Medical Science

pISSN 2321–7359; eISSN 2321–7367

Radiation protection: Are pediatrics health care providers up to date?

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To Cite:
Khafaji M, Kouzaba K, Tashkandi A, Almusallam S, Ghoneim A, Hagi S. Radiation protection: Are pediatrics health care providers up to date?. Medical Science, 2022, 26, ms69e2043.
doi: https://doi.org/10.54905/disssi/v26i120/ms69e2043

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Peer-Review History
Received: 28 December 2021
Reviewed & Revised: 30/December/2021 to 11/February/2022
Accepted: 13 February 2022
Published: 19 February 2022

Peer-review Method
External peer-review was done through double-blind method.

URL: https://www.discoveryjournals.org/medicalscience

DISCOVERY SCIENTIFIC SOCIETY

ABSTRACT

Objectives: To assess the knowledge and level of awareness of practitioners who provide pediatric care on radiation risks in pediatric computed tomography (CT) examinations. *Methods:* This cross-sectional study was conducted from July 2020 to January 2021 at King Abdulaziz University Hospital in Jeddah, Saudi Arabia. The sample comprised pediatric radiologists, pediatric surgeons, emergency pediatricians, general pediatricians, and radiographers. A three-part questionnaire consisting of 46 questions was used for data collection; correct responses were given a score of 1, and incorrect or incomplete answers were given 0. The maximum possible score was 40.Statistical Package for Social Sciences version 25 (IBM, Armonk, NY, USA) was used for all analyses. Statistical significance was set at $p < 0.05$. *Results:* A total of 34 participants completed the questionnaire, and the mean±standard deviation score was 17.5±8.97. More than half of pediatricians (63.2%) and radiographers (52%) estimated the radiation dose incorrectly. *Conclusion:* The pediatric CT practice in our hospital was suboptimal. Practitioners must be continuously educated and updated on radiation protection. Further studies from different regions of Saudi Arabia are needed to avoid this bias.

Keywords: CT imaging, Cancer risk, Diagnostic imaging, Pediatric patients, Radiation dose.

1. INTRODUCTION

Medical imaging is used to view the human body and provide clinicians with essential information that can be lifesaving to patients. Although imaging modalities positively affect morbidity, treatment options, and increasing life expectancy, there are raising concerns regarding the risks of radiation exposure from medical imaging in pediatric patients (Karim et al., 2016). Radiation damage to tissues or organs varies depending on radiosensitivity, amount of radiation, dose thresholds, and scanner exposure parameters (Kutanzi et al., 2016). Radiation can lead to both deterministic and stochastic biological effects. Deterministic effects are threshold-dependent, in which an effect occur if a threshold level is met. The deterministic effects increase in severity as the radiation dose increases. Conversely, stochastic effects are not threshold-dependent and result from innate randomness. However, it has an increased probability when dose is increased. Children are sensitive to exposure to high radiation doses in each organ, ten times more sensitive than middle-aged individuals (Dirik et al., 2018; Kamiya et al., 2015).

Computed tomography (CT) is an invaluable tool for the accurate diagnosis and treatment of various conditions because it allows high-resolution cross-sectional images to be obtained quickly. CT examinations performed worldwide has progressed in number rapidly (Ogbole, 2010). At the King Abdulaziz University Hospital (KAUH) in Jeddah, Saudi Arabia, 76,500 CT scans have been performed in the last 5 years, of which 5,297 were for children. The high number of children exposed to CT radiation has created a growing concern regarding patient protection. Greater than 62 million CT scans are performed per year and 4 million of those scans are performed in pediatric patients (Ogbole, 2010). Radiation exposure from CT scan is higher compared to conventional x-ray imaging (Merzenich et al., 2012). Pediatric CT scans are of serious concern because of their high cell proliferation rate and increased opportunity to express delayed cancer effects. The International Commission on Radiological Protection estimated that the risk coefficient for an average population is 5% Sv^{-1}, whereas, for children, it is 13% Sv^{-1} for stochastic effects (Alzimami, 2014).

A study conducted in the United Kingdom evaluated the impact of a brief educational message on clinicians. The results revealed an inadequate perception of the long-term risks associated with diagnostic radiation exposure, which could be improved through continuous mandatory education on radiation protection (Young et al., 2019). In 2012, Pearce et al., (2012) conducted a study that concluded that children who received radiation doses of 50 mGy or higher from brain CT were at 2.8 times greater risk of brain cancer. A nationwide registry-based case-control study conducted in Finland involving a review of pediatric CT scan records between 1975 and 2011 to study the odds ratios and likelihood of developing leukemia found an additional odds ratio of childhood leukemia to be 0.13 per mGy of absorbed dose to the bone marrow (Nikkilä et al., 2018). This suggests that the exposure of pediatric patients to even the smallest radiation doses can result in a measurable increase in risk. Moreover, a German study found that one in 1000 children may die due to cancer after a single non-optimized head CT (Sorantin et al., 2013). Furthermore, a study conducted in Sweden in 2015 showed that lectures, seminars, and conferences could optimize the use of medical imaging (Fatahi et al., 2015).

A prospective questionnaire-based study in China stated that the radiation doses knowledge for various investigations is insufficient among radiologists and poor among non-radiologists. Radiation doses underestimation may expose pediatric patients to more radiological investigations and radiation risks (Lee et al., 2012). Surprisingly, a California-based American study reported that one physician said,' I do not want any radiation dose reduction. I want my scans to look beautiful" (Whitebird et al., 2021).

In Saudi Arabia, a cross-sectional study conducted in 2016 concluded that knowledge about radiation doses among pediatricians should be improved to address the underestimation of CT radiation doses and its potential hazards to children. Additionally, they suggested that radiologists, pediatricians, technicians, and medical physicists should unite their efforts to optimize CT guidelines and examinations to lower radiation risks for children (Al-Rammah, 2016). Furthermore, a cross-sectional study conducted in 2018 in Saudi Arabia showed that emergency doctors have poor knowledge regardingrisks of radiation doses (Barnawi et al., 2018). The need to apply referral guidelines of medical imaging in routine clinical practice has been part of the call for action by several international organizations and published statements concerning patient safety in medical imaging. The American College of Radiology and European Commission supports the implementation and use of referral criteria for radiological investigations in the European Union and the United States. These efforts aim to improve the suitability of medical imaging referral, reduce unnecessary radiation doses, and provide a reliable justification process through a structured workflow (ESR, Summary of the proceedings of the international forum, 2016).

The Image Gently Alliance stated in an article that "medical imaging (with CT scans as the largest contributor) approaches background radiation as the single source of radiation for humans (NCRP, April 2007)" (Image Gently, 2021). Overuse should be diminished by using ionizing radiation imaging only when necessary, limiting exposure to the region of interest, and optimizing CT examinations to minimize unnecessary doses (Greenwood et al., 2015). The expected risk from CT radiation in pediatric imaging must be justified based on the risk versus benefit evaluation and optimized based on principles that are as low as reasonably achievable (Almohiy et al., 2020). The American Association of Physicists in Medicine and the Alliance Radiation for Safety in Pediatric Imaging support the position that medical imaging should be appropriate and should use the radiation dose necessary to accomplish the clinical task (AAPM, Position Statements, Policies and Procedures, 2021; Frush et al., 2015). The appropriate use of radiation and the safety of patients from CT examinations are shared responsibilities between referring physicians and radiologists (Frush et al., 2015). Radiologists may approve CT imaging orders from referring physicians as requested without further questioning if they are justified.

In this study, we aimed to assess the current knowledge and level of awareness about radiation risks in pediatric CT among healthcare providers who care for pediatric patients and evaluate the use of referral guidelines for CT examinations. The study sample included pediatric radiologists, surgeons, general pediatricians, emergency pediatricians, and radiographers.

2. MATERIALS AND METHODS

Study design, setting, time and aim

This cross-sectional study was conducted at the KAUH in Jeddah, Saudi Arabia, from July 2020 to January 2021. We aimed to assess the current level of knowledge about radiation risks in pediatric CT among radiographers and physicians who provide care to pediatric patients.

Population

The sample size required for this study was calculated to be 42, with a 95% confidence level and margin of error of 5%. Calculations were performed using the Raosoft sample size calculator (http://www.raosoft.com/samplesize.html). The survey was distributed to 41 physicians (including consultants from pediatric radiology, pediatric surgery, emergency pediatrics, and general pediatricians) and six radiographers. These specialties are considered to have different roots in training during their residency.

Data Collection and definition of variables (instrument)

The questionnaire was adapted from the study by Karim et al., (2016), which was stratified into three sections. The first section included general demographic information. The second section included questions on radiation awareness. The questions in the third section were related to CT examinations and parameters. The questionnaire consisted of 46 questions, of which when 40 were attempted; the participants' responses were scored. Thirty-six were in the form of multiple-choice questions, and the remaining four were in the form of short answers. Correct responses were assigned a score of 1, whereas incorrect or incomplete answers were assigned a score of 0. The maximum possible score was 40. The remaining six questions out of 46 were related to consent, sex, medical specialty, imaging guidelines adherence, years of experience, and confidence to alter CT parameters correctly.

Statistical analysis

Statistical Package for Social Sciences version 25 (IBM, Armonk, NY, USA) was used for all analyses. Frequencies and percentages were calculated for categorical variables and central tendency measures for continuous variables. Statistical differences between groups defined by each demographic variable (e.g., sex or medical specialty) were examined using the chi-square test, independent t-test for 2-group comparisons, and one-way analysis of variance for more than 2-group comparisons. Statistical significance was set at $p < 0.05$.

3. RESULTS

A total of 34 participants completed the questionnaire, and 13 refused to participate. The respondents were categorized according to their profession as follows: 7 (20.5%) pediatric radiologists, 13(38%) general pediatricians, 1 (3%) pediatric surgeon, 7 (20.5%) emergency pediatricians, and 6 (18%) radiographers. Fifteen (44.1%) were men, and 19 (55.9%) were women. Participants with 1–5 years of experience responded most frequently. Most respondents reported that their confidence in correctly altering CT imaging parameters was fair 11(32.4%), (Table 1). Nine (26.5%) participants reported that they did not follow any guidelines, whereas 25 (73.5%) followed practice guidelines, as shown in Table 2.

Twenty-three participants (67.6%) did not attend any radiation protection course; these included 1 (2.9%) pediatric radiologist, 2 (5.9%) radiographers, 6 (17.6%) ER pediatricians, 14 (41.1%) pediatric surgeons, and general pediatricians. The participants' responses to the radiation protection course according to their experiences are shown in Table 3. A higher percentage of men (81.8%) attended radiation protection courses than did women (18.2%). Thirty-three (97.1%) participants (both sexes and different healthcare providers) believed that continuous education in optimizing CT parameters would be beneficial. One woman believed the opposite. In terms of experience, 13 (38.2%) participants were in the 1–5 years experience group, 9 (26.5%) were in the 6–10 years group, 3 (8.8%) were in the 11–15 yearsgroup, and 8 (23.5%) were in the above 15 years of experience group. Most participants who rated their confidence as fair 11 (32.4%) had more than 15 years of experience (five out of 11 participants [45.5%]; the other groups are shown in Table 1. A noteworthy result was that four (50%) pediatric radiologists out of eight participants rated their confidence to be "uncertain." Pediatric radiologists who were uncertain had 1–5 years of experience, while most ER pediatricians (four responses) and general pediatricians (five responses) rated their confidence to be "fair," as shown in Table 1. All data mentioned above, except those in the tables, were statistically significant (P<0.05).

Table 1 Participants' confidence in their ability to alter computed tomography parameters correctly

Years of experience	Poor	Uncertain	Fair	Good	Excellent	P-value
1-5y	3	6	1	2	1	N.S.
6-10y	1	2	3	1	2	
11-15y	1	N/A	2	N/A	1	
>15	N/A	N/A	5	1	2	
Medical specialty						
Pediatric Radiologists	1	4	N/A	N/A	2	N.S.
General Pediatricians	2	3	5	2	1	
Pediatric surgeons	N/A	N/A	1	N/A	N/A	
ER Pediatricians	2	N/A	4	N/A	1	
Radiographer	N/A	1	1	2	2	

NA, not applicable, N.S, not significant (P-value ≥0.05)

Table 2 Participant guidelines mean score

Guideline	Frequency	Percent	Mean Score	Standard Deviation	P-value
American	8	23.5%	12.12	5.81	P<0.006
Canadian	14	41.2%	21.28	9.75	
European	1	2.9%	21	6.36	
Other	2	5.9%	31.5	3.78	
Not following any guideline	9	26.5%	12.88	8.97	

Table 3 Have you ever attended a radiation protection course?

Years of experience	Yes	No	P-value
1–5years	6	7	N.S.
6–10years	3	6	
11–15years	N/A	4	
>15 years	2	6	

N.S., not significant (P-value ≥0.05), N/A, not applicable

Table 4 Radiation dose estimation

	Medical professions (Number)			Allied Health profession (Number)		
	Under estimated	Correct	Over estimated	Under estimated	Correct	Over estimated
CT Brain	0	13	15	0	3	3
CT Thorax	7	8	13	2	2	2
CT Abdomen	13	6	9	3	2	1
CT Lumbar Spine	0	5	23	0	3	3
Skull X-Ray	0	17	11	0	3	3
Intravenous urography (IVU)	0	7	21	0	3	3
Lumbar spine X-Ray	2	16	10	0	4	2
Total (%)	11.2%	36.7%	52%	11.9%	47.6%	40.4%

CT, computed tomography

Regarding radiation dose estimation, we categorized the participants into two groups: the medical profession group (practitioners, such as pediatric radiologists, surgeons, and general and emergency pediatricians) and the allied health profession group (indicating the category of radiographers in the Radiology Department). There was no significant difference between the two groups (P>0.05). The correct, underestimated, and overestimated responses are presented in Table 4.

The mean number of correct answers was 17.5±8.97 standard deviation [SD] (ranging from 7 to 36) for all participants. The mean total score for males was 21.06±7.67 SD, and for females, it was 14.68±2.08 SD, representing a significant difference (P<0.05). While pediatric radiologists were uncertain about their confidence in correctly altering CT parameters, their mean score was the highest, as shown in Figure 1. A significant difference was observed between the groups (p <0.001). Of note, the highest score (36 out of 40) was achieved by a radiographer with >15 years ofexperience. Despite this, there was no statistically significant difference between the years of experience and mean total score. The ER and general pediatricians scored the lowest score (Score=7 out of 36), although they rated their confidence to alter CT parameters correctly to be "fair." The mean total scores of participants who followed and those who did not are presented in Table 2. The respondents who rated their confidence to alter CT parameters to be fair had the lowest mean total score (11.36±4.056), whereas participants who answered with "good" and "excellent" had the highest means (25 and 26, respectively). There was a significant difference between the groups (p <0.002).

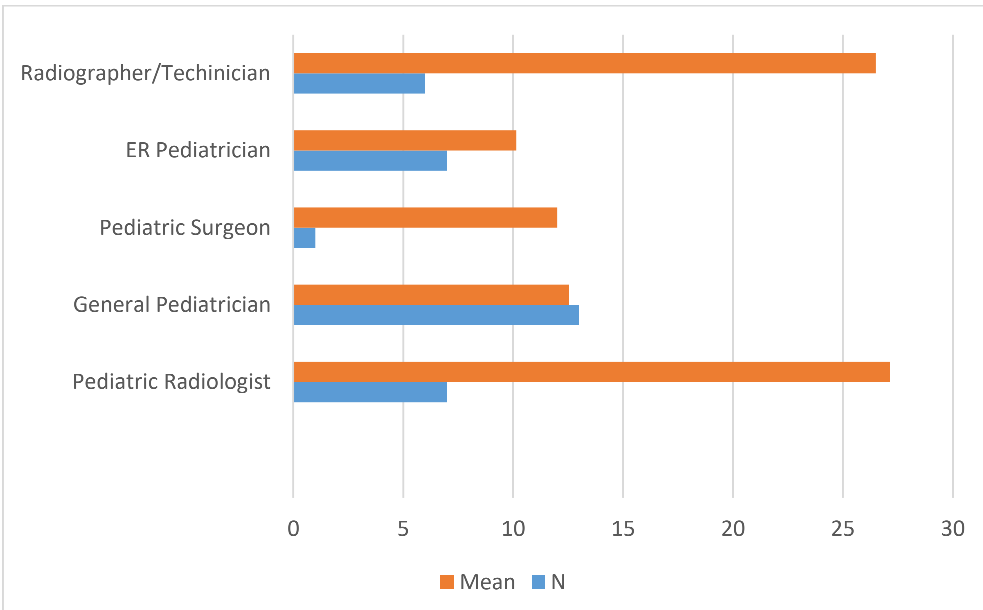

Figure 1 Mean score of participants according to medical specialty

4. DISCUSSION

Our study aimed to assess the current knowledge and level of awareness about radiation risks in pediatric CT among radiographers and physicians who provide care to pediatric patients. In particular, their knowledge of the radiation risks associated with pediatric CT and referral guidelines for CT examinations was assessed. We found that pediatric CT practice in our hospital requires further enhancement because a large fraction of pediatric practitioners and radiographers incorrectly estimate radiation risks, as shown in Table 4. Our findings are consistent with those of previous studies (Karim et al., 2016; Lee et al., 2012; Whitebird et al., 2021; Al-Rammah, 2016) conducted in Malaysia, China, the United States, and Saudi Arabia. Our results show that 62% of pediatric healthcare providers are knowledgeable and somewhat confident in optimizing CT examinations, which is different from a Malaysian study that found that only 18% of their participants were knowledgeable and confident in optimizing CT examinations (Karim et al., 2016). However, the average score in our study (mean=17.5±8.97 out of 40, which equals 43.75%) suggested that a significant number of practitioners had insufficient ability and knowledge (P<0.05) to refer and apply pediatric CT examinations correctly, indicating a possible overconfidence bias. Unexpectedly, the results also showed that general and emergency pediatricians were overconfident and lacked knowledge (P<0.001).

In our study, emergency pediatricians demonstrated the lowest level of knowledge (mean=10.14±2.60 out of 40, which equals 25.4%). This is consistent with the results of another study conducted in Saudi Arabia (Barnawi et al., 2018), which found that emergency doctors had a poor level of knowledge about radiation doses and risks. Hence, they are likely to order imaging investigations and expose patients to unnecessary radiation doses (Barnawi et al., 2018; Lee et al., 2016). In contrast, pediatric radiologists and radiographers demonstrated good knowledge. This finding is consistent with a study conducted in China by Lee et al., (2012). Our results showed a wide gap between the knowledge of pediatric healthcare providers and pediatric radiologists (P<0.001). This result is validated by the nature of their different training sessions. Pediatric radiologists receive substantial education in radiation physics during their residency. Therefore, continuous education regarding CT radiation protection for medical specialties involved in pediatric care is critical. In our study, the average score for general pediatricians (mean= 12.5±5.57 out of 40, which equals 31.25%) was low. This is similar to the study by Al-Rammah Saudi Arabia, which found widespread incorrect estimations (93%) of ionizing radiation among general pediatricians (Al-Rammah, 2016).

Although radiographers play an important role in radiation dose determination and protection, we found that radiographers were not well versed in CT optimization techniques (mean=26.5±5.54 out of 40, which equals 66.25%). This is consistent with a study by Karim et al., (2016) in Malaysia, which reported approximately the same mean. Our data showed that almost all pediatric healthcare providers were eager to provide continuous education regarding optimizing CT examinations and radiation awareness. Likewise, the study published by Lee et al., (2012) suggested that seminars, lectures, and conferences could help optimize medical imaging practices and support the continuous education of pediatric healthcare providers. Furthermore, our results demonstrated that approximately one-third of pediatric healthcare providers answered that they did not follow any referral guidelines. Since referral guidelines are the most effective method of reducing or eliminating unnecessary and inappropriate referrals, strict criteria for CT examination referrals are either established locally or internationally via published guidelines (Kutanzi et al., 2016). It is mandatory for pediatric healthcare providers to implement guidelines to justify the radiation dose, maximize safety, and minimize short-and long-term complications associated with CT (Kutanzi et al., 2016).

A study in Saudi Arabia suggested that pediatric healthcare providers from different sources should work together to optimize CT guidelines and examinations to reduce radiation risks among children (Al-Rammah, 2016). They also highlighted the relevance of having a common guideline for pediatric healthcare providers in Saudi Arabia. The expected outcomes of having a common guideline are improved appropriateness in imaging referrals, lowering unnecessary radiation exposure, a reliable justification process, good accountability via a structured workflow, and eventually a simple workflow (ESR, Summary of the proceedings of the International Forum, 2016). In terms of radiation awareness, two-thirds of our sample (general and ER pediatricians) were not aware of radiation risks as they did not attend any radiation protection courses. This finding agrees with that of a previous study that found that general pediatricians have a low awareness of radiation risks (Al-Rammah, 2016).

The effect of radiation on health is a critical issue in clinical practice. As reported in a previous study, even the lowest doses of ionizing radiation increase the risk of leukemia in exposed children (Nikkilä et al., 2018). Studies by Pearce et al., (2012) and Strauss et al., (2019) found evidence of brain tumors in pediatric patients due to increased CT radiation doses. In addition, a prospective study from China by Lee et al., (2012) reported that radiation dose knowledge is insufficient among radiologists and poor among non-radiologists. Excess radiation doses may expose pediatric patients to increased radiation risks and hazards.

Our study had several limitations. Only one pediatric surgeon participated; thus, the pediatric surgeons group was not well represented, resulting in bias. Second, participants' responses may have been biased because of their ability to access medical knowledge.

5. CONCLUSION

Taken together, our findings highlight that pediatric CT practice in our hospital requires further enhancement. Regarding radiation dose estimation, most pediatricians and radiographers incorrectly estimated the radiation dose. It is important for practitioners to be continuously educated and have sufficient knowledge to optimize and justify radiation exposure. Further studies with a large sample size from different regions in Saudi Arabia are needed to avoid bias and confirm our findings. Additionally, pediatric healthcare practitioners need to be continuously educated about medical imaging through lectures, seminars, and conferences, regardless of their subspecialty. Standardized guidelines for health care practitioners are also required.

Acknowledgments

we would like to thank https://www.editage.com/ for the English language editing.

Authors' Contributions

MAK conceptualized and designed the study, participated in data collection, revised the final version of the manuscript, and supervised the project. KAK assisted in writing the introduction, provided statistical analysis and interpretation of the results, drafted the Results and Discussion section, revised the final manuscript, administered the project, and assigned various tasks. AMT wrote the introduction and collected and organized the data. SAA wrote the methods section. AHG validated the data and revised the manuscript accordingly. SKH validated the data and revised the final manuscript. All authors critically reviewed and approved the final draft after revision, and were jointly responsible for the content and similarity index of the manuscript.

Ethical approval

This study was approved by the Biomedical Ethical Committee at the King Abdulaziz University Hospital (Reference No 431-20).

Consent

All participants were notified of the study objectives and confidentiality of their responses, and their consent was obtained.

Funding

This study has not received any external funding.

Conflict of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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