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Examining proficiency in radiation safety among pediatric residents in Palestine: a multicenter cross-sectional survey

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Abstract

Background Safe radiological practices are essential in pediatric healthcare because of children's vulnerability to the chronic impacts of radiation exposure. Having sufficient knowledge is crucial for adopting radiological safety and effective communication with patients. This study aimed to assess the level of knowledge about radiation safety among pediatric residents.

Methods This multicenter cross-sectional study was conducted from January 2022 to May 2022 in 15 Palestinian hospitals. All pediatric residents registered in the national pediatric residency program were eligible for inclusion. Convenience sampling was used to invite the participants. The questionnaire was based on a literature review and consisted of questions on demographic characteristics and sources of knowledge, in addition to 10 questions assessing knowledge about radiation safety. The proposed questions were reviewed by a panel of experts, and a pilot study was then conducted among 20 pediatric residents to improve linguistic accuracy and clarity. Descriptive and inferential statistics were used to analyze the data. The Mann–Whitney and Kruskal–Wallis tests were used to assess potential associations between knowledge scores and other categorical variables.

Results The final sample comprised 108 pediatric residents, for a response rate of 93.1%. Of those, 55.6% were females, and 44.4% were males. Most participants cited either personal study (36.1%) or medical school (36.1%) as the main sources of information about radiation safety. Approximately half had attended a conference related to radiological safety (47.2%), and over half said that they think the workplace was prepared for radiation safety (57.4%). The median knowledge score of the participants was 6.0/10.0. Years of pediatric training ($p = 0.001$) and source of information ($p = 0.037$) were significantly associated with higher knowledge scores. Most of the participants correctly identified the imaging modalities that use X-ray (97.2%) and cause the highest radiation dose (89.8%). The majority said they were familiar with the ALARA principle (60.2%). However, only 19.4% correctly chose the number of CXRs

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equivalent to an abdominal MDCT (19.4%), and less than a third correctly labeled orthopantomography as safe during pregnancy (28.7%).

Conclusions This study identified knowledge gaps in radiation safety among pediatric residents, which could be addressed through tailored educational integration into pediatric training programs, emphasizing the risks pertinent to pediatric age groups. Moreover, the formulation of national guidelines is crucial for applying radiation knowledge in the field.

Keywords Radiation safety, Radiology, Pediatric radiology, Pediatrics, Knowledge

Background

Ionizing radiation can cause multiple acute and chronic effects on the human body that may persist for decades after exposure through direct damage to body tissues, including the skin and lens of the eye [1, 2], or DNA damage, leading to the development of cancers [3]. Children are particularly vulnerable to radiation risks [4]. Epidemiological studies have revealed that exposure to radiation during childhood is associated with a greater risk of developing cancer than is subsequent exposure to radiation [5–7]. This is, first, due to the greater sensitivity of growing body tissues and proliferating cells in children, as proliferating cells are more susceptible to genetic damage [8, 9]. Second, the lifetime risk of manifesting cancers is greater in children than in adults due to their greater life expectancy postexposure than in adults [10]. Therefore, healthcare professionals dealing with children should possess sufficient knowledge about radiation safety, especially regarding the justification of radiological examination, to help minimize the risks associated with radiation exposure.

Several principles of radiation safety have been developed and evolved throughout the past century. The principles of '*justification, optimization, and dose limitation*' were proposed by the International Commission on Radiologic Protection (ICRP) in 1977 [11]. Among those, pediatric residents and pediatricians are particularly concerned with the principle of justification in their capacity as healthcare workers involved in ordering radiological tests for pediatric patients. The principle of justification requires that exposure to radiation should be avoided unless the benefits of an indicated radiological examination outweigh the detriments associated with radiation exposure [12, 13].

In the 2022 symposium in Vancouver, the ICRP concluded that global expertise in radiation protection can be improved through several measures, including strengthening resources, improving research, enhancing academic education, using appropriate language when communicating about radiation safety, and, importantly, raising awareness through education and training [14]. With the rapid development in radiology and the constant introduction of novel modalities, healthcare workers often struggle to acquire practical knowledge that matches the progress made in radiology [15]. Practical knowledge about radiation safety is essential for increasing radiation safety and communicating effectively with patients [15, 16]. Only two studies have explored the level of knowledge about radiation safety in Palestine. These studies were conducted among medical students and radiation technologists and demonstrated varying degrees of knowledge [17, 18]. Given the importance of radioprotection for children as a vulnerable group, radiation safety education is a priority for pediatricians and pediatric residents. Identifying the existing the characteristics and needs of the target population is key to designing and implementing effective educational interventions. This study aimed to explore the level and sources of knowledge among pediatric residents in Palestine, which may inform educational interventions and technical guidelines to improve practical radiation safety.

Methods

Study design

This was a cross-sectional, questionnaire-based study. The study was conducted from January 2022 to May 2022 at 15 hospitals in Palestine.

Population, inclusion criteria, and sampling

This study investigated the level of knowledge about radiation safety among the population of pediatric residents of the Palestinian West Bank. All pediatric residents who were officially registered in the Palestinian Pediatric Medicine Residency Program in 2022 were eligible for inclusion. To ensure that a representative sample was drawn, pediatric residents were approached at every Palestinian hospital participating in the national pediatric training program. These included five, four, and six hospitals distributed in the northern, middle, and southern governorates, respectively. A convenience sampling technique was used to invite pediatric residents during their work shifts at the listed hospitals. The following formula was used to estimate the sample size:

$n = Z^2.P. (1-P)/d^2$, where:

n is the sample size,

Z is the *Z value* of 1.96 corresponding to the 95% confidence level.

P is the estimated median of the knowledge score (if unknown, 0.5 is used to provide the widest confidence interval and maximize the sample size).

d is the margin of error selected as 0.05.

The formula yielded a sample size of 384. According to the Palestinian Medical Counsel, 143 pediatric residents were registered in the national pediatric residency program in 2022. The final sample size was estimated at 104 using the following formula to adjust for a finite population:

$N\ adjusted = n/1+(n-1/N)$, where N is the population count.

Data collection and variables

The questionnaire was developed by the authors on the basis of a literature review [19–21], emphasizing concepts of radioprotection and risks associated with radiation exposure resulting from the most common pediatric radiological tests. It was prepared in English, as this is the language of medical education in local and regional institutions. Understanding medical questions and concepts in English is easier for pediatric residents. The questions were reviewed by a group of experts, including pediatricians, radiologists, and public health practitioners, to check their scientific relevance, topic comprehensiveness, clarity, accuracy, and efficiency. A pilot study was subsequently conducted among 20 pediatric residents whose comments on questionnaire clarity, language, accuracy, and acceptability were used to modify the questionnaire. The residents who participated in the pilot study were not included in the final analysis.

The final questionnaire consisted of two sections. The first section included background questions, including questions about age, sex, year of training, source of knowledge about radiation safety, the period during which most education about radiation safety was received, and opinions about the adequacy of preparation for radiation safety in the field. The second section contains 10 questions concerning knowledge of radiation safety, including radiological tests that use X-ray; the ALARA principle; patient weight and radiation exposure; the exam causing the highest radiation dose; the exposure time of radiological tests; the radiation dose resulting from abdominal MDCT in young children; the radiation dose resulting from MRI exposure in young children; orthopantomography safety during pregnancy; the recommended entrance surface dose for a CXR in neonates; and the minimum radiation dose associated with damage to a fetus. The questionnaires were subsequently distributed to the respondents in paper form.

Data analysis

The Statistical Package for Social Sciences program version 24 (IBM SPSS Statistics 24) was used for data insertion and analysis. Descriptive and inferential statistics were employed for analysis. The mean (± SD) was reported for age, and percentages and frequencies were reported for categorical and ordinal variables. Age was also categorized as <30 or ≥ 30 years. The proportions and frequencies of answers were calculated for each question in the knowledge section, and the median score was reported after each question was assigned a score of 1, resulting in a final score of 10. For inferential statistics, the Mann−Whitney and Kruskal−Wallis tests were used to analyze the bivariate associations between knowledge scores and other categorical variables. This is because the knowledge score was found to be nonnormally distributed (Shapiro–Wilk test, $p < 0.05$), which is expected for epidemiological scales. A threshold p value of < 0.05 was selected to determine significance.

Ethical considerations

Approval for conducting the study was obtained from the Institutional Review Board (IRB) at An-Najah National University (reference: Med. Nov. 2021/31) and the directors of every hospital. The objectives of the research were explained to the participants. The questionnaires were completed anonymously. The confidentiality of the participants was ensured, and the data provided were safely discarded after the conclusion of the research. The provided data were used solely for research purposes.

Results

The final sample consisted of 108 participants out of the 116 pediatric residents who were approached, resulting in a response rate of 93.1%. The mean age of the participants was 28.2 years ($SD = 1.9$), with 55.6% females and 44.4% males. For years of training, 30.6% were first-year residents, 27.8% were second-year residents, 22.2% were third-year residents, and 19.4% were fourth-year residents (see Table 1).

When asked about the main source of knowledge about radiation safety, exactly equal percentages (36.1%) cited personal study or medical school, followed by pediatric training (27.8%). Nearly half said they had attended a radiological safety conference (47.2%). Almost one-third of the participants had received radiological safety lessons during medical school (31.5%), whereas approximately one-third had received such lessons during their residency program (29.6%). Over half said that they think the workplace was adequately prepared for radiation safety (57.4%).

The majority of the participants correctly identified the imaging modality that uses X-ray (97.2%), were familiar with the ALARA principle (60.2%), and recognized weight as a factor affecting the radiation dose (86.1%). Most correctly identified the recommended entrance surface dose for neonatal CXR (63.9%) and the radiation

Table 1 Demographic characteristics of the participants and knowledge score related to radiation safety

Variable		Frequency (%) *n* = 108	Mean Rank	Median (minimum-maximum)	p-value
Age category (Years)	< 30	95 (88.0)	53.3	6.0 (2–9)	0.288
	≥ 30	13 (12.0)	63.0	6.0 (3–9)	
Sex	Male	48 (44.4)	52.0	5.0 (3–8)	0.448
	Female	60 (55.6)	56.5	6.0 (2–9)	
Training year	1st year	33 (30.6)	39.7	5.0 (2–9)	**0.001***
	2nd year	30 (27.8)	52.0	6.0 (2–9)	
	3rd year	24 (22.2)	71.5	6.0 (5–9)	
	4th year	21 (19.4)	62.0	6.0 (3–9)	
The main source of knowledge	Medical school	39 (36.1)	64.4	6.0 (2–9)	**0.037***
	Pediatric training	30 (27.8)	46.8	5.0 (3–7)	
	Personal	39 (36.1)	50.6	5.0 (2–9)	

*****: *p-value* is below the threshold for significance (0.05)

dose with a high probability risk for the fetus (53.7%). Most of the participants identified an MDCT examination as the modality with the highest radiation dose (89.8%), but only a minority selected renal scintigraphy as the modality with the longest exposure time (10.2%). While the majority correctly identified MRI as an imaging procedure without X-ray-equivalent radiation exposure (64.8%), fewer than one-fifth identified the number of CXRs equivalent in radiation exposure to an abdominal MDCT in young children (19.4%). Similarly, fewer than one-third correctly answered that orthopantomography is safe during pregnancy (28.7%) (see Table 2).

The median knowledge score of the participants was 6.0/10.0. The year of training ($p = 0.001$) and the main source of information ($p = 0.037$) were significantly associated with a higher knowledge score, whereas age ($p = 0.288$) and sex ($p = 0.448$) did not significantly influence the median knowledge score (see Table 1).

Discussion

Pediatric age groups are vulnerable to radiation exposure due to the increased lifetime risk of cancer development. Therefore, pediatric residents, who are the main healthcare providers for these age groups, should possess sufficient knowledge that enables them to appropriately request and justify radiological tests. This study aimed to explore the level of knowledge about radiation safety and risks among pediatric residents, in addition to identifying the sources of radiation safety information. The findings revealed that pediatric residents' knowledge varied widely across different topics, and its level was associated with the year of residency and source of knowledge. Inadequate preparation for radiation safety in the field was also reported by the participants.

No methodological classification was used to categorize the knowledge score in the present study, as classifying knowledge scores is complex and needs rigorous validation. While a median score of 6/10 might be judged as inadequate to fair, other studies conducted among pediatric residents, in particular, used different assessment tools and reported insufficient levels of knowledge [21–23]. These studies were carried out in diverse settings, including high-, middle-, and low-income settings, possibly highlighting a global problem where education about radiation safety is disregarded. Despite the harmful impact of radiation and the potential benefits of safe practice in radiology, this lack of knowledge also seems prevalent among other populations in different types of specialties and levels of education, including pediatricians, surgeons, radiologists, oncologists [20, 24–28], and medical students [29, 30]. However, radiation safety and protection are particularly important for pediatric residents, whose patient population is more vulnerable to radiation effects than adults. This inadequate knowledge may be attributed, in part, to the lack of sufficient integration of knowledge about radiation safety within formal education, whether during undergraduate or postgraduate training. In this study, only 29.6% of the participants received a form of related education during their residency training. Similarly, two global studies reported low proportions of pediatricians who received information about radiation safety in formal educational settings [24, 26]. Moreover, the significant association between the median knowledge score and the year of residency in this study can be attributed to the expected incremental learning and the increased responsibility in patient care as residents progress through the residency program. Although a considerable minority of residents said that they had attended a conference related to radiological safety, this alone does not reflect a systematic delivery of continuous professional development, especially given the gaps in training, education, and knowledge identified in this study.

Radiation exposure is important for the practice of many specialties, such as radiology, pediatrics, orthopedics, and urology. Therefore, education about radiation

Table 2 Questions and answers of the knowledge test in radiation safety

Question	Answers	Frequency (%)
1. **Which of the following radiological investigations uses X-ray?**	**MDCT**	91 (84.2)
	MRI	3 (2.8)
	PET	14 (13.0)
2. **Which of the following statements best describes the ALARA principle?**	Dose parameters in MDCT	13 (12.0)
	Estimation of organ dose	22 (20.4)
	Exact organ dose	8 (7.4)
	Minimum dose to achieve results	65 (60.2)
3. **Does patient weight affect the radiation dose that the patient is exposed to?**	**Yes**	93 (86.1)
	No, only in preterm	11 (10.2)
	No, never	4 (3.7)
4. **Which exam exposes the patient to a higher radiation dose?**	**Total body MDCT**	97 (89.8)
	Color-doppler	0 (0.0)
	Tc99 renal scintigraphy	11 (10.2)
5. **Which of the following radiological tests is associated with the longest radiation exposure time?**	**Renal scintigraphy**	11 (10.2)
	MRI	17 (15.7)
	MDCT	21 (19.4)
	PET-CT	59 (54.6)
6. **Which of the following amounts of CXRs corresponds to a radiation dose resulting from an abdominal MDCT study performed for young children (< 5 y/o)?**	0.5 CXR	8 (7.4)
	1 CXR	10 (9.3)
	8 CXRs	12 (11.1)
	50 CXRs	57 (52.8)
	300 CXRs	21 (19.4)
7. **Which of the following numbers of CXRs corresponds to a radiation dose resulting from an MRI performed for young children (< 5 y/o)?**	**0 chest X-ray**	70 (64.8)
	0.5 chest X-ray	8 (7.4)
	1 chest X-ray	8 (7.4)
	8 chest X-rays	19 (17.6)
	50 chest X-rays	3 (2.8)
8. **Can orthopantomography be performed safely during pregnancy?**	No, never	15 (13.9)
	Yes	31 (28.7)
	Yes, but wearing a shield	62 (57.4)
9. **Which of the following doses is the entrance surface dose recommended for a chest X-ray performed for a neonate?**	**50 μGy**	69 (63.9)
	50 Gy	34 (31.5)
	600 Gy	5 (4.6)
10. **Which of the following minimum radiation doses is associated with a high probability damage to a fetus?**	Less than 1 mSv	13 (12.0)
	Approximately 1 mSv	8 (7.4)
	Approximately 3 mSv	29 (26.9)
	More than 50 mSv	58 (53.7)

-Abbreviations: ALARA: as low as reasonably achievable; MDCT: multidetector computed tomography; MRI: magnetic resonance imaging; PET: positron emission tomography; CXR: chest X-ray; Tc99: technetium-99; Gy: the grey; Sv: the Sievert

safety should be provided through educational interventions and curricular integration throughout medical careers, starting in medical school and continuing after specialty, as part of continuous professional development. These interventions and curriculum modifications should be tailored to the requirements of each career stage and specialty. For example, a panel of clinical experts and radiologists in the UK participated in a multistage process to develop a set of competencies and topics suited to medical students [31]. Another intervention specifically designed to raise awareness among endoscopy fellows was significantly associated with reduced patient exposure to radiation [32].

Pediatricians are primarily responsible for justifying requested radiological examinations in accordance with the principle of justification and having basic information about imaging modalities and associated risks. Tailored lectures, workshops, and refresher courses can be delivered throughout the residency program, with a focus on risk-benefit analysis and the introduction of decision-support tools to assist pediatricians in justifying requested radiological tests, especially given the absence of national guidelines. To bridge the gap between technical knowledge and clinical application, these educational interventions should be supervised by senior pediatricians but also involve radiologists and use case-based scenarios and real-time assessments during clinical rotations to reinforce the practical application of radiation safety. Moreover, educational content should be tailored to the specific needs of pediatric age groups, addressing the risks related to children and improving communication skills with parents and children. Given the age-related cognitive and emotional variations of children and the personal and sociocultural beliefs of parents, effective patient communication is particularly complex. Therefore, educational interventions should provide pediatricians with effective communication strategies, addressing the nuances of language, amount, complexity, and setting of communication with children [33].

The proportion of correct responses to different questions varied widely in the present study. The proportions of correct answers to easy questions about common information were high. For example, 84.2% and 89.8% of participants correctly identified MDCT as using X-rays and causing high radiation exposure, respectively. On the other hand, questions on orthopantomography and estimation of the effective dose, for instance, were only correctly answered by less than one-third of the respondents. Although variations in the proportions of correct answers in knowledge questionnaires are expected due to the varying difficulties of different questions, the high variation in this study points to topics that might have been disregarded in formal undergraduate and postgraduate education nationally.

Despite the substantial inconsistencies in formal education about radiation safety worldwide, the gaps in knowledge differ across settings. Appropriate research informs the development of educational interventions in healthcare by analyzing the problem and identifying the characteristics of the target population, including their level of knowledge, gaps in knowledge, and preferred sources of information. These characteristics are specific to the target subgroup and interact with multiple environmental factors, including the prevailing culture, nature of the healthcare system, existing educational curricula, and different distributions of diseases that are prioritized in different settings [34, 35]. Therefore, the applicability and translation of knowledge research findings should be limited to the target population. This study identified certain knowledge gaps specific to the target population of pediatric residents. While only a minority of the participants in the present study were unfamiliar with the ALARA principle (39.8%), research conducted among similar populations in different settings revealed that most of the participants were unfamiliar with this principle, with proportions ranging between 73% and 89% [21, 24, 26]. Another study included a similar question on orthopantomography, which was correctly answered by a higher proportion of participants than that reported by the present study [21]. These variations indicate that the particular knowledge gaps in radiation safety identified by this study should guide the development of educational interventions tailored to pediatric residents in Palestine.

In Palestine, practitioners lack sufficient resources, such as imaging guidelines and radiation protection equipment, to minimize the risk of radiation in the field, as political attention to radiation safety is nearly absent in national policymaking and radiology departments. The relevant professional societies and ministry of health should create national referral guidelines to help pediatricians make and justify such clinical decisions, especially given the emerging complexities associated with the advances made in radiology. These guidelines should be formulated on the basis of scientific evidence and expert advice and benefit from global referral guidelines, such as the ACR Appropriateness Criteria [36]. Furthermore, the implementation of these guidelines should be monitored and evaluated by audits and quality improvement programs. Moreover, implementation, monitoring, and evaluation are facilitated by streamlining top-down and upward communication among senior managers, supervisors, and healthcare workers to foster a radiation safety culture in health organizations. The ability to obtain knowledge should be coupled with application, sharing, and retaining this knowledge within an organization [37]. In addition to the absence of guidelines, radiation protection equipment, such as lead aprons and thyroid shields, are available in low quantities. In this study, a considerable minority thought that the field is inadequately prepared for radiation safety, indicating that the equipment and infrastructures are not sufficient to empower practitioners to adopt safety measures, which is in line with a previous local study conducted among radiology technologists [38]. Overall, enhancement of provider knowledge, provision of training programs, implementation of guidelines, and availability of an adequate quantity of radiation protection equipment are key for ensuring that radiation safety measures are applied in practice.

This study is subject to various limitations. A significant constraint lies in its cross-sectional design, which establishes associations but cannot establish causality. Furthermore, the lack of a published validated, standardized assessment tool may have resulted in underestimation or overestimation of the knowledge levels, as the tool that was used in the study was not rigorously validated. This lack of standardization might have introduced some questions whose level of difficulty is not suited to the limited knowledge of nonradiologist professionals, such as those related to the doses of radiological modalities. This also limited comparability across studies owing to possible heterogeneity in question topics. Moreover, the questionnaire has some limitations in its content and design. First, it focuses on exposures more than risks, both of which should have been included in the assessment. Second, it contains forced-choice questions that lack the "I do not know" choice, potentially leading to response bias. This is in addition to some leading questions that might have guided the respondents toward a desired answer by using a phrase, such as never and always, or a numerical difference in listed choices. The questionnaire should have been built via word selection that accurately matches the question to its correct answer. Nevertheless, this study adds to the scarce, local literature concerning radiology practice and safety. This is especially important since radiology is a developing field in Palestine. In 2019, the Palestinian Ministry of Health announced mammography recommendations for females older than 50 years, reflecting the potential to improve radiology practices [39]. The present study is, therefore, expected to contribute to developing policies and informing interventions aimed at improving radiation safety.

Conclusions

Pediatricians' knowledge of radiation safety is crucial for choosing radiological tests and adopting effective communication strategies with children and parents. This study aimed to assess the level of knowledge about radiation safety among pediatric residents. The results identified knowledge gaps in radiation safety, with the proportions of correct answers related to different topics demonstrating wide variation. The year of training and the main source of information were significantly associated with a higher knowledge score. Educational interventions should incorporate radiation safety knowledge into pediatric training programs, addressing the knowledge gaps identified by this study and emphasizing pediatric-specific risks. Moreover, the formulation, implementation, and monitoring of imaging referral guidelines by professional bodies are crucial for applying radiation knowledge.

Abbreviations

ROS	Reactive oxygen species
ICRP	International Commission on Radiologic Protection
ALARA	As Low As is Reasonably Achievable
MDCT	Multidetector computed tomography
PET-CT	Positron Emission Tomography-Computed Tomography
CXRs	Chest X-rays
MRI	Magnetic Resonance Imaging

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Author contributions

ST performed the literature search, collected and analyzed the data, and drafted the manuscript. SMZ, LGK, AAFA, and KA were responsible for the integrity of the data and results, participated in the writing of the manuscript and data analysis, and provided critical input to improve the intellectual content of the study. JMH, and MM provided valuable logistical support and on-site study coordination, and they also significantly revised the manuscript to enhance its intellectual content. SHZ established the concept and design, supervised the survey team, led the data analysis, and contributed to the final writing of the manuscript. All the authors have read and accepted the final manuscript.

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Data availability

Additional datasets collected and analyzed for this research can be obtained from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The Institutional Review Board (IRB) of An-Najah National University approved this study (reference: Med. Nov. 2021/31). They issued appropriate permission documents for the study. The participants were free to agree or reject participation in the study. Verbal informed consent to agree to participate in the study was obtained from each participant. The confidentiality of the data was ensured. The IRB *of* An-Najah National University approved only verbal informed consent. The reason for verbal informed consent is that the questionnaire was the only data collection tool, and participants were not subjected to any harm. All methods were performed as per the relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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