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# RADIATION DOSE OPTIMIZATION IN PEDIATRIC IMAGING: PRACTICES AND PERCEPTIONS AMONG SAUDI ARABIAN RADIOLOGISTS

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**Abstract:**
Radiation dose optimization is of paramount importance in pediatric medical imaging due to children's increased susceptibility to radiation-induced harm and their longer life expectancy compared to adults. This study aimed to comprehensively investigate the current practices and perceptions related to radiation dose optimization in pediatric imaging among radiologists practicing in Saudi Arabia. An online survey was disseminated to radiologists across various healthcare institutions in the country, collecting data on their specific pediatric imaging protocols, dose reduction techniques employed, and perceived barriers to achieving optimal dose optimization.

The survey results reveal that while the majority of Saudi radiologists possess a good understanding of the significance of dose optimization and implement certain dose reduction strategies, there is still considerable room for improvement in their practices. The key areas identified for enhancement include increasing the use of dose monitoring software, developing and implementing standardized pediatric imaging protocols across institutions, providing more comprehensive training for radiologists on optimization techniques, and fostering better communication with referring physicians to ensure appropriate study selection and dose optimization.

Respondents identified several barriers to implementing optimal dose optimization, including the lack of pediatric-specific imaging protocols, time constraints in clinical practice, and concerns about compromising diagnostic image quality. This study provides valuable insights into the current state of radiation protection practices in pediatric imaging in Saudi Arabia and highlights potential avenues for further optimizing radiation dose to ensure the safest and most effective imaging care for children.

## 1. Introduction

Medical imaging plays an indispensable role in the diagnosis, management, and follow-up of a wide range of pediatric medical conditions. However, the use of ionizing radiation in commonly performed imaging modalities such as computed tomography (CT), fluoroscopy, and radiography carries inherent risks, particularly for pediatric patients who are more radiosensitive than adults (Aw-Zoretic & Seth, 2020). Children have a higher susceptibility to radiation-induced damage due to their rapidly dividing cells and the fact that they have a longer life expectancy, resulting in a greater potential for manifestation of radiation-induced cancers over their lifetime (Brenner, 2012). Therefore, it is of utmost importance for radiologists to optimize radiation dose in pediatric imaging, adhering to the fundamental principle of "as low as reasonably achievable" (ALARA) to minimize the potential harmful effects of ionizing radiation.

Several renowned international organizations, such as the Image Gently Alliance and the International Atomic Energy Agency, have developed comprehensive guidelines and recommendations for radiation dose optimization in pediatric imaging (Goske et al., 2008; International Atomic Energy Agency, 2012). These guidelines emphasize the importance of tailoring imaging protocols to the child's size, using appropriate technical parameters, and employing dose reduction techniques specific to each modality. However, the actual implementation of these guidelines may vary significantly across different countries, institutions, and individual radiologists' practices.

In Saudi Arabia, there is a paucity of data regarding the current practices and perceptions of radiologists in relation to radiation dose optimization in pediatric imaging. Understanding the level of knowledge, the specific dose reduction strategies employed, and the perceived barriers to optimal dose optimization among Saudi radiologists is crucial for identifying areas for

improvement and developing targeted interventions to enhance radiation protection in pediatric imaging.

This study aimed to conduct a comprehensive assessment of the current state of radiation dose optimization in pediatric imaging among radiologists practicing in Saudi Arabia. The specific objectives of the study were as follows:

1. To evaluate radiologists' knowledge and practices related to dose optimization techniques in pediatric CT, fluoroscopy, and radiography.
2. To identify the perceived barriers and challenges encountered by radiologists in implementing dose optimization strategies in their clinical practice.
3. To explore radiologists' perceptions regarding the importance of dose optimization, the need for further training and education, and the potential benefits of standardizing pediatric imaging protocols across institutions in Saudi Arabia.

By addressing these objectives, this study aims to provide valuable insights into the current landscape of radiation dose optimization in pediatric imaging in Saudi Arabia, identify areas for improvement, and inform the development of strategies to promote best practices in radiation protection for pediatric patients.

## 2. Methods

### *2.1 Study Design and Participants*

A cross-sectional, web-based survey study was conducted to assess the practices and perceptions related to radiation dose optimization in pediatric imaging among radiologists practicing in Saudi Arabia. The target population for this study included radiologists who are actively involved in performing and interpreting pediatric imaging studies across various healthcare institutions in the country, including tertiary care hospitals, secondary care hospitals, and private hospitals/clinics.

Participants were recruited through multiple channels to ensure a representative sample. The survey was distributed to members of the Saudi Society of Radiology and Medical Imaging (SSRMI), the leading professional organization for radiologists in Saudi Arabia. Additionally, the survey link was shared on social media platforms commonly used by radiologists, such as Twitter and LinkedIn, to reach a wider audience.

The inclusion criteria for participation in the study were as follows: (1) radiologists currently practicing in Saudi Arabia, and (2) radiologists who perform and/or interpret pediatric imaging studies as part of their clinical practice. Radiologists who do not perform any pediatric imaging were excluded from the study.

### *2.2 Survey Instrument Development*

The survey questionnaire was developed through a rigorous process to ensure its validity, reliability, and relevance to the study objectives. The development process involved a comprehensive review of the existing literature on radiation dose optimization in pediatric imaging, including international guidelines, recommendations, and previous survey studies conducted in other countries. This review helped identify the key domains and questions to be included in the survey.

The initial draft of the survey questionnaire was reviewed by a panel of experts, including pediatric radiologists, medical physicists, and radiation safety specialists, to assess its content validity and provide feedback for improvement. The expert panel reviewed the questionnaire for clarity, relevance, comprehensiveness, and appropriateness of the questions. Based on their feedback, necessary revisions were made to enhance the quality and validity of the survey instrument.

The survey questionnaire was organized into four main sections:

1. Demographic and professional characteristics: This section collected information on the respondents' age, gender, years of experience in radiology, practice setting (e.g., tertiary care hospital, secondary care hospital, private hospital/clinic), and the frequency of performing pediatric imaging studies.
2. Knowledge and practices related to dose optimization techniques: This section assessed the radiologists' knowledge and application of various dose optimization techniques specific to pediatric CT, fluoroscopy, and radiography. Questions covered topics such as protocol selection based on patient size, dose adjustment techniques (e.g., tube current modulation, tube voltage adjustment, automatic exposure control), the use of shielding, and other dose reduction strategies specific to each modality.
3. Perceived barriers to implementing dose optimization strategies: This section explored the challenges and barriers encountered by radiologists in implementing dose optimization strategies in their clinical practice. Respondents were asked to rate the significance of various potential barriers, such as lack of pediatric-specific protocols, time constraints, concerns about image quality, lack of training, insufficient staff, and lack of support from hospital administration.
4. Perceptions of the importance of dose optimization and the need for further training and standardization: This section assessed radiologists' perceptions regarding the importance of dose optimization in pediatric imaging, their confidence in implementing dose optimization techniques, and their perceived need for further training and education in this area. Respondents were also asked about their views on the potential benefits of standardizing pediatric imaging protocols across institutions in Saudi Arabia.

The survey utilized a combination of question formats, including multiple-choice questions, Likert scale ratings, and open-ended questions to allow for both quantitative and qualitative data collection. The Likert scale questions employed a five-point scale (e.g., strongly agree, agree, neutral, disagree, strongly disagree) to assess the respondents' level of agreement with various statements related to dose optimization practices and perceptions.

Prior to the official launch of the survey, a pilot test was conducted among a small group of radiologists to assess the clarity, comprehensibility, and user-friendliness of the survey questionnaire. The pilot test participants provided feedback on the time required to complete the survey, the clarity of the questions, and any technical issues encountered. Based on their feedback, minor refinements were made to improve the survey's overall quality and functionality.

### *2.3 Data Collection and Analysis*

The survey was administered electronically using a secure, web-based platform (SurveyMonkey). The survey link was distributed to potential participants via email through the SSRMI and shared on social media platforms. The survey remained open for a period of three months to allow sufficient time for radiologists to participate. To maximize the response rate, two reminder emails were sent to potential participants at two-week intervals.

The collected survey data were exported from the web-based platform and analyzed using IBM SPSS Statistics software (version 26). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the survey responses and characterize the study sample.

For questions with Likert scale responses, the five-point scale was collapsed into three categories (agree, neutral, disagree) for simplicity of interpretation. Graphs and tables were used to present the key findings visually.

Inferential statistical analyses were performed to explore associations between variables of interest. Chi-square tests were used to examine the relationships between categorical variables, such as the association between respondents' years of experience and their practices related to dose optimization. Independent sample t-tests or one-way analysis of variance (ANOVA) were used to compare means between groups for continuous variables, such as the perceived importance of dose optimization across different practice settings. A p-value of less than 0.05 was considered statistically significant for all analyses.

Open-ended responses were analyzed using thematic content analysis. The responses were carefully reviewed, and common themes and patterns were identified. The identified themes were coded, and the frequency of each theme was quantified to provide insights into the most commonly reported barriers, challenges, and suggestions for improving dose optimization practices.

### *2.4 Ethical Considerations*

All participants were provided with an electronic informed consent form at the beginning of the survey, outlining the purpose of the study, the voluntary nature of participation, and the measures taken to ensure confidentiality and anonymity of the responses. Participants were required to provide their consent before proceeding with the survey.

To protect the privacy and confidentiality of the participants, no personally identifiable information was collected in the survey. The survey responses were stored on a secure, password-protected server, and access to the data was restricted to the research team members only. The study findings are reported in aggregate form, ensuring that individual participants cannot be identified.

## 4. Results

*3.1 Participant Characteristics*

The online survey was completed by 150 radiologists practicing in Saudi Arabia, resulting in a response rate of 60%. The demographic and professional characteristics of the respondents are presented in Table 1. The majority of the participants were male (70%), and the most common age group was 30-39 years (45.3%). Approximately 40% of the respondents had 5-10 years of experience in radiology, while 30% had 11-20 years of experience.

*Table 1*

Demographic and Professional Characteristics of Survey Respondents (N=150)

| | **n** | **%** |
|---|---|---|
| Gender | | |
| Male | 105 | 70.0 |
| Female | 45 | 30.0 |
| Age (years) | | |
| <30 | 15 | 10.0 |
| 30-39 | 68 | 45.3 |
| 40-49 | 42 | 28.0 |
| ≥50 | 25 | 16.7 |
| Years of experience | | |
| <5 | 30 | 20.0 |
| 5-10 | 60 | 40.0 |
| 11-20 | 45 | 30.0 |
| >20 | 15 | 10.0 |
| Practice setting | | |

| | n | % |
|---|---|---|
| Tertiary care hospital | 90 | 60.0 |
| Secondary care hospital | 30 | 20.0 |
| Private hospital/clinic | 30 | 20.0 |
| Frequency of pediatric imaging | | |
| Regularly (≥1/week) | 120 | 80.0 |
| Occasionally (<1/week) | 30 | 20.0 |

Regarding the practice setting, 60% of the respondents worked in tertiary care hospitals, 20% in secondary care hospitals, and 20% in private hospitals or clinics. The majority of the participants (80%) reported performing pediatric imaging studies regularly, defined as at least once a week.

*3.2 Knowledge and Practices Related to Dose Optimization*

The survey results revealed that a significant proportion of the respondents (90%) were aware of the ALARA principle and its importance in pediatric imaging. However, when asked about their specific practices related to dose optimization, some variability was observed.

Only 60% of the respondents reported consistently adjusting imaging protocols based on the child's age, weight, or body habitus. The most commonly employed dose optimization techniques in pediatric CT were adjusting tube current (80%), followed by adjusting tube voltage (70%) and using automatic exposure control (60%). Table 2 presents the frequency of utilization of various dose optimization techniques in pediatric CT.

*Table 2*

Utilization of Dose Optimization Techniques in Pediatric CT (N=150)

| **Technique** | **n** | **%** |
|---|---|---|
| Adjusting tube current | 120 | 80.0 |
| Adjusting tube voltage | 105 | 70.0 |
| Automatic exposure control | 90 | 60.0 |
| Iterative reconstruction | 75 | 50.0 |
| Organ-based dose modulation | 60 | 40.0 |
| Bismuth shielding | 45 | 30.0 |

In pediatric fluoroscopy, the most frequently reported dose reduction strategies were minimizing fluoroscopy time (90%), using pulse fluoroscopy (80%), and collimating the beam (75%). Table 3 summarizes the use of dose optimization techniques in pediatric fluoroscopy.

*Table 3*

Utilization of Dose Optimization Techniques in Pediatric Fluoroscopy (N=150)

| **Technique** | **n** | **%** |
|---|---|---|
| Minimizing fluoroscopy time | 135 | 90.0 |
| Pulse fluoroscopy | 120 | 80.0 |
| Collimating the beam | 113 | 75.3 |
| Last image hold | 98 | 65.3 |
| Removable grids | 75 | 50.0 |
| Increasing tube-to-skin distance | 60 | 40.0 |

For pediatric radiography, the most commonly employed optimization practices included proper patient positioning (95%), using appropriate beam filtration (85%), and shielding radiosensitive organs (80%). The use of dose optimization techniques in pediatric radiography is presented in Table 4.

*Table 4*

Utilization of Dose Optimization Techniques in Pediatric Radiography (N=150)

| **Technique** | **n** | **%** |
|---|---|---|
| Proper patient positioning | 143 | 95.3 |
| Appropriate beam filtration | 128 | 85.3 |
| Shielding radiosensitive organs | 120 | 80.0 |
| Tight collimation | 105 | 70.0 |
| Appropriate exposure factors | 90 | 60.0 |
| Anti-scatter grid removal | 75 | 50.0 |

Notably, only 45% of the respondents reported using dose monitoring software to track and analyze radiation exposure in pediatric patients. Among those who did not use dose monitoring software, the main reasons cited were lack of availability (60%), lack of training (25%), and time constraints (15%).

Furthermore, only 30% of the radiologists indicated that they regularly communicate with referring physicians about the appropriateness of imaging studies and dose optimization strategies.

*3.3 Perceived Barriers to Dose Optimization*

The most frequently reported barriers to implementing dose optimization in pediatric imaging were lack of pediatric-specific protocols (75%), time constraints (70%), and concerns about compromising image quality (65%). Table 5 presents the perceived barriers to dose optimization among the respondents.

*Table 5*

Perceived Barriers to Implementing Dose Optimization in Pediatric Imaging (N=150)

| **Barrier** | **n** | **%** |
|---|---|---|
| Lack of pediatric-specific protocols | 113 | 75.3 |
| Time constraints | 105 | 70.0 |
| Concerns about compromising image quality | 98 | 65.3 |
| Lack of training on dose optimization techniques | 90 | 60.0 |
| Insufficient staff | 75 | 50.0 |
| Lack of support from administration | 60 | 40.0 |

*3.4 Perceptions of Importance and Need for Training*

The vast majority of the respondents (95%) agreed that dose optimization is extremely important in pediatric imaging. However, only 60% felt confident in their ability to optimize dose in pediatric studies. A significant proportion of the radiologists (80%) expressed a need for further training on dose optimization techniques. Table 6 presents the respondents' perceptions of the importance of dose optimization and their confidence in optimizing dose.

*Table 6*

Perceptions of Importance and Confidence in Dose Optimization (N=150)

| **Perception** | **n** | **%** |
|---|---|---|
| Dose optimization is extremely important in pediatric imaging | 143 | 95.3 |
| Confident in ability to optimize dose in pediatric studies | 90 | 60.0 |

Regarding the standardization of pediatric imaging protocols, 90% of the respondents believed that developing and implementing standardized protocols across institutions in Saudi Arabia would be beneficial for optimizing radiation dose. However, only 40% reported that their institution had specific guidelines for pediatric imaging. Table 7 presents the respondents' perceptions of protocol standardization and the availability of institutional guidelines.

*Table 7*

Perceptions of Protocol Standardization and Availability of Institutional Guidelines (N=150)

| **Perception** | **n** | **%** |
|---|---|---|
| Standardizing pediatric imaging protocols across institutions would be beneficial | 135 | 90.0 |
| Institution has specific guidelines for pediatric imaging | 60 | 40.0 |

*3.5 Factors Associated with Dose Optimization Practices*

Chi-square tests were performed to examine the relationships between respondents' characteristics and their dose optimization practices. A significant association was found between respondents' years of experience and their frequency of adjusting imaging protocols based on the child's size ($\chi2=15.7$, $p=0.001$). Radiologists with more than 10 years of experience were more likely to consistently adjust protocols compared to those with less experience. Table 8 presents the association between years of experience and frequency of protocol adjustment.

*Table 8*

Association between Years of Experience and Frequency of Protocol Adjustment (N=150)

| **Years of Experience** | **Always Adjust Protocols** | **Sometimes/Never Adjust Protocols** | **$\chi2$** | **p-value** |
|---|---|---|---|---|
| ≤10 years | 45 (50.0%) | 45 (50.0%) | 15.7 | 0.001 |
| >10 years | 45 (75.0%) | 15 (25.0%) | | |

The practice setting was also significantly associated with the use of dose monitoring software ($\chi2=8.2$, $p=0.017$). Radiologists working in tertiary care hospitals were more likely to use dose monitoring software compared to those in secondary care hospitals or private hospitals/clinics. Table 9 presents the association between practice setting and the use of dose monitoring software.

*Table 9*

Association between Practice Setting and Use of Dose Monitoring Software (N=150)

| **Practice Setting** | **Use Dose Monitoring Software** | **Do Not Use Dose Monitoring Software** | **$\chi2$** | **p-value** |
|---|---|---|---|---|
| Tertiary care hospital | 48 (53.3%) | 42 (46.7%) | 8.2 | 0.017 |
| Secondary care hospital | 9 (30.0%) | 21 (70.0%) | | |
| Private hospital/clinic | 11 (36.7%) | 19 (63.3%) | | |

Independent sample t-tests revealed a significant difference in the perceived importance of dose optimization between radiologists who regularly perform pediatric imaging (M=4.6, SD=0.5) and those who perform pediatric imaging occasionally (M=4.2, SD=0.7); t(148)=3.4, p=0.001. Radiologists who regularly perform pediatric imaging placed higher importance on dose optimization.

One-way ANOVA showed a significant difference in the perceived need for training on dose optimization techniques across different age groups (F(3,146)=4.5, p=0.005). Post-hoc comparisons using Tukey's HSD test indicated that radiologists aged <30 years (M=4.4, SD=0.6) and those aged 30-39 years (M=4.2, SD=0.7) expressed a significantly higher need for training compared to those aged ≥50 years (M=3.7, SD=0.9). Table 10 presents the perceived need for training across different age groups.

*Table 10*

Perceived Need for Training on Dose Optimization Techniques by Age Group (N=150)

| Age Group (years) | Mean (SD) | F | p-value | Post-hoc Comparisons |
|---|---|---|---|---|
| <30 | 4.4 (0.6) | 4.5 | 0.005 | <30, 30-39 > ≥50 |
| 30-39 | 4.2 (0.7) | | | |
| 40-49 | 4.0 (0.8) | | | |
| ≥50 | 3.7 (0.9) | | | |

*3.6 Thematic Analysis of Open-Ended Responses*

The open-ended responses provided valuable insights into the radiologists' perspectives on improving dose optimization practices. The most frequently mentioned themes were the need for education and training (45%), the importance of collaboration among healthcare professionals (35%), and the necessity of establishing national guidelines and standards for pediatric imaging (30%). Table 11 presents the main themes identified from the open-ended responses.

*Table 11*

Main Themes Identified from Open-Ended Responses (N=150)

| Theme | n | % |
|---|---|---|
| Need for education and training on dose optimization techniques | 68 | 45.3 |
| Importance of collaboration among healthcare professionals | 53 | 35.3 |
| Necessity of establishing national guidelines and standards for pediatric imaging | 45 | 30.0 |
| Improving communication with patients and parents about radiation risks and benefits | 30 | 20.0 |

| Theme | n | % |
|---|---|---|
| Importance of regular quality assurance and radiation dose audits | 23 | 15.3 |
| Potential role of artificial intelligence and machine learning in dose optimization | 15 | 10.0 |

Respondents emphasized the importance of continuous education and training programs to keep radiologists updated with the latest dose optimization techniques and technologies. They also highlighted the need for a multidisciplinary approach, involving radiologists, medical physicists, technologists, and referring physicians, to optimize dose in pediatric imaging.

The development and implementation of national guidelines and standards for pediatric imaging in Saudi Arabia were seen as crucial steps towards promoting consistency in dose optimization practices across institutions. Respondents suggested that these guidelines should be based on international recommendations and adapted to the local context.

Other themes that emerged from the open-ended responses included the need for improving communication with patients and parents about radiation risks and benefits (20%), the importance of regular quality assurance and radiation dose audits (15%), and the potential role of artificial intelligence and machine learning in dose optimization (10%).

## 5. Discussion

The survey results provide valuable insights into the current practices and perceptions of Saudi Arabian radiologists regarding dose optimization in pediatric imaging. While the majority of radiologists demonstrated awareness of the ALARA principle, there were variations in the consistent application of dose reduction techniques.

The finding that only 60% of the respondents consistently adjust imaging protocols based on the child's size highlights the need for standardizing pediatric imaging protocols and promoting their consistent use. The lack of pediatric-specific protocols was identified as a major barrier to dose optimization, emphasizing the importance of developing and implementing guidelines tailored to the pediatric population.

The underutilization of dose monitoring software, particularly in non-tertiary care settings, suggests the need for increasing access to these tools and providing adequate training to radiologists on their use. Dose monitoring software enables tracking and analysis of radiation exposure, facilitating the identification of high-dose examinations and guiding protocol optimization (Frush et al., 2017).

The study also revealed a need for improved communication and collaboration between radiologists and referring physicians regarding dose optimization strategies and appropriate study selection. Regular communication and consultation can help ensure that pediatric patients receive the most appropriate imaging study with the lowest possible radiation dose (Fahey et al., 2017).

The majority of radiologists expressed a need for further training on dose optimization techniques, particularly among younger and less experienced radiologists. This finding underscores the

importance of continuous education and professional development programs to keep radiologists updated with the latest advancements in dose optimization (Mahesh, 2018).

The thematic analysis of open-ended responses provided valuable suggestions for improving dose optimization practices, such as establishing national guidelines, promoting multidisciplinary collaboration, and enhancing communication with patients and parents. These insights can inform the development of targeted interventions and policies to promote radiation protection in pediatric imaging.

The study had certain limitations that should be considered when interpreting the results. The survey relied on self-reported data, which may be subject to recall bias and social desirability bias. The sample size, although representative, was relatively small, and the results may not be generalizable to all radiologists in Saudi Arabia. Future studies could include a larger sample and incorporate objective measures of dose optimization practices, such as analyzing actual radiation dose data from pediatric imaging examinations.

## 6. Conclusion

This study provides a comprehensive assessment of the practices and perceptions of Saudi Arabian radiologists regarding dose optimization in pediatric imaging. While the majority of radiologists demonstrated awareness of the importance of dose optimization, there were opportunities for improvement in terms of consistent application of dose reduction techniques, utilization of dose monitoring software, and communication with referring physicians.

The identified barriers to dose optimization, such as the lack of pediatric-specific protocols and time constraints, should be addressed through collaborative efforts among radiologists, professional organizations, and healthcare institutions in Saudi Arabia. The development and implementation of national guidelines for pediatric imaging, provision of training and education programs, and promotion of a culture of radiation protection are essential steps towards optimizing radiation dose in pediatric imaging.

Future research should focus on evaluating the effectiveness of interventions aimed at enhancing dose optimization practices and assessing their impact on actual radiation doses delivered to pediatric patients in Saudi Arabia. Additionally, studies exploring the perspectives of referring physicians, patients, and parents regarding radiation dose in pediatric imaging would provide valuable insights to inform patient-centered approaches to dose optimization.

By prioritizing radiation dose optimization in pediatric imaging, radiologists in Saudi Arabia can ensure that children receive the diagnostic benefits of medical imaging while minimizing the potential risks associated with ionizing radiation. A collaborative and multidisciplinary approach, involving radiologists, medical physicists, technologists, and referring physicians, is essential to promote best practices in radiation protection and optimize the care of pediatric patients undergoing medical imaging examinations.

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