	–0.766	0.445
Continuing training	0.205	0.095	0.128	2.157	0.032
Availability of PPE: Yes†	0.057	0.067	0.044	0.885	0.392
Availability of dosimeters: Yes†	–0.006	0.040	–0.007	–0.145	0.885
R^2 = 0.571, Adjusted R^2 = 0.532, F = 14.72, p < 0.001					

† Reference group: Gender: male, Age group: ≥ 50 years, Work experience: > 15 years, Workplace: Public hospital, Specialty: Urology, Radiation protection training: No, Availability of PPE: No, Availability of dosimeters: No.

personal protective equipment (PPE) use. Our findings, consistent with previous research, highlight the importance of physical comfort (Antunes-Raposo *et al.*, 2022; Shubayr, 2024). Specifically, 43.1% of nurses reported discomfort associated with prolonged PPE use, particularly during complex procedures. Additionally, misunderstandings about the effectiveness and reliability of dosimeters, combined with frequent forgetfulness, contribute to their underutilization among healthcare workers exposed to ionizing radiation (Antunes-Raposo *et al.*, 2022). The need for ongoing education is evident, as 31.9% of nurses desired additional training in PPE use and dosimeter interpretation. Conversely, the perception of PPE advantages, the recognized severity of exposure risks, and a sense of self-efficacy enhance adherence to PPE (Shubayr, 2024).

These findings highlight the need for targeted training and awareness initiatives alongside organizational improvements that promote compliance with radiation safety protocols. A systemic approach integrating organizational and individual factors is essential to overcoming these barriers and strengthening radiation safety in healthcare settings rather than relying solely on personal responsibility (Neves *et al.*, 2011).

Univariate analysis revealed significant differences in radiation protection knowledge and practice scores based on socio-demographic parameters. Male nurses constituted the majority of the sample (81.1%), which contrasts with general trends in the nursing profession (Jeong and Jang, 2016; Babaloui *et al.*, 2018; Park and Yang, 2021; Jeyasugiththan *et al.*, 2023;Alomairy, 2024). They demonstrated higher levels of knowledge, confirming previously observed gender disparities (Hirvonen *et al.*, 2019; Rahimi *et al.*, 2021). However, after adjusting for age and professional experience, multivariate analysis showed that gender was no longer a significant predictor. Older and more experienced participants and those with a PhD in nursing achieved better results, highlighting the importance of higher education (Alzubaidi *et al.*, 2017; Jeyasugiththan *et al.*, 2023). Nurses in cardiac surgery demonstrated better knowledge and adherence to radiation safety protocols, consistent with variations observed across work units (Hirvonen *et al.*, 2019). Public sector nurses demonstrated a greater understanding of ionizing radiation, while private sector nurses excelled in radiation protection practices, likely due to differences in institutional policies and resources.

A multivariate regression analysis identified general knowledge, professional experience, and engagement in continuing education as significant predictors of radiation protection practices among operating room nurses. While socio-demographic factors like gender, age, workplace, and surgical specialty had no significant impact, general knowledge emerged as the primary predictor ($\beta = 0.28$, $p < 0.001$), underscoring the importance of a solid theoretical foundation. Moreover, experienced nurses and those with continuing education in radiation protection demonstrated a greater likelihood of adhering to safety protocols ($\beta = 0.128$, $p < 0.05$), highlighting the value of ongoing professional development.

Despite the positive impact of continuous education, participants' radiation protection practices remain insufficient. This persistent discrepancy between knowledge and practice underscores the need for more effective strategies to bridge the gap. Previous research supports this finding, frequently highlighting a disparity between knowledge acquisition and practical application. For example, at the Memorial Sloan-Kettering Cancer Center in New York, an educational intervention significantly increased knowledge from 58.9% to 71.6% yet had a minimal impact on attitudes (Dauer *et al.*, 2006). Similarly, in France, a single training session improved knowledge among operating room doctors but failed to produce substantial changes in their daily practices (Brun *et al.*, 2018).

The frequency of training emerges as a critical factor. A Korean study showed that nurses receiving regular instruction were more inclined to adopt safe behaviors (Kim *et al.*, 2018). However, low participation rates remain a significant obstacle: only 6.8% of nurses engage in ongoing education, and just 1.5% receive initial instruction. This situation contrasts sharply with the recommendations of the IAEA and ICRP, which advocate for mandatory education for all personnel exposed to ionizing radiation (ICRP, 2007). Limited involvement impedes the dissemination of a radiation safety culture within teams, creating a divide between trained and untrained professionals, which hinders the widespread adoption of protective measures.

5 Limitations

Our study has limitations that warrant consideration. The overrepresentation of men (81%) may limit the generalizability of our findings, even though our analysis showed no significant gender effect. In addition, self-reported questionnaire data may introduce response bias, such as overestimating knowledge or adherence. Additionally, questionnaires may not fully capture the nuances of real-world operating room settings. Future research with a more balanced gender distribution could explore potential gender-specific differences in radiation protection knowledge and practices. It would also be beneficial to incorporate direct observations or practical assessments.

6 Conclusion

This study reveals a substantial disparity between Moroccan operating room nurses' theoretical understanding of radiation protection and their actual practices. Despite their comprehensive knowledge of radiation risks, adherence to safety protocols remains inadequate. A multifaceted strategy is required to address this gap, including mandatory in-service training, revised institutional policies, improved working conditions, and fostering a culture of radiation protection. A supportive work environment, characterized by open communication and institutional backing, is crucial for sustaining these efforts. Further research is necessary to assess the effectiveness of these interventions, explore the underlying factors contributing to the knowledge-practice gap, and identify additional strategies to minimize healthcare professionals' exposure to ionizing radiation and enhance radiological safety in Moroccan operating rooms.

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Conflicts of interest

The authors declare that they have no conflict interest.

Data availability statement

The research data associated with this article are including within the article.

Author contribution statement

I. Harbaj: methodology, questionnaire design, data collection, data analys
A. Kharchaf: data analysis,
E. Chakir: writing-reviewing,
S. Harbaj: data collection, data analysis.

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